GROUND IMPROVEMENT BY STABILIZATION TECHNIQUE USING POND ASH AND SODIUM LIGNO SULPHONATE

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Abstract

The admixture Pond Ash and chemical Sodium Lignosulphonate are used for stabilization. The present study is to investigate the properties such as maximum dry density, optimum moisture content and unconfined compressive strength of black cotton soil stabilized with admixture, chemical and combination of both with varying percentages. So, the present study is conducted to check the performance by individual (i.e. parent soil) and combinations of both chemical and Pond Ash with soil. It was expected that, the combination of soil with Pond Ash and Sodium Lignosulphonate may improves Engineering Properties (by means of strength) with respect to parent soil. Black cotton soil is stabilized with the Pond Ash and Sodium Lignosulphonate. The quantities of Pond Ash and Sodium Lignosulphonate contents are varied gradually as 6%, 12%, 18%, 24% and 1%, 2%, 3%, 4% respectively by weight of total mix. Optimum quantity of Pond Ash is determined. Optimum amount of Pond Ash is kept constant and percentage of chemical is varied to study the properties of soil such as Consistency limits, MDD. The MDD and OMC values are determined for IS-light compaction.

Maximum dry density (MDD) and optimum moisture content (OMC) were 1.55gm/cc and 24% respectively when BC soil was treated with Sodium lignosulphonate. Chemical alone produced a better results compared to pond ash alone (1.61 gm/cc and 22%) and combination of both (1.58gm/cc and 22%). Unconfined compressive strength value improved by addition of pond ash 1.54(kg/cm^2) as (optimum 18% Pond Ash).

Keywords: Black Cotton Soi; Stabilization, Pond Ash; Sodium Lignosulphonat; Consistency limits; Maximum Dry Density.

INTRODUCTION

There are many types of soils which possess low strength that causes problems for geotechnical constructions. The reason for low strength of soil is associated with the increased water content, expansiveness (swelling behavior), low density and disturbance to the in-situ condition. There were many instances of failures associated with expansive soils especially Black cotton soils. The failures include erosion of soils of earthen dams, hydraulic structures, road embankments and some buildings with sub soil failure.

Thus the stabilization of the problematic soils such as soft fine-grained and expansive soils is very important for many of the geotechnical engineering applications such as pavement structures, roadways, building foundations, channel and reservoir linings, irrigation systems, water lines and sewer lines to avoid the damage due to the settlement of the soft soil or to the swelling action or heave of the expansive soils. It is undesirable to take up construction activities because of demand for land where this soil was encountered. Hence there is a need to improve its properties in order to make it stable to support the structures which are to be constructed over it.

Effective and bulk utilization of both locally available weak construction material and large quantity of disposed industrial waste is of global concern. Two major subjects of serious concern are availability of good construction material and safe disposal of huge amount of solid waste from industries. In the very first decade of second millennium, India saw sudden boost in infrastructure development and it is still in boom state, which might continue for long. There should be a safe disposal of huge amount of coal ash generated at a rate of more than 110 Metric tonnes per annum as a waste by-product from the large number of thermal power stations, which causes hazards and environmental problems. As the disposal of coal ash requires large area, therefore it is important to have its bulk utilization in base and sub base courses of the pavement, embankments, backfills etc., to increase ash utilization in the country.

Lignosulphonates are natural polymers derived from lignin that stabilises soil by physically binding the soils particles together with minor chemical effects. Individual soil particles can become coated in a thin adhesive-like film that acts to cement the particles together. Lignosulphonates are ionic and therefore there is potential for cation exchange that can alter the molecular structure of the soil. This has the potential to reduce the surface charge that can lead to flocculation, close packing and hydrophobic characteristics.

An attempt has been made to study the behaviour of treated black cotton soil and to improve the properties with the aid of locally available admixture pond ash and a chemical sodium lignosulphonate which is derived from lignin. The geotechnical properties of the soil play an important role in influencing its behaviour and the aim of the thesis is to expose the effects of admixture and a chemical.

Expansive soil bar have their own characteristics to the presence of swelling clay minerals. As they get wet, the clay minerals absorb water molecules and expand; conversely, as they dry they shrink, leaving large voids in the soil. Swelling clays can control the behavior of virtually any type of soil if the percentage of clay is more than about 5 percent by weight. Soils with clay minerals, such as montmorillonite, exhibit the most profound swelling properties. Potentially expansive soils can typically be recognized in the lab by their plastic properties. Inorganic clays of high plasticity, generally those with liquid limits exceeding 50 percent and plasticity index over 30, usually have high inherent swelling capacity.

Expansion of soils can also be measured in the lab directly, every year millions of tonnes of fly ash is produced all over India which is categorized as hazardous waste material. Its a medium grain size ash, mixture of ESP ash and bottom ash. It is best suited for use in agriculture, waste land development and forestry applications. It"s also a good material for geotechnical applications as a substitute of soil. It is better to use such waste materials in variety of ways, including roadbeds, construction fill, Ceramic tiles, Refractory aggregates, Refractory Bricks, Synthetic Granite or cement admixture. Indian fly ashes are not self-cementing and contain very low Calcium oxide. Hence improvement in strength properties of soil, when mixed with fly ash alone, is very maginal, however it can be used in combination with lime or cement for strength. Fly ashes can provide only cation exchange and weak pozzolonic reaction, but these reaction effectively reduce swelling properties.Based on their experimental study found that the MDD for pond ash sample is increased, due to addition of pond ash in soil. While the OMC decreases with increase in the pond ash content. The UCS value for peat and pond ash mixed sample increases.

The compressive strength of peat-pond ash sample almost doubled in comparison with original peat soil with addition of 20% pond ash of weight of modified soil presents the laboratory test results of a Class F pond ash alone and stabilized with varying percentages of lime and PG to study the suitability of stabilized pond ash for road base and sub-base construction. Standard and modified Proctor compaction tests have been conducted to reveal the compaction characteristics of the stabilized pond ash. Bearing ratio tests have been conducted on specimens, compacted at maximum dry density and optimum moisture content obtained from standard Proctor compaction tests, Both un-soaked and soaked bearing ratio tests have been conducted The empirical model has been developed to estimate the bearing ratio for the stabilized mixes through multiple regression analysis. Linear empirical relationship has been presented herein to estimate soaked bearing ratio from un-soaked bearing ratio of stabilized pond ash.

The experimental results indicate that pond ash-lime-PG mixes have potential for applications as road base and sub base materials. Numerous investigators have studied the influence of lime, cement, lime-cement, lime-fly ash, lime–rice husk- ash and cement – fly ash mixes on soil properties, mostly focusing on the strength aspects to study their suitability for road bases and sub basses. As lime and cement are binding materials, the strength of soil-additive mixtures increases provided the soil is reactive with them. However, for large-scale field use, the problems of soil.

MATERIALS AND METHODOLOGY

The Main Aim Of The Present Work Is To Understand The Improvement Of Geotechnical Properties Of Black Cotton Soil Stabilized With Pond Ash And Sodium Lignosulphonate. In Order To Achieve This; It Is Necessary To Carry Out Tests On Index And Engineering Properties By Treating The Soil At Variable Percentages.

Materials used:

Soil:

The black cotton soil used in the present study is procured from Mantur Road Mudhol. The soil samples were collected at a depth of 2m to perform experimental study to enhance the properties of soil. The Soil used in this study is a blackish gray inorganic clayey soil of high plasticity which belongs to CH group.

Table.1 Properties of untreated black cotton soil

Sr. No	Properties	Value
1	Specific gravity	2.64
2	Grain size distribution (%) ➢ Coarse sand ➢ Medium sand ➢ Fine sand	 44.8 51.2 3.6
3	Liquid limit (%)	75.2
4	Plastic limit (%)	38.77
5	Plasticity index (%)	36.43
6	Free swell index	38
7	IS classification of soil	CH
8	Proctor Compaction Test ➢ Max.dry density (g/cc) ➢ Optimum moisture content (%)	 1.34 28
9	Unconfined compressive strength	1.45

Pond Ash:

Pond ash has been collected from the Thermal Power Plant Shaktinagar Raichur, India. This is generally grey in colour and pozzoloanic in nature. The most common chemical compositions of pond ash are SiO_2, Al_2O_3, MgO, CaO, Fe_2O_3, organic carbons and others. The pond ash was collected from near the slurry disposal point which is coarser in nature.

Pond ash is the by-product of thermal power plants, which is considered as a waste material and its disposal is a major problem from an environmental point of view and also it requires a lot of disposal areas. Actually, there are three types of ash produced by thermal power plants, viz. (1) fly ash, (2) bottom ash, and (3) pond ash. Fly ash is collected by mechanical or electrostatic precipitators from the flue gases of power plant; whereas, bottom ash is collected from the bottom of the boilers. When these two types of ash, mixed together, are transported in the form of slurry and stored in the lagoons, the deposit is called pond ash.

The volume of pond ash produced by thermal power plants is very large compared to that of the other two ashes, viz. fly ash and bottom ash .The task to utilize the pond ash to the maximum possible extent is still a major problem throughout the world. To solve the problem, pond ash has potential applications in different areas like structural fills and highway embankment. Pond ash is a lightweight and self-draining material compared to natural soil. For successful application of pond ash as fill material in civil engineering construction, knowledge of compaction characteristics of the fill material is essential to achieve effective compaction in the field.

Pond Ash which can be used for soil improvements has gained tremendous impetus during the last two decades. Initial uses of pond ash, stabilized with lime, as a highway sub grade dates back to the late 1950s and early 1960s (Davidson & Handy 1960; Snyder and Nelson 1962). In1970s the variety of fly ash applications increased (Copp & Spencer 1970 Joshi et.al 1975), and applications enveloping cement stabilized fly ash were introduced.

However, the present scenario of the utilization of pond ash in India is grim. About 8% of the produced fly ash is being used commercially .This shows that there exists a tremendous potential of utilization of pond ash in geotechnical constructions in order to preserve the valuable top soil.

Geotechnical constructions like embankments, retaining structures, etc require huge amount of earth materials. Rapid industrialization and non availability of conventional earth material have forced the engineers and scientist to utilize the waste product of industries which either degrade the environmental pose problems for their disposal. In this connection utilization of by-products like pond ash needs special attention. Pond ash is a byproduct of a coal fired thermal power plants and contains particles of fine sand to silt sizes. For the design of cement stabilized reinforced pond ash structures, a proper understanding of the interaction between reinforcement materials and stabilized fly ash is necessary. The properties of pond ash are as shown in Table.2

Table.2 Properties of Pond Ash

Properties	Results	IS CODES
Specific gravity	2.05	IS 2720 PART 3 1980
Grain size		
Coarse sand (%) Medium sand (%) Fine sand (%) Fines (silt & clay) (%)	3.85 21.45 52.36 21.85	IS 2720 PART 4 1985
Liquid limit	NP	IS 2720 PART 5 1985
Plastic limit	NP	
MDD(KN/m^3)	11.2	IS 2720 PART 7 1980

Estimation of Chemical composition of Pond Ash (Sio_2, Al_2O_3 , Fe_2O_3 and Cao) as per IS: 1727- 1967

Accurately weighed sample (1.50gm) cooked with conc. Hcl (20-30ml) for about 2 hours. Then the flask was cooled, side walls washed with distilled water, total volume made up to about 100ml.Then it is filtered through what man No 41 filter paper. Washed the residue several times with dil. Hcl, finely with distilled water. The residue with filter paper dried, incinerated and weighed as sio_2 (heating and weighing done till constant weight).

Filtrate neutralized by adding NH_4OH. The precipitated Al_2o_3 and Fe_2o_3 filtered through whatman No 41filter paper. Residue washed several times with distilled water, dried and incinerated weight as R_2O_3 ($Al_2o_3 + Fe_2o_3$).

Volume remaining filtrate reduced to about 100ml then titrated against EDTA using EBT indicator and Cao calculated.

Table.3 Chemical composition of Pond Ash

Sl. No	Major element	Percentage
1	SiO_2	91.33
2	Al_2O_3	0.117
3	Fe_2O_3	0.103
4	Cao	2.33

Chemical: Sodium lignosulphonate

It is a naturally occurring polymer found in wood and works by binding the road surface particles together. Water evaporates from the lignosulphonate as it dries, and the dust particles are trapped by the high-viscosity, naturally sticky material.

Sodium lignosulphonate is available in both liquid as well as in powdered form. In this present study a powdered form sodium lignosulphonate is used and it is added to the soil in varying percentages by dry soil weight.

Table.4 Composition of Sodium Lignosulphonate

Parameters	Percentage
Molecular formula	$C_{20}H_{24}Na_2O_{10}S_2$
Molecular weight	534.51
Description	Mealy powder
PH of 3% soln	6
Reducing sugar on dry (%)	6.5
Sulphur (%)	4
Sodium (%)	10
Ash on dry (%)	7.5

Methodology:

Black cotton soil is stabilized with the Pond Ash and Sodium lignosulphonate. The quantities of pond ash and sodium lignosulphonate contents are varied gradually as 6%, 12%, 18%, 24% and 1%, 2%, 3%, 4% respectively by weight of total mix. Optimum quantity of pond ash is determined. Optimum amount of pond ash is kept constant and percentage of chemical is varied to study the properties of soil such as Consistency limits, MDD. The MDD and OMC values are determined for IS-light compaction.

RESULTS AND DISCUSSIONS

1. Consistency limits of soil treated with Pond Ash

To determine the effect of pond ash on consistency limits of Black cotton soil, liquid limit and plastic limit tests were conducted. The pond ash is incorporated into the soil as 6%, 12%, 18% and 24% . Table.5 indicates the consistency limits of untreated and treated black cotton soil for different percentages of pond ash.

Table.5 Effect of pond ash content on Consistency limits

Pond Ash (%)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
0	75.2	38.77	36.43
6	70.2	41.78	28.47
12	64.70	42.10	22.6
18	60.70	44.21	16.50
24	53.4	44.64	8.76

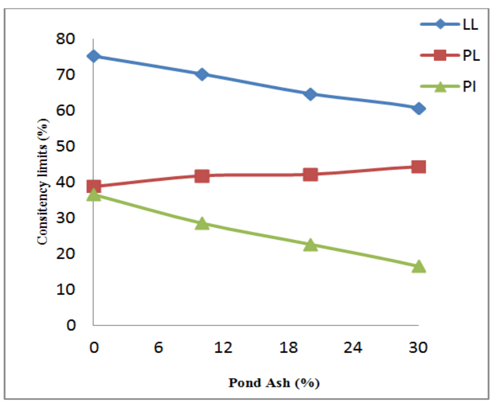

Figure.1 Variation of Consistency limits with Pond Ash content

Figure.1 shows the variation of liquid limit for various percentages of the pond ash. From the above figure it is clearly observed that the treated soil has followed a trend of continuous reduction in the liquid limit with increase in percentages of pond ash.

2. Compaction characteristics of soil treated with Pond ash

The compaction characteristics of the Black cotton soil were determined by Standard Proctor Compaction test i.e. with the aid of light compaction. The soil was compacted in three layers with 25 blows for each layer. The rammer used for compaction was 2.6 kg with a free fall being 310 mm and the volume of the cylindrical mould used in the compaction was 1000 cc.

The compaction test was carried out to determine the maximum dry density and optimum moisture content of the untreated and treated Black cotton soil for different percentages of pond ash and the compaction tests results are shown in Table.6 below.

Table.6 Effect of Pond ash content on MDD and OMC

Pond Ash (%)	Maximum dry density (gm/cc)	Optimum moisture content (%)
0	1.34	28
6	1.45	26
12	1.43	26
18	1.55	24
24	1.45	24

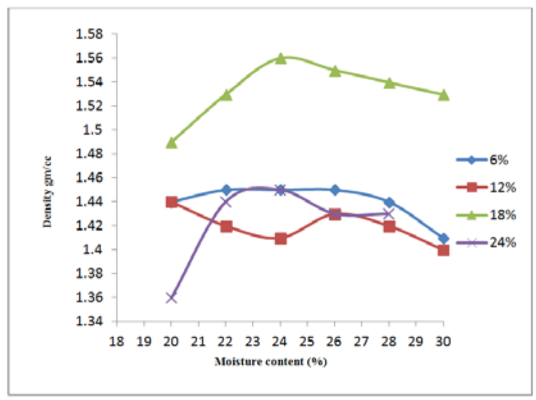

Fig.2 Variation of MDD with OMC on Addition of Pond Ash

Figure.2 shows the compaction curve for different percentages of pond ash used to treat the black cotton soil. The MDD and OMC for untreated soil were 1.34 gm/cc and 28% respectively. Whereas for treated soil are 1.45gm/cc, 1.43gm/cc, 1.54gm/cc, 1.45gm/cc and 26.0%, 26%, 24% and 24% respectively. At low percentages of pond ash the MDD did not show much variation but for higher percentages (12%, 18% and 24%), there is a much variation in the dry density. It is because the flocculated soil particles might have collapsed during compaction which has increased its weight. As density depends up on the weight of the soil compacted. Here 18% is considered as the optimum since beyond 18% of pond ash MDD got decreased and OMC increased.

3. Consistency limits of soil treated with Sodium Lignosulphonate

To determine the effects sodium lignosulphonate on consistency limits of Black cotton soil liquid limit and plastic limit tests were conducted. The sodium lignosulphonate is incorporated into the soil as 1%, 2%, 3%, and 4%. Table.7 indicates the consistency limits of untreated and treated black cotton soil for different percentages of sodium lignosulphonate.

Table.7 Effect of Sodium Lignosulphonate on Consistency limits

Sodium lignosulphonate (%)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
0	75.2	38.77	36.43
1	73.6	39.84	33.76
2	70	41.67	28.33
3	68	42.86	25.14
4	62	45.38	16.17

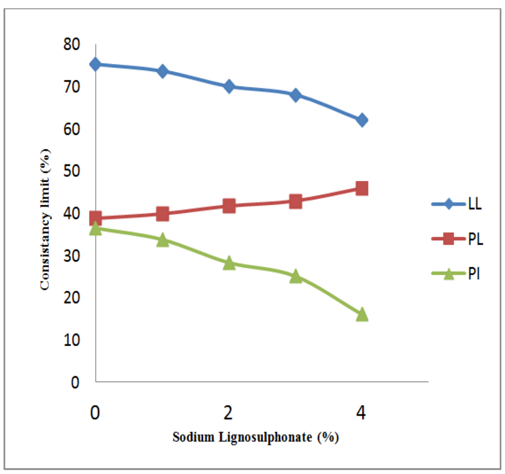

Figure.3 Variation of Consistency Limits with Sodium Lignosulphonate

Figure.3 shows the variation of liquid limit for various percentages of the sodium lignosulphonate. From the above figure it is clearly observed that the treated soil has followed a trend of continuous reduction in the liquid limit with increase in percentages of sodium lignosulphonate. This can be considered to be as a result of the binding soil particles and dispersion of the clay fraction by Lignosulphonate (Which acts a binder to glue the soil particles together).

4. Compaction characteristics of soil treated with Sodium Lignosulphonate

The compaction characteristics of the Black cotton soil were determined by Standard Proctor Compaction test i.e. with the aid of light compaction. The compaction test was carried out to determine the maximum dry density and optimum moisture content of the untreated and treated Black cotton soil for different percentages of sodium lignosulphonate and the compaction tests results are shown in Table.8 below.

Table.8 Effect of Sodium Lignosulphonate onMDD and OMC

Sodium Lignosulphonate (%)	Maximum dry density (gm/cc)	Optimum moisture content (%)
0	1.34	28
1	1.54	22
2	1.61	22
3	1.54	26
4	1.55	20

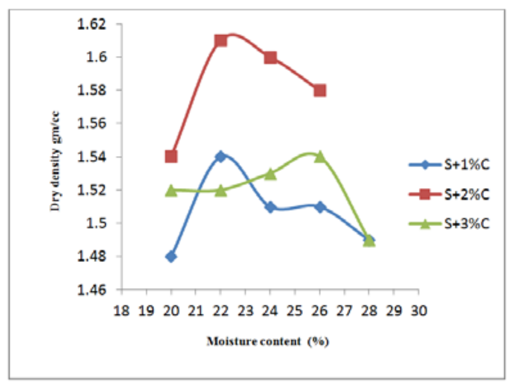

Figure.4 Variation of MDD with OMC on addition of Sodium Lignosulphonate

Figure.4 shows the compaction curve for different percentages of pond ash used to treat the black cotton soil. The MDD and OMC for untreated soil were 1.34 gm/cc and 28% respectively. Whereas for treated soil are 1.54gm/cc, 1.61gm/cc, 1.54gm/cc, 1.55gm/cc and 22%, 22%, 26% and 20% respectively. This is because Lignosulphonate binds the soils particles together with minor chemical effects. Individual soil particles can become coated in a thin adhesive-like film that acts to cement the particles together. It is clearly observed that, addition of small amount of chemical there is a tremendous change in maximum dry densities and optimum moisture contents. For example just addition of 1% chemical MDD got increased to 1.54gm/cc from 1.34gm/cc and OMC reduced to 22% from 28%. Here 2% is more effective in obtaining maximum dry density i.e. 1.61 gm/cc and minimum OMC i.e. 22%.

5. Consistency limits of soil treated with optimum (18%) Pond Ash and varying percentages of Sodium Lignosulphonate

To determine the effect of combination of optimum 18% pond ash and varying percentages sodium lignosulphonate on consistency limits of Black cotton soil, liquid limit and plastic limit tests were conducted. The combination is incorporated into the soil as(18%PA+1%Sodiumlignosulphonate,18%PA +2%Sodiumlignosulphonate, 18%PA+3% Sodium lignosulphonate). Table.9 indicates the consistency limits of treated black cotton soil for combination.

Table.9 Effect of Pond Ash and Sodium Lignosulphonate (combination) on Consistency limits

Optimum pond ash (%) + Sodium lignosulphonate (%)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
18+1	68	40.05	27.95
18+2	66.4	41.35	24.65
18+3	66	43.03	23.37
18+4	65.8	44.87	20.93

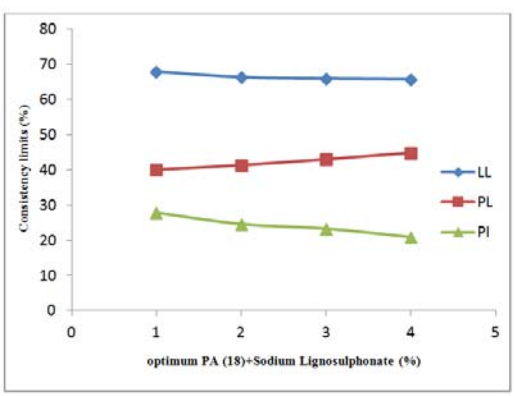

Figure.5 Variation of Consistency limits on combination of Pond Ash and Sodium Lignosulphonate

Figure.5 shows the liquid limit for variation of percentages of chemical with optimum pond ash content. Liquid limit reduced to 65.8% with 18% pond ash and 4% chemical and PI reached to very low value i.e. 20.93%. This is because of the resistance offered by the pond ash against liquidity of the treated soil and addition of chemical made Individual soil particles to become coated in a thin adhesive-like film that acts to cement the particles together. Here 4% chemical content with 18% of pond ash is effective in reducing the liquidity.

6. Compaction characteristics of soil treated with optimum (18%) Pond Ash and varying percentages of Sodium Lignosulphonate

The compaction characteristics of the Black cotton soil were determined by Standard Proctor Compaction test i.e. with the aid of light compaction. The compaction test was carried out to determine the maximum dry density and optimum moisture content of the treated Black cotton soil for combinations of optimum percentage pond ash (18%) ash and varying percentages of sodium lignosulphonate. The compaction tests results are shown in Table.10

Table.10 Effect of Pond Ash and Sodium Lignosulphonate (combination) on MDD and OMC

Optimum pond ash (%) + Sodium lignosulphonate (%)	Maximum dry density (gm/cc)	Optimum moisture content (%)
18+1	1.55	22
18+2	1.53	22
18+3	1.58	22
18+4	1.57	22

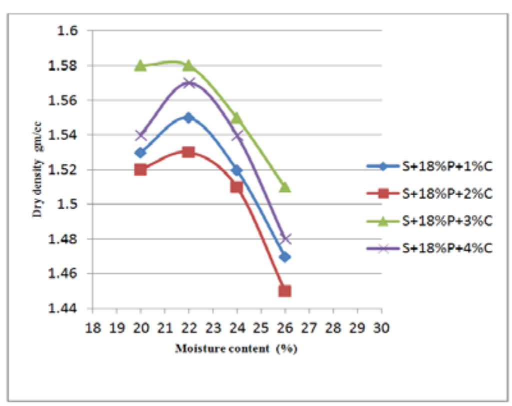

Figure.6 Variation of MDD with OMC on addition of Pond Ash and Sodium Lignosulphonate

Figure.6 shows the compaction curve for different percentages of chemical with optimum pond ash content used to treat the black cotton soil. The MDD and OMC for untreated soil were 1.34 gm/cc and 28% respectively. Whereas for treated soil with combinations are 1.55gm/cc, 1.53gm/cc, 1.58gm/cc and 1.57gm/cc and 22% for all combination respectively. It is because the flocculated soil particles might have collapsed during compaction which has increased its weight and Lignosulphonate binds the soils particles together with minor chemical effects. Here 3% chemical content with 18% of optimum pond ash is more effective in obtaining maximum dry density i.e. 1.58gm/cc and minimum OMC i.e. 22%.

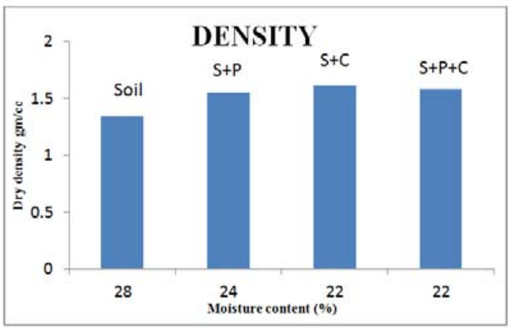

Figure.7 Variation of MDD with respect to addition of admixture and chemical

Figure.7 shows that the combination of optimum soil and chemical gives the maximum dry density 1.6 gm/cc compared to other combination (i.e., S+P, S+P+C) and soil alone.

Unconfined Compressive Strength of soil treated with Pond Ash

This test was conducted on treated Black cotton soil under unsoaked condition. The pond ash was mixed to the soil as 18% percentage (optimum percentage of pond ash) to the black cotton soil and results have been obtained as follow. The unconfined compressive strengths for 18% percentage is shown in table.11

Table.11 Effect of Pond Ash (18%) on Unconfined Compressive Strength

Pond Ash (%)	UCS (kg/cm^2)
18	1.54

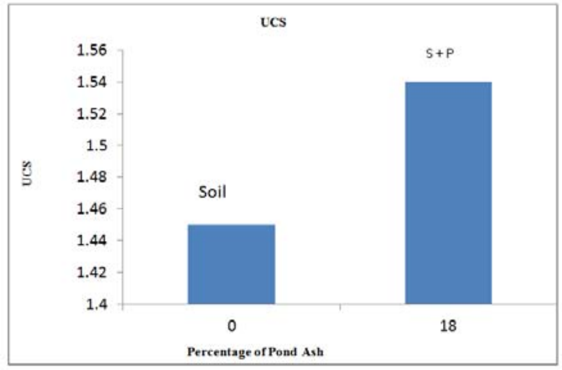

Fig .8 The Increased values of UCS of soil in addition of Pond Ash

Figure.8 shows that the UCS of untreated black cotton soil was 1.45kg/cm^2 and the UCS for optimum 18% Pond Ash was 1.54kg/cm^2.

CONCLUSION

Following conclusions were drawn from results obtained from experiments carried out.

1. The optimum dosage was found to be 18% for pond ash stabilized with black cotton soil. Whereas for sodium lignosulphonate optimum was found to be 2%.

2. Liquid limit (LL), plasticity index (PI) reduced by 19.30% and 54.71% respectively when pond ash was added to BC soil. Whereas for Sodium lignosulphonate and combination, Liquid limit (LL), and plasticity index (PI) reduced by 21.30%, 55.61% and 13.93%, 55.88% respectively.

3. Maximum dry density (MDD) and optimum moisture content (OMC) were 1.55gm/cc and 24% respectively when BC soil was treated with Sodium lignosulphonate. Chemical alone produced a better results compared to pond ash alone (1.61 gm/cc and 22%) and combination of both (1.58gm/cc and 22%).

4. Unconfined compressive strength value improved by addition of pond ash 1.54(kg/cm^2) as (optimum 18% Pond ash) .

5. For better stabilization results, chemical alone can be used as it provided higher MDD, low OMC and low liquid limit when compared to pond ash alone.

6. Soil treated with ash and chemical (S+PA+C) will give appreciable results of consistency limits, MDD and OMC with respect to than that of soil alone.

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