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STABILIZATION OF EXPANSIVE SOILS USING ALKALI ACTIVATED FLY ASH

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Abstract: : Nearly 51.8 million hectares of land area in India are covered with Expansive soil. The property of expansive soil is hard in dry state soft in wet state because of cohesiveness. Due to cohesiveness property in expansive soil it became weak and good for foundation or pavement subgrade. Soil Stabilization is one of the most important aspects for construction industry, which is used widely in foundation and road pavement constructions; this is because such stabilization improves geotechnical properties of the soil, such as volume stability, strength and durability. The process of removing weaker soil or adding the binder materials to soil to make the stabilization. In the present study, using fly ash to stabilize the black cotton soil obtained from site. With various proportions of i.e. 10%, 20%, 30%, 40% & 50%, expansive soils are stabilized. In conclusion, addition of fly ash results in decrease in plasticity of the expansive soil, and increase in workability by changing its grain size and colloidal reaction.

I INTRODUCTION

1.1 GENERAL

Expansive soil, also called shrink-swell soil, is a very common cause of foundation problems. Depending upon the supply of moisture in the ground, shrink-swell soils will experience changes in volume of up to thirty percent or more. Foundation soils which are expansive will “heave” and can cause lifting of a building or other structure during periods of high moisture. Conversely during periods of falling soil moisture, expansive soil will “collapse” and can result in building settlement. Either way, damage can be extensive.

Expansive soil will also exert pressure on the vertical face of a foundation, basement or retaining wall resulting in lateral movement. Shrink-swell soils which have expanded due to high ground moisture experience a loss of soil strength or “capacity” and the resulting instability can result in various forms of foundation problems and slope failure. Expansive soil should always be a suspect when there is evidence of active foundation movement.

In order for expansive soil to cause foundation problems, there must be fluctuations in the amount of moisture contained in the foundation soils. If the moisture content of the foundation soils can be stabilized, foundation problems can often be avoided. I will be following up on this concept a bit later.

Expansive soils contain minerals such as smectite clays that are capable of absorbing water. When they absorb water, they increase in volume. The more water they absorb, the more their volume increases. Expansions of ten percent or more are not uncommon. This change in volume can exert enough force on a building or other structure to cause damage.

Cracked foundations, floors, and basement walls are typical types of damage done by swelling soils. Damage to the upper floors of the building can occur when motion in the structure is significant.

Expansive soils will also shrink when they dry out. This shrinkage can remove support from buildings or other structures and result in damaging subsidence. Fissures in the soil can also develop. These fissures can facilitate the deep penetration of water when moist conditions or runoff occurs. This produces a cycle of shrinkage and swelling that places repetitive stress on structures.

Expansive soils are present throughout the world and are known in every US state. Every year they cause billions of dollars in damage. The American Society of

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Civil Engineers estimates that 1/4 of all homes in the United States have some damage caused by expansive soils. In a typical year in the United States, they cause a greater financial loss to property owners than earthquakes, floods, hurricanes, and tornadoes combined.

Even though expansive soils cause enormous amounts of damage, most people have never heard of them. This is because their damage is done slowly and cannot be attributed to a specific event. The damage done by expansive soils is then attributed to poor construction practices or a misconception that all buildings experience this type of damage as they age.

Expandable soils are referred to by many names. "Expandable soils," "expansive clays," "shrink-swell soils," and "heavable soils" are some of the many names used for these materials.

The map on this page shows the geographic distribution of soils that are known to have expandable clay minerals which can cause damage to foundations and structures. It also includes soils that have a clay mineral composition which can potentially cause damage.

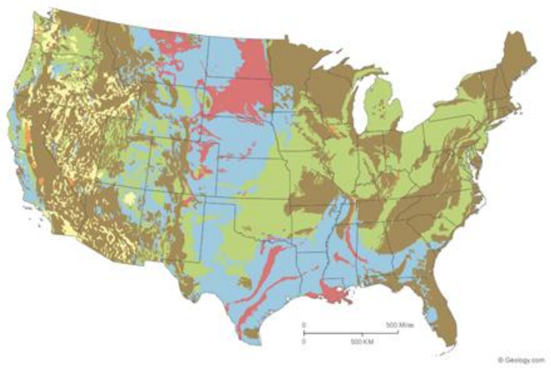

Fig.1.1 Expansive Soil: The Hidden Force behind Basement and Foundation Problems

- Over 50 percent of these areas are underlain by soils with abundant clays of high swelling potential.
- Less than 50 percent of these areas are underlain by soils with clays of high swelling potential.
- Over 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.
- Less than 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.
- These areas are underlain by soils with little to no clays with swelling potential.
- Data insufficient to indicate the clay content or the swelling potential of soils.

Soils are composed of a variety of materials, most of which do not expand in the presence of moisture. However, a number of clay minerals are expansive. These include: smectite, bentonite, montmorillonite, beidellite, vermiculite, attapulgite, nontronite, and chlorite. There are also some sulfate salts that will expand with changes in temperature.

When a soil contains a large amount of expansive minerals, it has the potential of significant expansion. When the soil contains very little expansive minerals, it has little expansive potential.

When expansive soils are present, they will generally not cause a problem if their water content remains constant. The situation where greatest damage occurs is when there are significant or repeated moisture content changes.

It is possible to build successfully and safely on expansive soils if stable moisture content can be maintained or if the building can be insulated from any soil volume change that occurs. The procedure for success is as follows:

- Testing to identify any problems
- Design to minimize moisture content changes and insulate from soil volume changes.
- Build in a way that will not change the conditions of the soil.
- Maintain a constant moisture environment after construction.

II. REVIEW OF LITERATURE

Stabilization is one of the methods of treating the expansive soils to make them fit for construction. Variety of stabilizers may be divided into three groups (Petry 2002): (a) traditional stabilizers (lime, cement etc.), (b) by-product stabilizers (fly ash, quarry dust, phosphor-gypsum, slag etc.) and (c) non-traditional stabilizers (sulfonated oils, potassium compounds, polymer, enzymes, ammonium chlorides etc.). Disposal of large quantities of industrial by products as fills on disposal sites adjacent to industries not only requires large space but also create a lot of geo-environment problems. Attempts are being made by various organizations and researchers to use them in bulk at suitable places. Stabilization of expansive soil is one way of utilization of these by products. Some of the research work conducted by earlier researchers on the above has been described below.

Sharma et al. (1992) studied stabilization of expansive soil using mixture of fly ash, gypsum and blast furnace slag. They found that fly ash, gypsum and blast furnace slag in the proportion of 6: 12: 18 decreased the swelling pressure of the soil from 248 kN/m2 to 17 kN/m2 and increased the unconfined compressive strength by 300%.

Srivastava et al. (1997) studied the change in micro structure and fabric of expansive soil due to addition of fly ash and lime sludge from SEM photograph and found changes in micro structure and fabric when 16% fly ash and 16% lime sludge were added to expansive soil. Srivastava et al. (1999) have also described the results of experiments carried out to study the consolidation and swelling behaviour of expansive soil stabilized with lime sludge and fly ash and the best stabilizing effect was obtained with 16% of fly ash and 16% of lime sludge.

Cokca (2001) used up to 25% of Class-C fly ash (18.98 % of CaO) and the treated specimens were cured for 7 days and 28 days. The swelling pressure is found to decrease by 75% after 7 days curing and 79% with 28 days curing at 20% addition of fly ash.

Pandian et al. (2001) had made an effort to stabilize expansive soil with a class –F Fly ash and found that the fly ash could be an effective additive (about 20%) to improve the CBR of Black cotton soil (about 200%) significantly.

Turker and Cokca (2004) used Class C and Class F type fly ash along with sand for stabilization of expansive soil. As expected Class C fly ash was more effective and the free swell decreased with curing period. The best performance was observed with soil , Class C fly ash and sand as 75% , 15% and 10% respectively after 28 days of curing.

Satyanarayana et al. (2004) studied the combined effect of addition of fly ash and lime on engineering properties of expansive soil and found that the optimum proportions of soil: fly ash: lime should be 70:30:4 for construction of roads and embankments.

Phani Kumar and Sharma (2004) observed that plasticity, hydraulic conductivity and swelling properties of the expansive soil fly ash blends decreased and the dry unit weight and strength increased with increase in fly ash content. The resistance to penetration of the blends increased significantly with an increase in fly ash content for given water content. They presented a statistical model to predict the undrained shear strength of the treated soil.

Baytar (2005) studied the stabilization of expansive soils using the fly ash and desulpho-gypsum obtained from thermal power plant by 0 to 30 percent. Varied percentage of lime (0 to 8%) was added to the expansive soil-fly ash-desulphogypsum mixture. The treated samples were cured for 7 and 28 days. Swelling percentage decreased and rate of swell increased with increasing stabilizer percentage. Curing resulted in further reduction in swelling percentage and with 25 percent fly ash and 30 percent desulphogypsum additions reduced the swelling percentage to levels comparable to lime stabilization.

Amu et al. (2005) used cement and fly ash mixture for stabilization of expansive clayey Soil. Three different classes of sample (i) 12% cement, (ii) 9% cement + 3% fly ash and (iii) natural clay soil sample were tested for maximum dry densities (MDD), optimum moisture contents (OMC), California bearing ratio (CBR), unconfined compressive strength (UCS) and the undrained Triaxial tests. The results showed that the soil sample stabilized with a mixture of 9% cement + 3% fly ash is better with respect to MDD, OMC, CBR, and shearing resistance compared to samples stabilized with 12% cement, indicating the importance of fly ash in improving the stabilizing potential of cement on expansive soil.

Sabat et al. (2005) observed that fly ash-marble powder can improve the engineering properties of expansive soil and the optimum proportion of soil: fly ash: marble powder was 65:20: 15

Punthutaecha et al. (2006) evaluated class F fly ash, bottom ash, polypropylene fibers, and nylon fibers as potential stabilizers in enhancing volume change properties of sulfate rich expansive subgrade soils from two locations (Dallas and Arlington) in Texas, USA. Ash stabilizers showed improvements in reducing swelling, shrinkage, and plasticity characteristics by 20–80% , whereas fibers treatments resulted in varied improvements. In combined treatments, class F fly ash mixed with nylon fibers was the most effective treatment on both soils. They also discussed the possible mechanisms, recommended stabilizers and their dosages for expansive soil treatments.

Phanikumar and Rajesh (2006) discussed experimental study of expansive clay beds stabilized with fly ash columns and fly ash-lime columns. Swelling was observed in clay beds of 100 mm thickness reinforced with 30 mm diameter fly ash columns and fly ash-lime column. Heave decreased effectively with both fly ash and fly ash-lime columns, with, lime-stabilized fly ash yielded better results.

Wagh (2006) used fly ash, rock flour and lime separately and also in combination, in different proportion to stabilize black cotton soil from Nagpur Plateau, India. Addition of either rock-flour or fly ash or both together to black cotton soil improve the CBR to some extent and angle of shearing resistance increased with reduced cohesion. However, in addition to rock-flour and fly ash when lime is mixed to black cotton soil CBR value increases considerably with increase in both cohesion and frictional resistance.

Phani Kumar and Sharma (2007) studied the effect of fly ash on swelling of a highly plastic expansive clay and compressibility of another non-expansive high plasticity clay. The swell potential and swelling pressure, when determined at constant dry unit weight of the sample (mixture), decreased by nearly 50% and compression index and coefficient of secondary consolidation of both the clays decreased by 40% at 20% fly ash content.

Kumar et al. (2007) studied the effects of polyester fiber inclusions and lime stabilization on the geotechnical characteristics of fly ash-expansive soil mixtures. Lime and fly ash were added to an expansive soil at ranges of 1–10% and 1–20%, respectively. The samples with optimum proportion of fly ash and lime content (15% fly ash and 8% lime) based on compaction, unconfined compression and split tensile strength, were added with 0, 0.5, 1.0, 1.5, and 2% plain and crimped polyester fibers by weight. The MDD of soil-fly ash-lime mixes decreased with increase in fly ash and lime content. The polyester fibers (0.5–2.0%) had no significant effect on MDD and OMC of fly ash-soil-lime-fiber mixtures. However, the unconfined compressive strength and split tensile strength increased with addition of fibers.

Buhler et al. (2007) studied the stabilization of expansive soils using lime and Class C fly ash. The reduction in linear shrinkage was better with lime stabilization as compared to same % of Class C fly ash.

The quarry dust/ crusher dust obtained during crushing of stone to obtain aggregates causes health hazard in the vicinity and many times considered as an aggregate waste.

III. MATERIAL AND METHODOLOGY

3.1 Fly-Ash

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster or a partial replacement for Portland cement in concrete production.

3.2 Experimental Investigation:

The experimental investigation was made on expansive soils and stabilized expansive soil by using fly-ash as per standards. Fly-ash was added to expansive soil with 10%, 20%, 30%, 40%and 50%. We find the geotechnical properties of expansive soil and stabilized soil and compare the characteristic strength of the unconfined compression strength (UCS) for 3, 7 and 28 Days curing period.

IV . RESULTS AND DISCUSSION

4.1 Specific Gravity

Tests were done for both the expensive soil and stabilized with fly-ash. It is observed that specific gravity of each sample when added with different percentage of fly-ash decreases as compared to the expensive soil. The variation of specific gravity of expensive soil and stabilized soil show in Table 2. The decrease in specific gravity may be due to the low specific gravity of fly-ash.

Table.2: Specific Gravity of Expensive Soil & Stabilized soil

S.No	Sample	Specific Gravity
1	Expensive Soil	2.65
2	Expensive Soil+ (10%) Fly-Ash	2.54
3	Expensive Soil+ (20%) Fly-Ash	2.44
4	Expensive Soil+ (30%) Fly-Ash	2.35
5	Expensive Soil+ (40%) Fly-Ash	2.23
6	Expensive Soil+ (50%) Fly-Ash	2.15

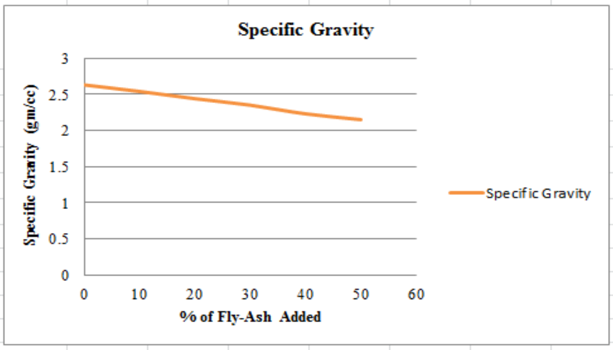

Fig.2 Specific Gravity vs. % Fly-Ash Mixer of Expansive Soil

4.2 Compaction Characteristics

Liquid limit (LL) and plasticity index (PI) of expensive soil and stabilized with fly-ash are evaluated. From the liquid limit and plasticity index of untreated expensive soil is found to be inorganic silts of high plasticity, and stabilized expensive Soil is found to be inorganic clays of low plasticity. Table shows liquid limit, plastic limit, plasticity index of expensive soil and fly-ash mixed sample. There is a increase in liquid limit (%) and decrease in plasticity limit (%) as compared to normal expensive soil without mixing of fly-ash. The plasticity index is also decreased for stabilized soil.

Table 3: OMC & MDD Values of Expensive Soil & Fly-Ash Mixed Soil

S.No	Sample	MDD (g/cc)	OMC (%)
1	Expensive Soil	1.768	22.546
2	Expensive Soil + (10%) Fly-Ash	1.754	23.414
3	Expensive Soil + (20%) Fly-Ash	1.78	23.49
4	Expensive Soil + (30%) Fly-Ash	1.792	21.638
5	Expensive Soil + (40%) Fly-Ash	1.752	23.308
6	Expensive Soil + (50%) Fly-Ash	1.682	21.928

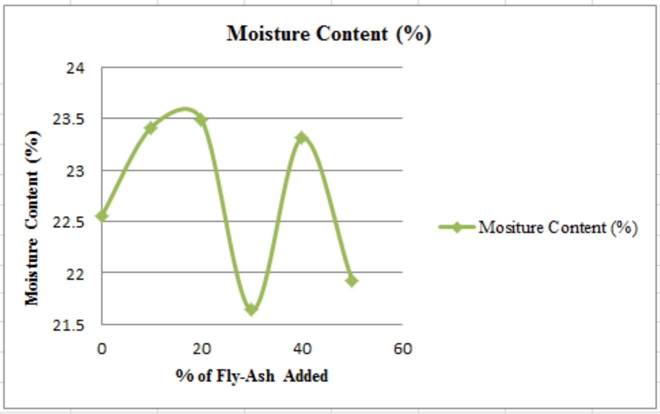

Fig.3A Optimum Moisture Content Vs % of Fly-Ash Mixer of Expansive Soil

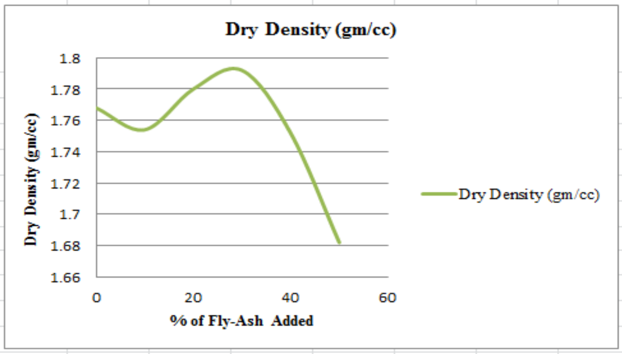

Fig.3B Maximum Dry Density Vs. % of Fly-Ash Mixer of Expansive Soil

4.3 Liquid Limit & Plastic Limit Test:

Liquid limit (LL) and plasticity index (PI) of expensive soil and stabilized with fly-ash are evaluated. From the liquid limit and plasticity index of untreated expensive soil is found to be inorganic silts of high plasticity, and stabilized expensive Soil is found to be inorganic clays of low plasticity. Table shows liquid limit, plastic limit, plasticity index of expensive soil and fly-ash mixed sample. There is a increase in liquid limit (%) and decrease in plasticity limit (%) as compared to normal expensive soil without mixing of fly-ash. The plasticity index is also decreased for stabilized soil.

Table 4: Results for Liquid Limit, Plastic Limit and Plasticity Index

Sample	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Expensive Soil	28.85	21.67	7.18
Expensive Soil + (10%) Fly-Ash	29.43	22.10	7.33
Expensive Soil + (20%) Fly-Ash	30.04	22.54	7.50
Expensive Soil + (30%) Fly-Ash	31.16	23.40	8.06
Expensive Soil + (40%) Fly-Ash	31.74	23.84	7.87
Expensive Soil + (50%) Fly-Ash	32.62	24.41	8.21

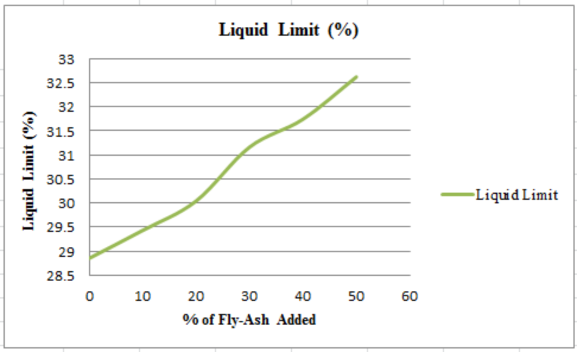

Fig.4 Liquid Limit.Vs % of Fly-Ash Mixer of Expansive Soil

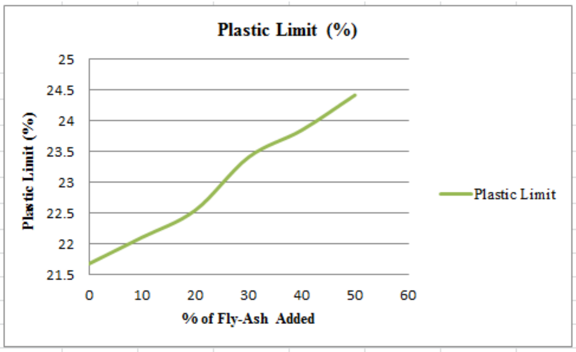

Fig.5 Plastic Limit.Vs % of Fly-Ash Mixer of Expansive Soil

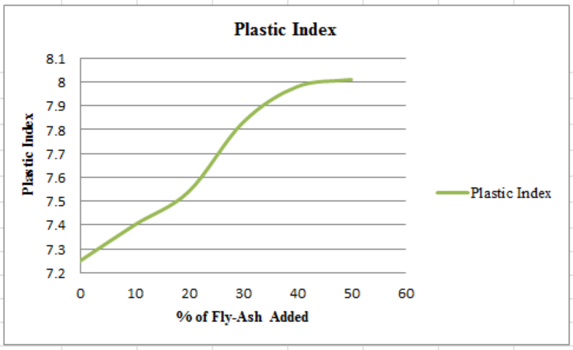

Fig.6 Plastic Index.Vs % of Fly-Ash Mixer of Expansive Soil

4.4 Unconfined Compressive Strength (UCS):

The increase in strength of expensive soils when then fly-ash is added to expansive soil for 3, 7,28 Days. The sample was prepared with 50mm dia and 100mm heights. Table 4.4 shows UCS value of expansive soil and stabilized soil. It is observed that expansive soil mixed with fly-ash has more strength than untreated expansive soil. Excess of fly-ash i.e. more than 20%, the mixture became decrease. So Optimum Percent of fly-ash is 20%.

Table 4: Unconfined Compressive Strength (UCS) Values of Expensive Soil & Fly-Ash Mixed Soil

Sample	Unconfined Compressive Strength (N/mm^2)		
Curing	3 Days	7 Days	28 Days
Expensive Soil	0.178	0.231	0.32
Expensive Soil + (10%) Fly-Ash	0.184	0.239	0.331
Expensive Soil + (20%) Fly-Ash	0.191	0.248	0.343
Expensive Soil + (30%) Fly-Ash	0.167	0.217	0.3
Expensive Soil + (40%) Fly-Ash	0.163	0.211	0.293
Expensive Soil + (50%) Fly-Ash	0.156	0.202	0.28

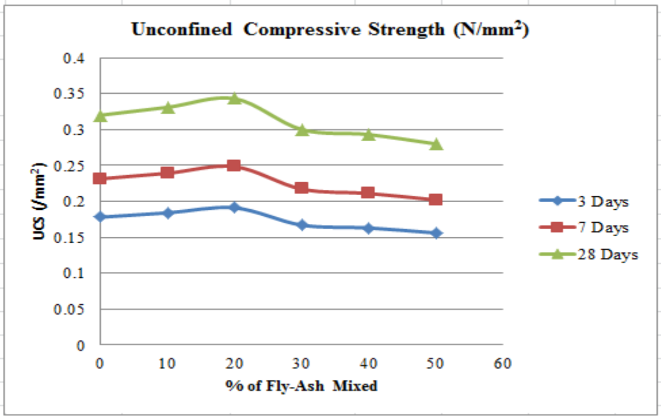

Fig.7: UCS for Expansive Soil with and Without Fly-Ash.

V CONCLUSION

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. Then, it showed increment with increasing fly ash content in the soil-fly ash mixture. The maximum value of MDD was observed for a mixture of soil and 30% of fly ash content by weight. The MDD values consistently decreased thereafter.

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.

With the increasing fly ash content in the soil-fly ash mixture, the decrease in value of free swell ratio was remarked. This decrease was also reciprocated by the plasticity index values. Plasticity index values are directly proportional to percent swell in an expansive soil, thus affecting the swelling behavior of the soil-fly ash mixture.

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

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