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EFFECT OF FLY ASH ON GEO-ENGINEERING PROPERTIES ON STABILIZATION OF EXPANSIVE SOIL

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Abstract

In this review, a high plastic commercial clay was settled utilizing fly ash (acquired from Rourkela Steel Plant). The geo-designing properties, for example, Atterberg limits, grain size distribution, linear shrinkage, free swell index, swelling pressure, compaction qualities, unconfined compressive strength and CBR worth of virgin earth and treated with fly ash were assessed and detailed. Extensive soil was settled with different extent of fly ash for example at 0, 20, 40, 60, 80, and 90 %. Fly ash has no pliancy. Pliancy list of mud fly debris blends diminishes with expansion in fly debris content. Unconfined compressive strength of earth fly debris blends is observed to be most extreme at 18% fly ash content and from that point the equivalent lessens with additional expansion in fly debris content. This shows that there exists an ideal fly ash content that gives better compressive strength. The CBR upsides of earth fly debris blends, tried under un-doused conditions, shows tops at 18% and 78% ash content. Comparative outcomes were gotten by Pandian (2004). The unsoaked CBR value is observed to be about 80% of the doused CBR esteem. Subsequently, it is reasoned that the fly debris has a decent potential to be utilized as an added substance for further developing the designing properties of sweeping soil.

KEYWORDS: Expansive soil, Fly ash, Plasticity characteristics, compaction characteristics, Unconfined compressive strength

INTRODUCTION

Expansive soil swell and shrink with change in water content and loose strength upon ingress of water. Excessive heave associated with swelling of expansive soil can cause considerable distress to light weight engineering structures. Several attempts have been made to control the swell-shrink behavior of these soils. There are several methods that have been used to minimize or eliminate the harmful effects of expansive/soft clayey soils on structures.

Several investigations were done to evaluate the soil stabilization process using lime and Fly ash. Numerous work has been done in this area by Rao (1994), Xeidakis ,G.S (1996), Porbaha *et al.* (2000), Cokca E.(2001), Kumar *et al.* (2003), Kaniraj, S.R. and Gayathri, V. (2004), Pandian, N.S. (2004), Das, S.K & Yudhbir (2005), Kim *et al.(*2005), Kumar. A, Walia, S.B and Bajaj A. (2007), Zha et al.(2008), Robert, M. B. (2009), Ramesh *et al.(*2010) and Kumar *et al.(*2010) Stabilization of expansive soils with admixtures controls the potential of soils for a change in volume, and improves the strength of soils.

Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Presently, India produces nearly 100 million metric tons of coal ash; that is expected to double in the next 10 years. The potential impacts on the environment suggest the need for proper disposal of fly ash and justify maximum utilization of fly ash when viable. In this context, an extensive research is needed to understand the mechanism and geo-engineering properties of expansive soil stabilized with fly ash. At present, the generation of fly ash is far in excess of its utilization. It can be used as an alternative to conventional materials in the construction of geotechnical and geo environmental infrastructures .Considering this in the present work an attempt has been made to evaluate the plasticity, swelling and strength characteristics of clay-fly ash mixes.

METHODS

This paper presents laboratory tests to evaluate the effect of addition of fly ash on the geotechnical behavior of the expansive soil in terms of grain size distribution, Atterberg limits, specific gravity, compaction characteristics, free swell, swell potential, swelling pressure, axial shrinkage percent, and unconfined compressive strength as per IS code. The soils used in this study are Sodium bentonite (expansive soil) and the fly ash collected from Rourkela steel Plant. The expansive soil is mixed with various proportions of fly ash ranging from 0, 20, 40,60,80,90 percentages .

Test techniques and sample preparation

The individual morphology and particle chemistry were studied by SEM and XRD analysis. The index and geo-engineering properties of fly ash-clay mixture have been evaluated in this work. The granulometry was studied for the different mixes by hydrometer analysis. Specimens for swelling pressure were prepared using standard proctor compaction effort of 592.8 kJ/m^3 with optimum water content and maximum dry weight. With a diameter of 100mm and height 25mm.Specimens for the unconfined compressive strength test of 50mm diameter and 100mm height were prepared under the optimum water content and dry density corresponding to 95% of

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maximum dry unit weight of soil. The free swell was obtained according to IS : 2720 (Part XL) - 1977.The chemical composition of fly ash are given in the table-1.

Table 1: Chemical composition of fly ash

Constituents	%age	Constituents	%age
MgO	0.57	Fe_2O_3	-
Al_2O_3	24.12	Na_2O	-
SiO_2	52.55	MnO	-
K_2O	0.965	TiO_2	-
P_2O_5	0.72	SO_3	-
CaO	2.65	Loss of Ignition	18.18

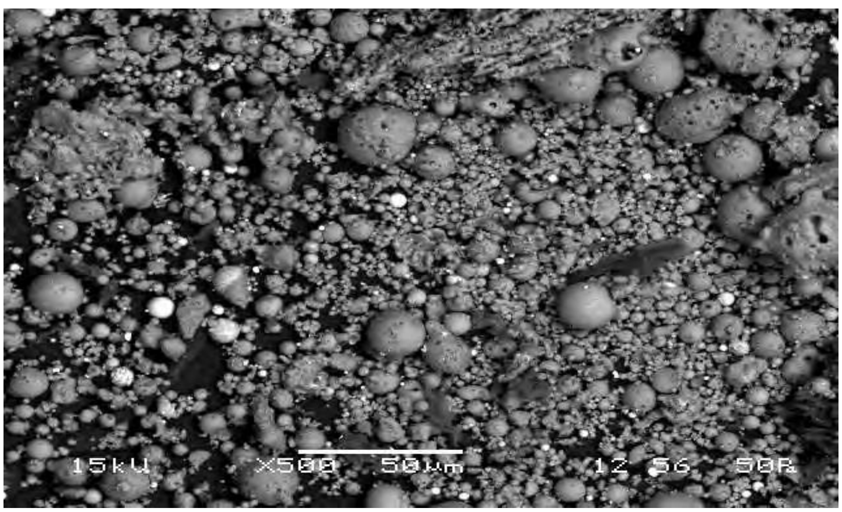


Figure 2: Particle arrangement (SEM) at 500M: Flyash

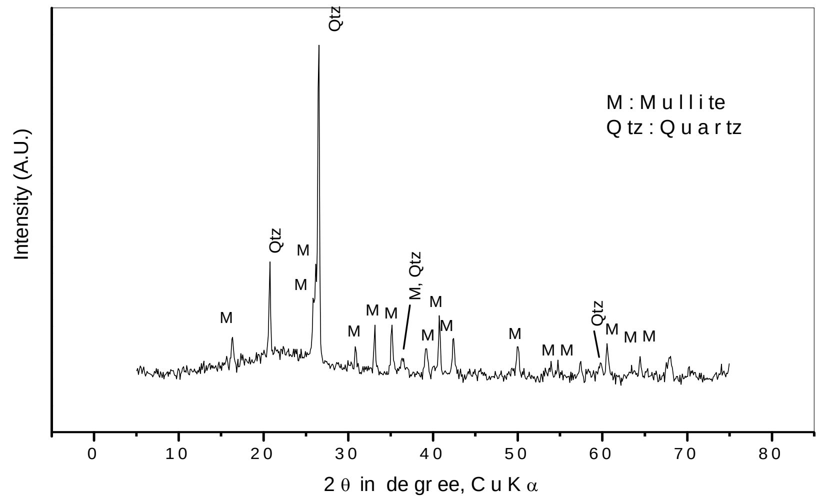


Figure 3: X-Ray diffractogram of fly ash

RESULT AND DISCUSSION

Plasticity

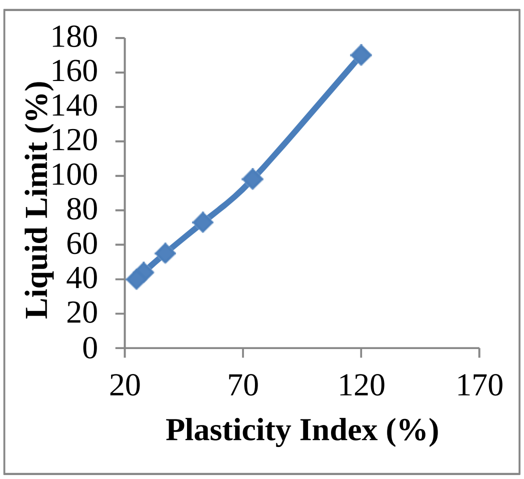


Figure 4: Variation of liquid limit with PI (%)

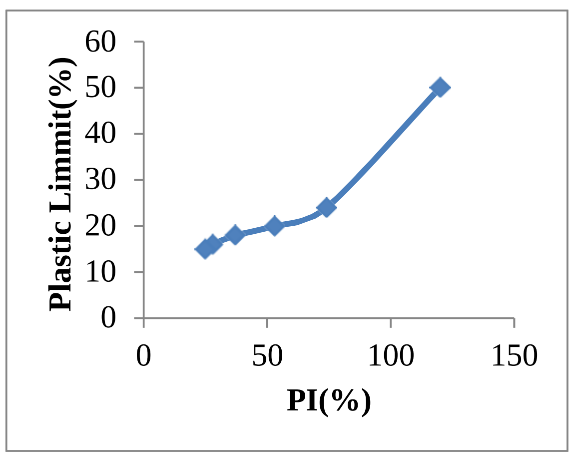


Figure 5: Variation of plastic limit with PI (%)

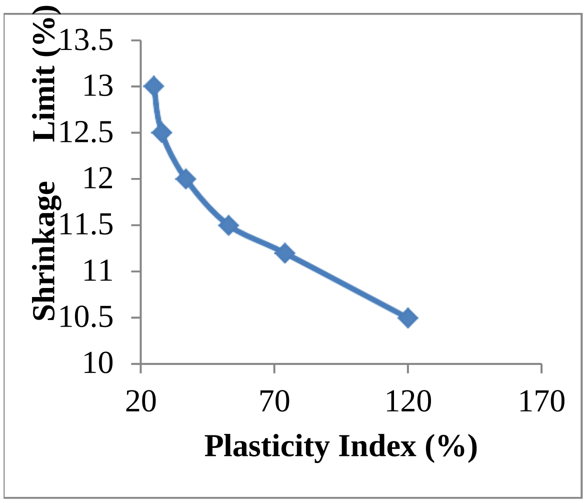


Figure 6: Variation of shrinkage limit with PI (%)

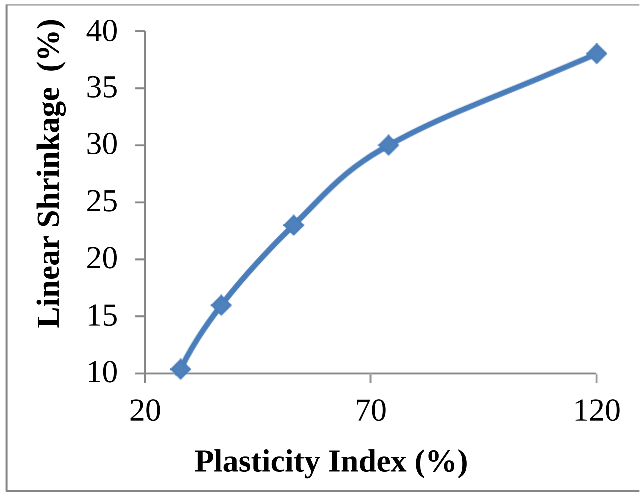


Figure 7: Variation of linear shrinkage with PI (%)

Table 3 summarizes the effect of fly ash on different physical properties of expansive soil. Atterberg limits play an important role in soil identification and classification. It is known that the addition of fly ash can reduce the thickness of the diffuse double layer clay particles, cause flocculation of clay particles, and increase the coarser particles content by substitute finer soil particles with coarser fly ash particles (Sivapullaiah *et al.* 1996). The immediate and long-term effects combine together to bring out the beneficial changes in the plasticity characteristics. These reasons all together cause the decrease in Liquid Limit ($L_{w)}$, Plasticity index (I_p), and the increase in Plastic Limit (L_w).

Liquid limit values of the samples decreased with increasing stabilizer percentages. Addition of 20%fly ash diminished the liquid limit of untreated clay by43%.Plastic limit values of the samples decreased with increasing stabilizer percentages. Addition of 20% fly ash caused the decrement 52% in the plastic limit of soil sample.

Plasticity indices of the samples decreased significantly with increasing stabilizer percentages. 20% fly ash reduced the plasticity index of sample by 39%. This is the maximum reduction obtained with the least amount of stabilizer. Plasticity Index varies directly with liquid limit, plastic limit, linear shrinkage and varies inversely with shrinkage limit.

Swelling Behavior

The values of free swell index, swelling pressure, and axial shrinkage decreased significantly with the increase in fly ash content. Addition of fly ash increased the shrinkage limit from 10% to 13% .The free swell index of clay was found to be 455%. After 90% fly ash addition, it reduced to

5%. The swelling pressure of expansive soil was found to be 4 kg/cm^2 and the value reduced gradually with the increase in percentage of fly ash.

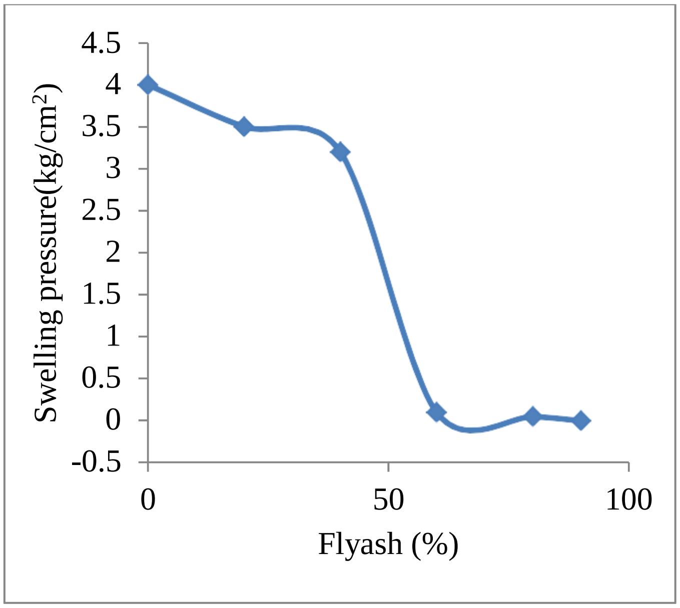


Figure 8: Effect of fly ash on swelling pressure of clay

Table 1: Physical property of expansive soil and fly ash

Property	Expansive soil	Fly ash
Colour	yellow	grey
Specific Gravity	2.65	2.2
Liquid Limit (%)	170	-
Plastic Limit (%)	50	-
Shrinkage Limit (%)	10.5	-
Linear shrinkage (%)	38	-
Volumetric shrinkage (%)	59	-
Swelling Pressure (kg/cm^2)	4	-
OMC(%) at standard proctor density	26	19
MDD (g/cc) at standard proctor density	1.4	1.35
OMC(%) at modified proctor density	21.38	16
MDD (g/cc) at modified proctor density	1.56	1.42
Unconfined compressive strength (N/mm2)	0.055	0.030
Free swell Index (%)	455	-6.48
Cu	-	45
Cc	-	35.5

Grain Size Distribution

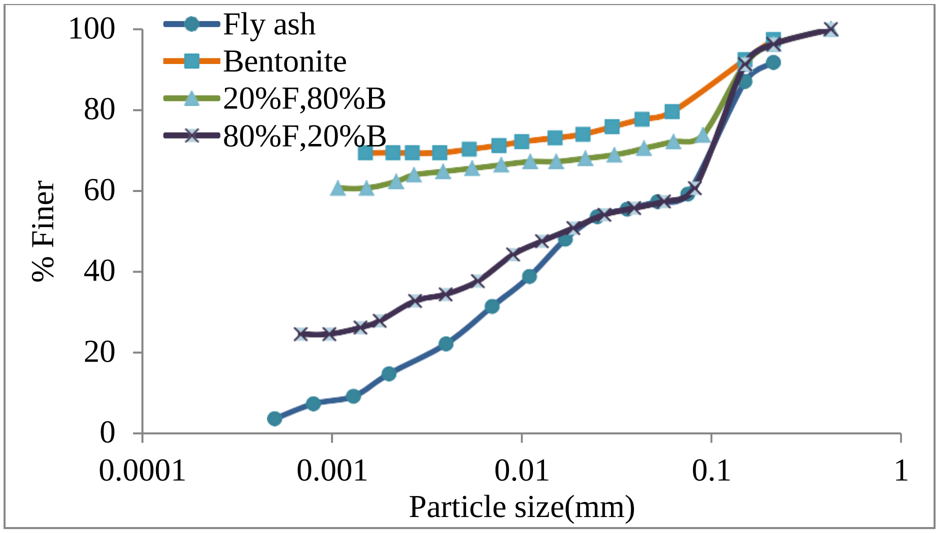


Figure 9: Grain size distribution of fly ash and clay

A particle size distribution curve gives us an idea about the type and the gradation of the soil. Grain size distribution indicates if a material is well graded, poorly graded, uniformly graded, fine or coarse. Here with addition of fly ash, the clay fraction decreases, silt and sand fractions increases. This may be partly due to that the flocculation of soil particles resulting from the cation exchange between the cations contained in the fly ash and the readily exchangeable cations on the soil particle surface. The increase in the particle size is as a result of aggregation of small size particles. This type of particle growth can be attributed to the formation of cementation compounds.

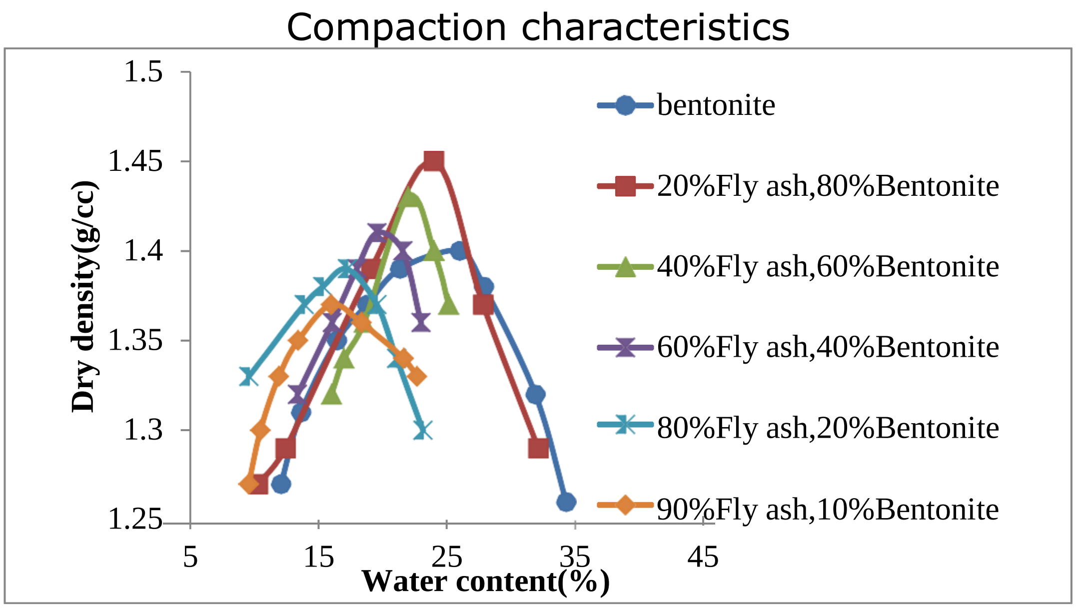


Figure 10: Standard Proctor Compaction test of expansive clay stabilized with fly ash

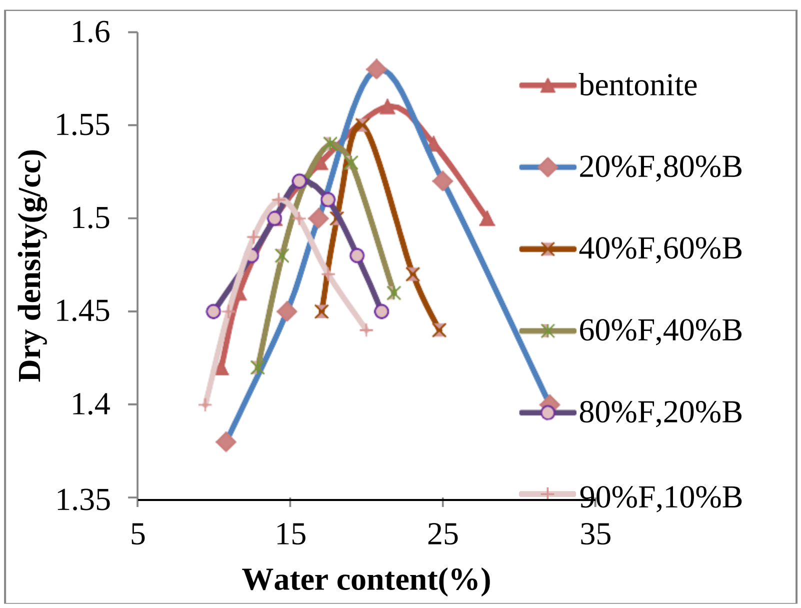
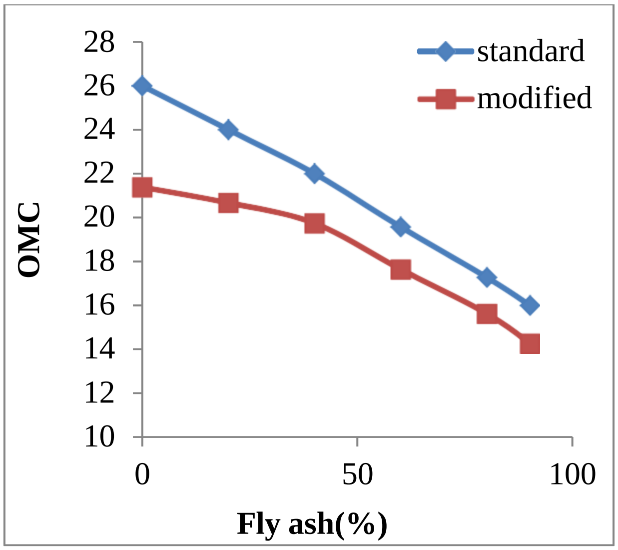


Figure 11: Modified proctor compaction test of expansive soil stabilized with fly ash



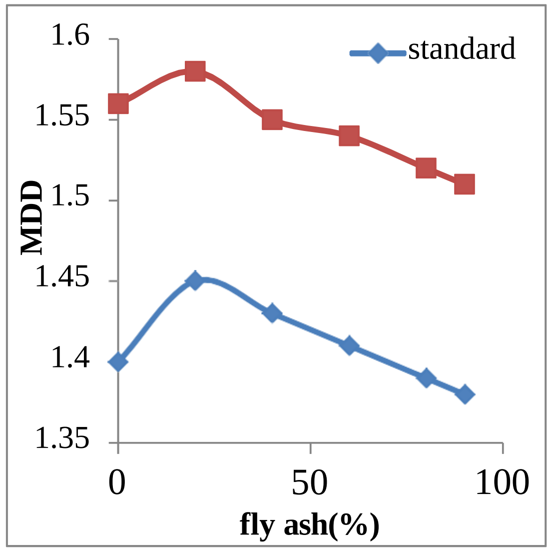


Figure 12: Variation of OMC with fly ash% **Figure 13:** Variation of MDD with Fly ash %

The tendency for fly ash to be less sensitive to variation in moisture content than for soils could be explained by the higher air void content of fly ash. Soils normally have air void content ranging between 1 and 5% at maximum dry density, whereas fly ash contains 5 to 15%. The higher void content could tend to limit the buildup of pore pressures during compaction, thus allowing the fly ash to be compacted over a larger range of water content. Both standard proctor compaction and modified proctor compaction tests were carried out on the fly ash treated soils by using a standard proctor compaction effort of 592.8 kJ/m^3 and modified proctor compaction effort of 2693.3 kJ/m^3. The effect of the fly ash treatment on the maximum dry unit weight and optimum water content for the soils are shown in Figs. 11 and 12. There is a clear tendency that the maximum dry unit weight increases at 20% fly ash content and then decreases whereas the optimum moisture content decreases gradually with increase in fly ash content. The cause for the reduction in the optimum water content when increasing the fly ash content can be explained as follows: the cation exchange between additives and expansive soil decreases the thickness of electric double layer and promotes the flocculation. The flocculation of the solid particles implies that the water-additives–soil mixtures can be compacted with lower water content, and the optimum water content is reduced. The decrease in the optimum water content indicates that expansive soil can be stabilized by adding fly ash even for soils with low water content. The decrease of the maximum dry unit weight with the increase of the percentage of fly ash is mainly due to the lower specific gravity of the fly ash and compared with expansive soil, and the immediate formation of cemented products which reduce the density of the treated soil (Lees et al. 1982; Bell 1996). The reduced dry density therefore reduces the swell-shrinkage properties of the compacted expansive soils (Du *et al.* 1999).

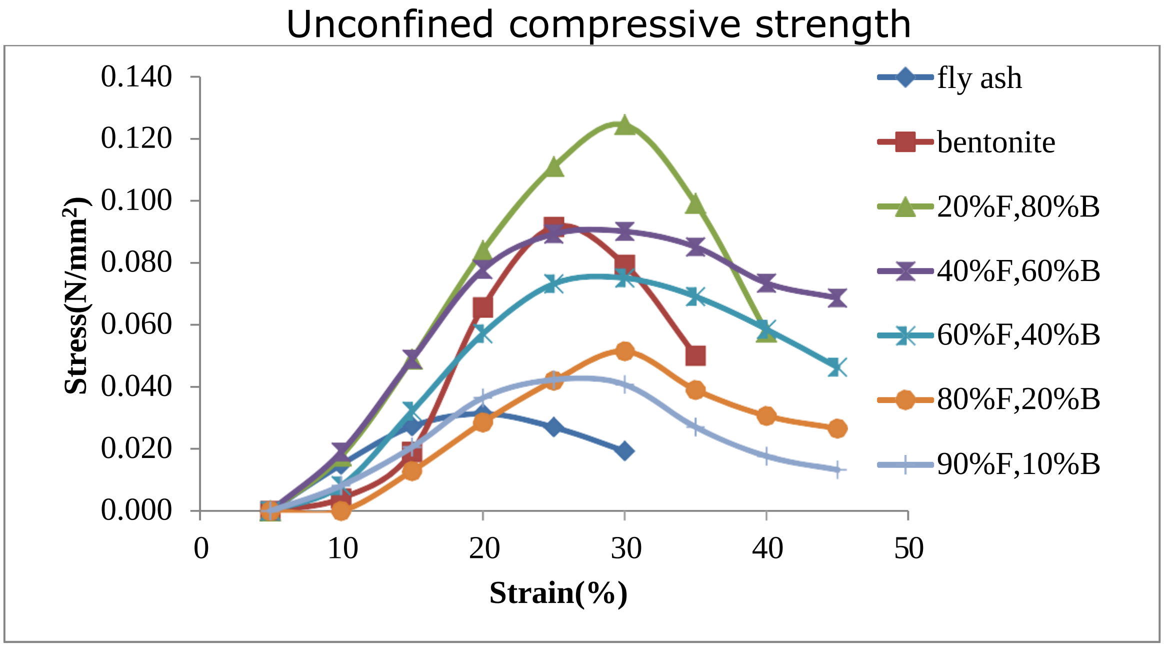


Figure 14: Unconfined compressive strength test result at standard proctor density

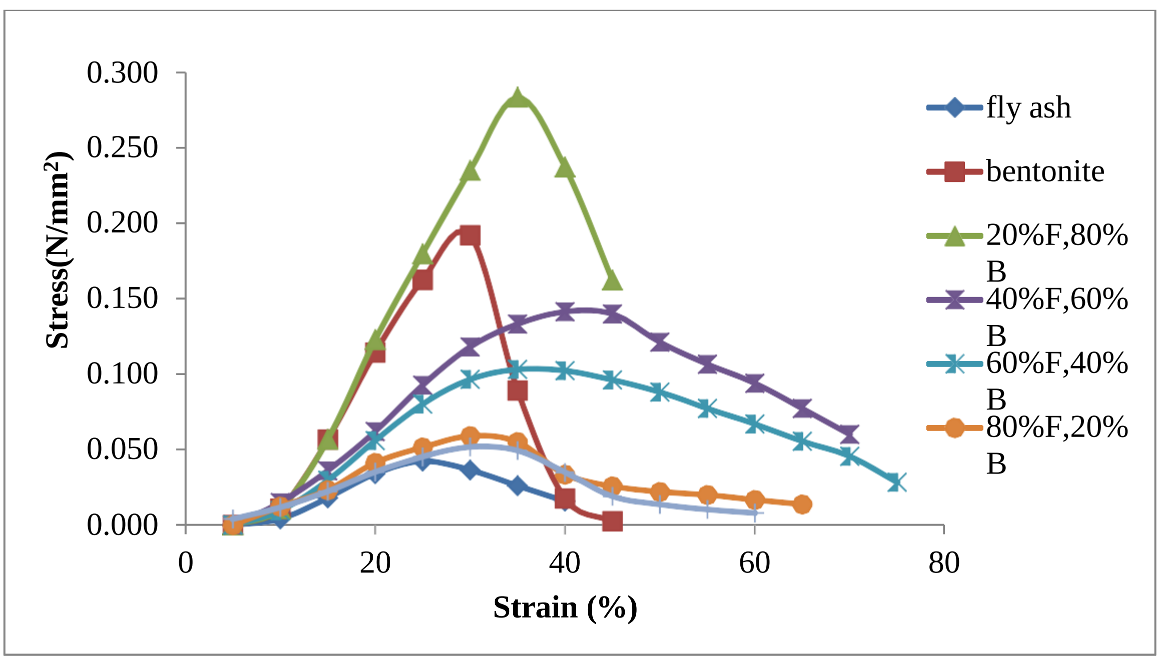


Figure 15: Unconfined compressive strength test result at modified proctor density

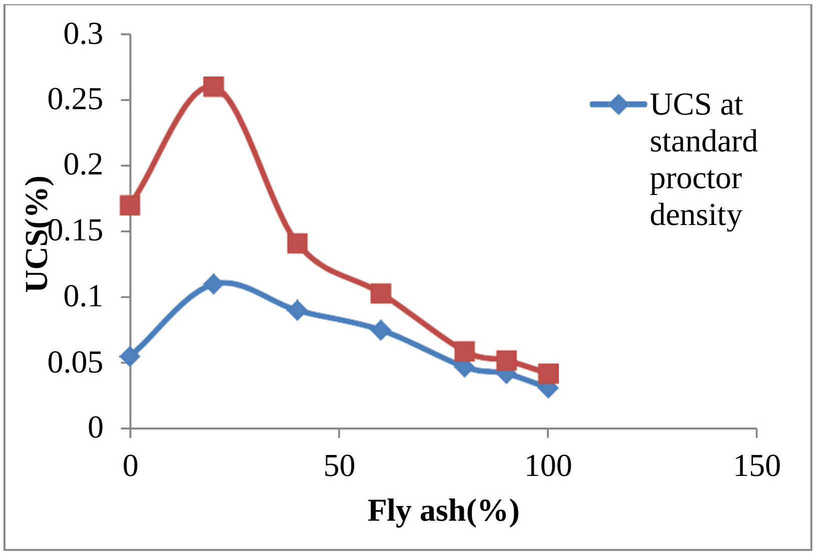


Figure 16: Variation of Unconfined compressive strength with fly ash content

The variation of unconfined compressive strength with fly ash content is given in Fig. 13 and 14 for standard proctor and modified proctor density, respectively. Increasing the fly ash content from 0 to 90% for the samples, the unconfined compressive strength increases at 20% fly ash -80% clay mix and then decreases with further addition of fly ash. The optimum fly ash content for improving the shear strength of the treated soils under the presented conditions is 20%. This indicates that the quantity of fly ash up to optimum content can induce pozzolanic reaction and cemented materials effectively contributing to shear strength increase, while the additional quantity of fly ash acts as unbounded silt particles, which has neither appreciable friction nor cohesion, causing decrease in strength (Bell 1996; Kate 2005).

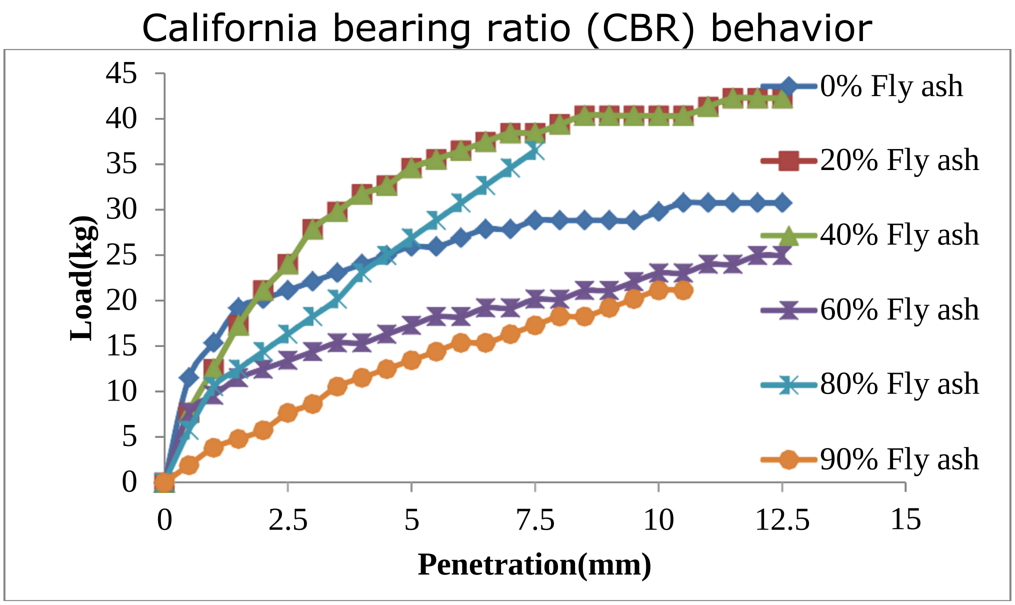


Figure 17: Soaked CBR test result expansive soil mixed with various proportion of fly ash

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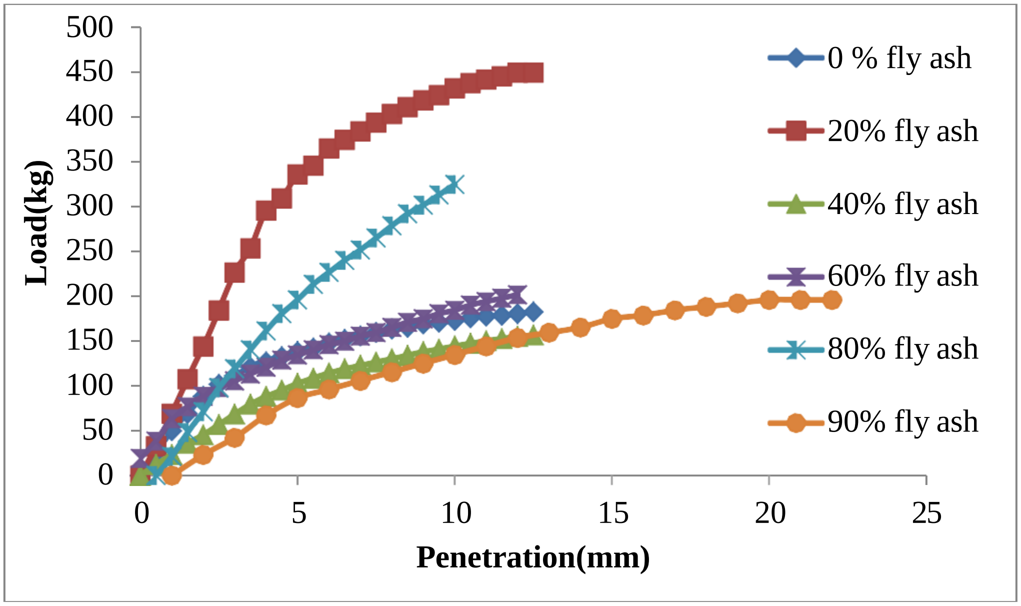

Figure 18: Unsoaked CBR test result expansive soil mixed with various proportion of fly ash

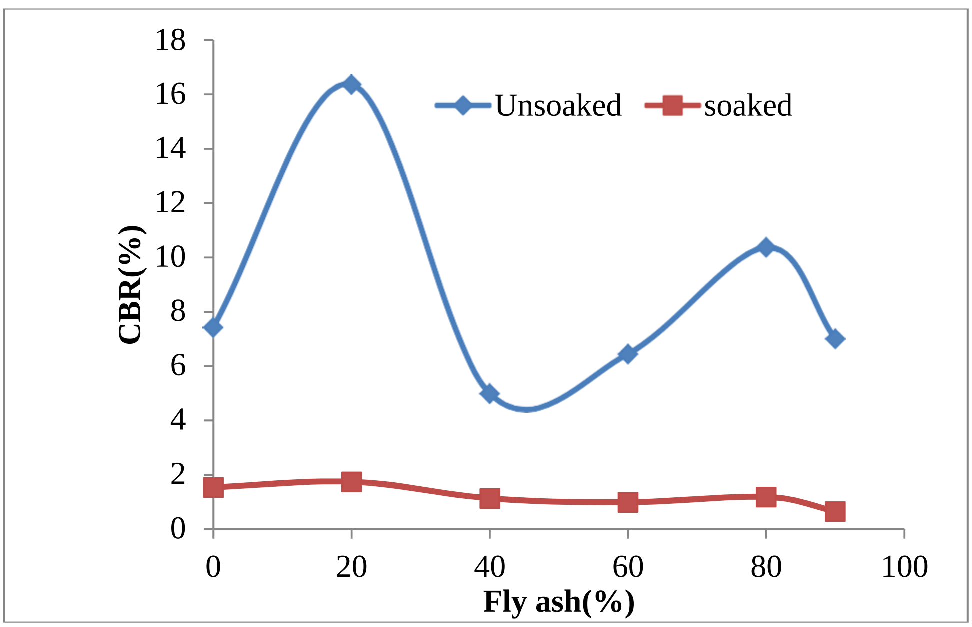

Figure 19: Variation of CBR (%) of expansive soil treated with fly ash

The results under unsoaked conditions show higher CBR values ranging between 7.4 and 16.3%. On the contrary, when the same fly ash samples are soaked for 96 hour maintaining the same placement conditions, they exhibited very low values of CBR between 0.65 and 1.91 % This can be attributed to the destruction of capillary forces under soaked conditions. It can be seen that the CBR values increase significantly with increase in percentage of black cotton soil up to 40% and a second peak is obtained with 80% of black cotton soil. It may be mentioned here that the fly ash used out here consists essentially of sandy and silt size fraction with a clay-size fraction of 12.9%. It is also a non plastic material. With the addition of black cotton soil, the cohesion component increases giving higher CBR values. With further increase in the clayey soil, the CBR value decreases because of the strength reduction due to reduction in fly ash decreasing the friction component. The second peak at 80% of black cotton soil can be attributed to the better packing of different fractions. It may be noted that while the water content was kept at saturation level, the density varies depending on the proportion of mixtures for a given compactive effort. The double peak in the CBR values is due to better packing of mixtures at constant compactive effort, with a small percentage of expansive soil. The CBR values of clay-fly ash mixes, tested under un-soaked conditions, shows peaks at 20% and 80% ash content. Similar results were obtained by Pandian (2004). The unsoaked CBR value is found to be about 80% of the soaked CBR value. It can be stated that the primary material (fly ash or Clayey soil) lacks certain fractions because of which it results in lower CBR values. The addition of such size fractions improves significantly the CBR values.

Table 3: Effect of fly ash on physical and engineering properties of expansive clay

Property	Fly ash content					
	0	20	40	60	80	90
Specific gravity	2.65	2.56	2.47	2.38	2.29	2.25
Liquid Limit (%)	170	98	73	55	44	40
Plastic Limit (%)	50	24	20	18	16	15
Plasticity Index (%)	120	74	53	37	28	25
Shrinkage Limit (%)	10.5	11.2	11.5	12	12.5	13
Linear shrinkage (%)	38	30	23	16	10.4	6.4
Free swell Index	455	284	210	105	30	5
Swelling Pressure (kg/cm^2)	4	3.5	3.1	0.1	0.05	0
Optimum moisture content at standard proctor density (%)	26	24	22	19.57	17.27	16
Maximum dry unit weight at standard proctor density (g/cc)	1.4	1.45	1.43	1.41	1.39	1.38
Optimum moisture content at modified proctor density (%)	21	20	19	17	15	14
Maximum dry unit weight at modified proctor density (g/cc)	1.56	1.58	1.55	1.54	1.52	1.51
UCS at standard proctor density (N/mm^2)	0.055	0.11	0.09	0.075	0.047	0.042

UCS at modified proctor density (N/mm^2)	0.17	0.26	0.141	0.103	0.059	0.052
CBR (Unsoaked) %	7.42	16.35	4.99	6.44	10.37	7.00
CBR (soaked) %	1.54	1.75	1.13	0.99	1.19	0.65

CONCLUSION

The present project can serve as an effective method to utilize fly ash in the stabilization of expansive soil. The conclusions are based on the tests carried out on various clay-fly ash mixes selected for the same. The addition of fly ash reduces the plasticity characteristics of expansive soil. The liquid limit, plastic limit, plasticity index, linear shrinkage decreased drastically and shrinkage limit increased with the addition of fly ash. The free swell Index value and swelling pressure is found to decrease with increase in fly ash content. Grain Size Distribution of soils were altered by the addition of fly ash. The maximum dry density increases up to 20% fly ash mix, and then gradually decreases whereas the optimum moisture content decreased with increase in fly ash content. Maximum Unconfined compressive strength was obtained at 20% fly ash mix with clay and further addition of fly ash reduces the strength. The CBR values of clay-fly ash mixes, tested under un-soaked conditions, shows peaks at 20% and 80% ash content. Similar results were obtained by Pandian (2004).

Fly ash has good potential for use in geotechnical applications. The relatively low unit weight of fly ash makes it well suited for placement over soft or low bearing strength soils. Its low specific gravity, freely draining nature, ease of compaction, insensitiveness to changes in moisture content, good frictional properties, etc. can be gainfully exploited in the construction of embankments, roads, reclamation of low-lying areas, fill behind retaining structures, etc.

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