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Study on Stabilization of Clayey Soil Using Fly Ash and Sea Shell Powder

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Abstract: **Fly ash is considered as a waste raw material which is generated from gases that comes from coal furnaces, mainly of a thermal power plant. The demand of electricity supply has boosted up in this era due to increase in urban and industrial development. This advancement has also increase the counting of electricity producing plants i.e. Thermal power plants, which results in more coal burning and the amount of residue (fly ash) also run-up. Disposal of Fly ash is a big global issue today, because of its fineness and ultra-light weight it tends to mix with the natural clean air and create many respiratory problems to living beings. Sea Shells are natural coastal waste found on the coastline. They are the hardened skeleton of mollusks. Before using the Fly ash as an additive material in soil stabilization in various engineering projects, its engineering properties need to be investigated and improved using other materials as an admixture. Sea Shell powder derived hard naturally available Sea Shell which is rich in calcium is used with Fly ash as an admixture to improve its engineering properties. The clayey soil used in this study was procured from Bholath town in district Kapurthala in the state of Punjab. Fly ash was obtained from local batching plant situated in Alawalpur in Jalandhar and Sea Shells in its natural form were obtained from a Chennai based dealer. The aim of the present work is to find the optimum amount of Fly Ash and Sea Shell powder required to improve the engineering properties (CBR AND UCS) of Clayey soil. It was noted that an increment of 176% in CBR and 30% in UCS of clayey soil may be achieved if Fly ash and Sea Shell powder were mixed in clayey soil.**

Keywords: **Stabilization, waste material, clayey soil, Fly Ash, Sea Shell.**

1. INTRODUCTION

A hard task for Civil Engineers is to deal with the clayey subgrade. Clayey soil have a propensity to bulk, with the increase in its moisture content. The moisture in clayey soil can accumulate from rain water, floods, damaged water/sewer lines, or by the depreciation in evaporation because of the coverage of the top surface layer of the earth by civil structures. Construction on clayey soil can be very challenging as it can cause damage to the structures like roadways, embankments, foundation of structures, etc. Constant premium repairing of these damaged structures has created a need for more staunch investigation of clayey soils, so that the ill effect of the volume change of clayey soil can be reduced and to make the soil more stable for construction.

Clayey soil:

Clayey soil is fine texture, impermeable and can hold water in it. Clayey soil generally is nutrient rich soil. Clayey soils are very plastic in nature and have dissimilar consistency depending upon the moisture content present in it. Due to the very small size of the particles present in the clayey soil their packaging at structural level is very tight. There is very little space between these particles so it becomes very difficult for water to drain through this soil. When it is in the wet state, i.e. moisture content is high, it is usually gluey and have a smooth texture and when the moisture content is low, it becomes brittle and its plastic properties also decreases. Clayey soil deposits are made up of minerals like phyllosilicate having varying water content in its mineral structure.

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Table 1: Different properties of clayey soil used

Properties	Values
Specific Gravity	2.49
Liquid Limit (%)	23.8
Plastic Limit (%)	14.8
Plasticity Index	8.02
Optimum Moisture Content (OMC) %	14
Maximum Dry Density (MDD) (g/cc)	1.57

Fly ash:

Fly ash is considered as a waste raw material which is generated from gases that comes from coal furnaces, mainly of a thermal power plant. Volcanic ashes were majorly used as hydraulic cements in earlier times, and the properties of fly ash resembles to volcanic ashes These ashes, having these types of properties are considered as binding agent commonly known as pozzolans, which are used worldwide. The demand of electricity supply has boosted up in this era due to increase in urban and industrial development. This advancement has also increases the counting of electricity producing plants, i.e. Thermal power plants, which results in more coal burning and the amount of residue (fly ash) also run-up. The filter installed in these power plants, namely (ESP) Electrostatic Precipitator helps in collecting fine particles of fly ash.

Table 2: Chemical properties of fly ash

Component	Bituminous	Subbituminous	Lignite
SiO_2 (%)	20-60	40-60	15-45
Al_2O_3 (%)	5-35	20-30	20-25
Fe_2O_3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

Seashell powder:

Naturally found material near and on the sea coastline. They are the hardened skeleton of mollusks. Sea shells are mostly made up of calcium content, up to 90 % of seashells are calcium and remaining 10% are impurities. The absorption rate of seashell powder is also very high. The sea shells which were used in this study were first finely grained and turned into powder form, this powder was passed through IS150 Micron sieve and the powder which retain on IS75 after passing from IS150 was taken into account for this experimental work.

2. METHODOLOGY

To lay the aftermath of fly ash used as an additive and stabilizing agent in clayey soils, Various tests were conducted, in which percentage of fly ash mixed with clayey soil was gradually increased from 10%, 14%, 18%, 22% (increased by 4%) with respect to the total weight of the sample taken.

1. To find Atterberg's Limits of soil sample taken.

i) Liquid limit value of soil

ii) Plastic limit value of soil

2. To find out the Optimum moisture content (OMC) and Maximum dry density (MDD) of the soil by Modified Proctor compaction test.

3. To discover the strength properties i.e. California Bearing Ratio value and Unconfined Compression Strength value.

3. RESULTS AND DISCUSSION

The results of various tests as CBR and UCS on virgin soil and as well as on admixed soil are shown in following graphs.

Compaction Behavior of Clayey Soil mixed with different percentages of Fly ash:

The compaction behavior of Clayey soil when mixed with Fly ash was represented in figure 1.The various curves in figure 1 shows the relation of moisture content and maximum dry density of Clayey soil when mixed with different dose of Fly ash. The dose of Fly ash was varied from 10% to 22% with an increment of 4%.

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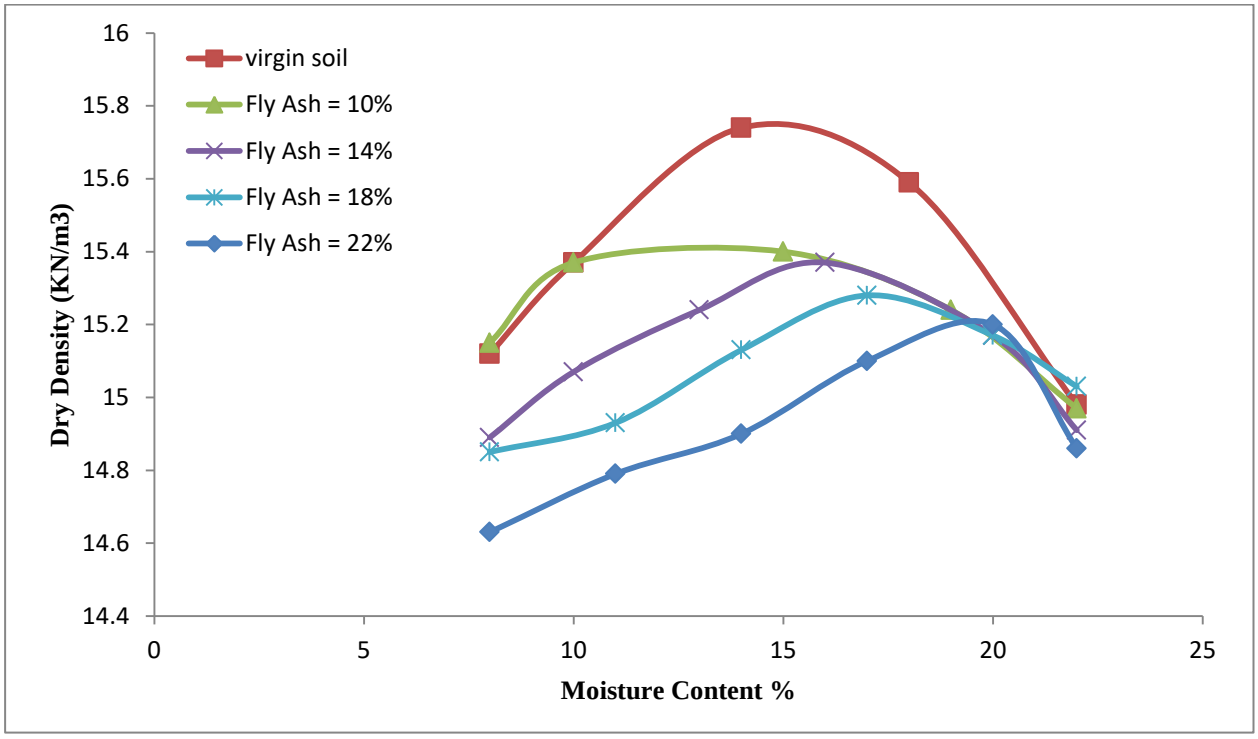

Fig 1: Comparative behaviour of virgin soil mixed with different % of Fly ash.

It was observed from fig.1, with increase in percentage of Fly ash from 10% to 22% in clayey soil, the MDD decreases from 15.46KN/m^3 to 15.01KN/m^3. However, OMC increases with the increase of content of Fly ash in clayey soil. OMC increases from 15% to 17% with the increase in Fly ash percentage from 10% TO 22%. A pozzolanic reaction takes place due to presence of calcium, Aluminium, Silica etc.in Fly ash. This results into formation of larger size of soil particles. The surface area of soil particles decreases, OMC must have to be decreased but as Fly ash absorbed water, more than water requirement decreases with increase in surface area of soil particle and hence finally OMC increase. The decrease in MDD with the increase in quantity of lime may be contributed to the light weight of Fly ash particle. The specific gravity of clayey soil is higher than that of Fly ash, hence as the content of Fly ash increases, the maximum dry density of soil mix decreases.

Table 3: Readings of compaction test for different mixes of soil with different % of fly ash

SOIL : FLY ASH	MDD (KN/m^3)	OMC (%)
100:0	15.74	14.00
90:10	15.46	15.00
86:14	15.39	16.00
82:18	15.28	17.00
78:22	15.01	17:00

Effect of Fly ash on CBR:

CBR tests were also performed as per Indian standards. Both soaked and un soaked tests were carried out .The load penetration reaction may take place, The load penetration curves for virgin soil and soil mixed with Fly ash into different percentage were represented in figure 2.CBR were determined corresponding to 2.5 and 5 mm. The CBR of mix blended with Fly ash in ratio varying from 10% to 22% at a constant interval of 4% were summarised in table.4.

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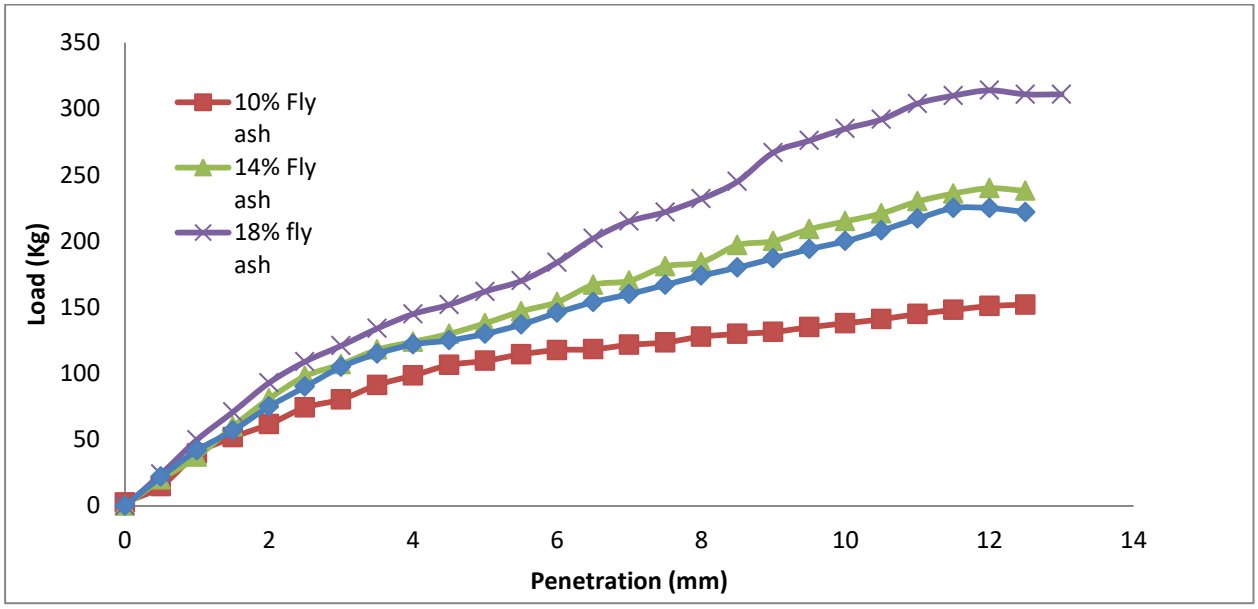

Fig 2: Load Penetration curve for different mix of Fly ash.

It was observed that CBR of clayey soil when mixed with Fly ash increases with the increase in content of Fly ash up to 18% of Fly ash. If lime content is further increased, CBR start decreasing.

Table 4: Readings of CBR of Clayey soil mix with Fly ash

SOIL:FLY ASH	CBR (UNSOAKED)
Virgin soil	3.57
90:10	5.4
86:14	6.64
82:18	7.66
78:22	6.32

Initially CBR of soil increases from 10% till 18%, it can be due to the fact that initially calcium available in the fly ash reacts and pozzonalic reaction takes place. The strength of the bond formed increases, but beyond 18% of fly ash, the fly ash present in the soil is not able to react and the CBR value declines.

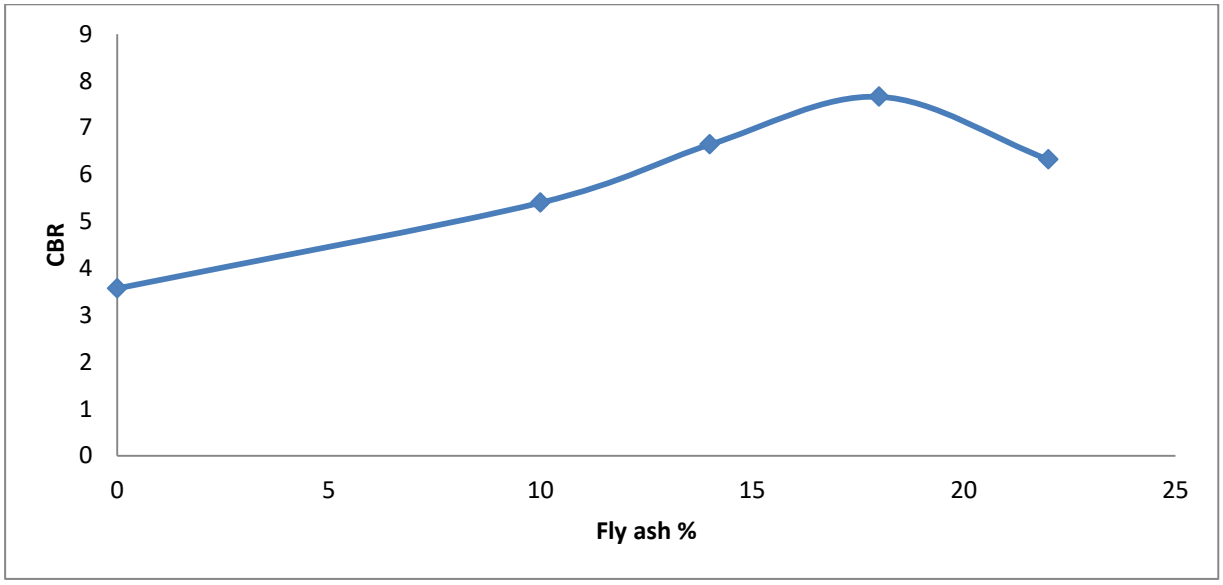

Fig 3: Effect of Fly ash on CBR.

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It may be concluded that if 18% of Fly ash is mixed in clayey soil, CBR of clayey soil increases to its maximum from 3.57 to 7.66 which is an increase of 114%. Therefore 18% of Fly ash content is the optimum quantity with respect to the CBR of soil.

Compaction Behaviours of Clayey soil with Fly ash and Seashell powder:

Seashell powder (SSP) is mixed with clayey soil in different proportions ranging from 6% to 14% with an increment of 4%. The compaction behaviour of clayey soil mix was represented in figure.4.

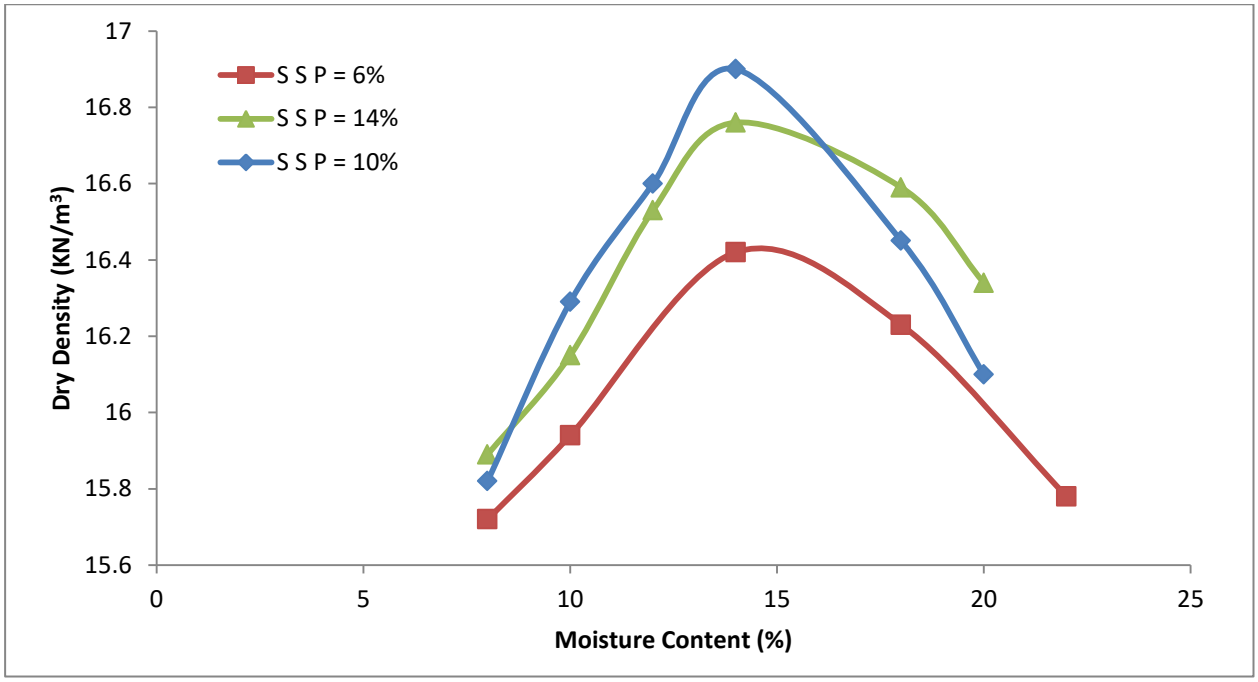

Fig 4: Compaction behaviour of Clayey soil with varying percentages of seashell powder.

OMC and MDD of soil mix with different % of Seashell powder were determined as per Indian standard. Figure 5 represent the effect of Seashell powder on OMC of clayey soil.

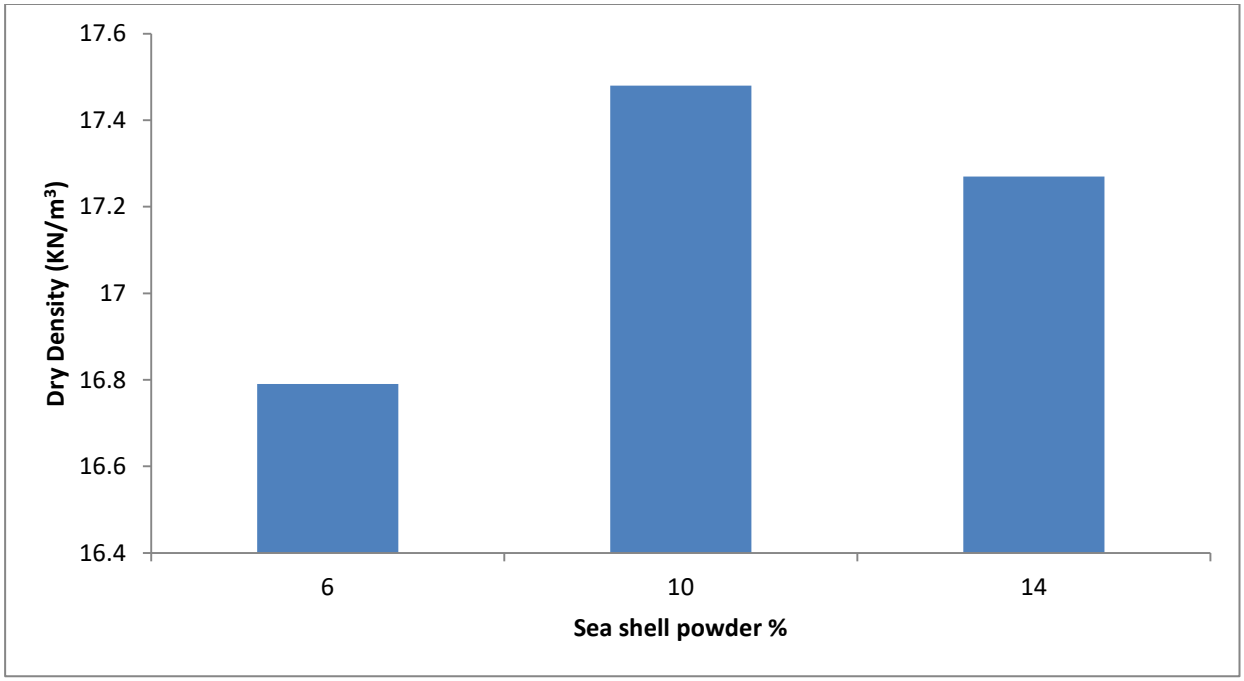

Fig 5: Effect of Seashell on MDD

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It was observed that maximum dry density for clayey soil was observed at 10% seashell powder. Furrher addition of seashell in clayey soil decrease the the MDD value, it may be due the lower specific gravity of seashell powder as compare to the clayey soil and with the increase in the content of seashell in the mix, the MDD decrease as shown in fig.5.

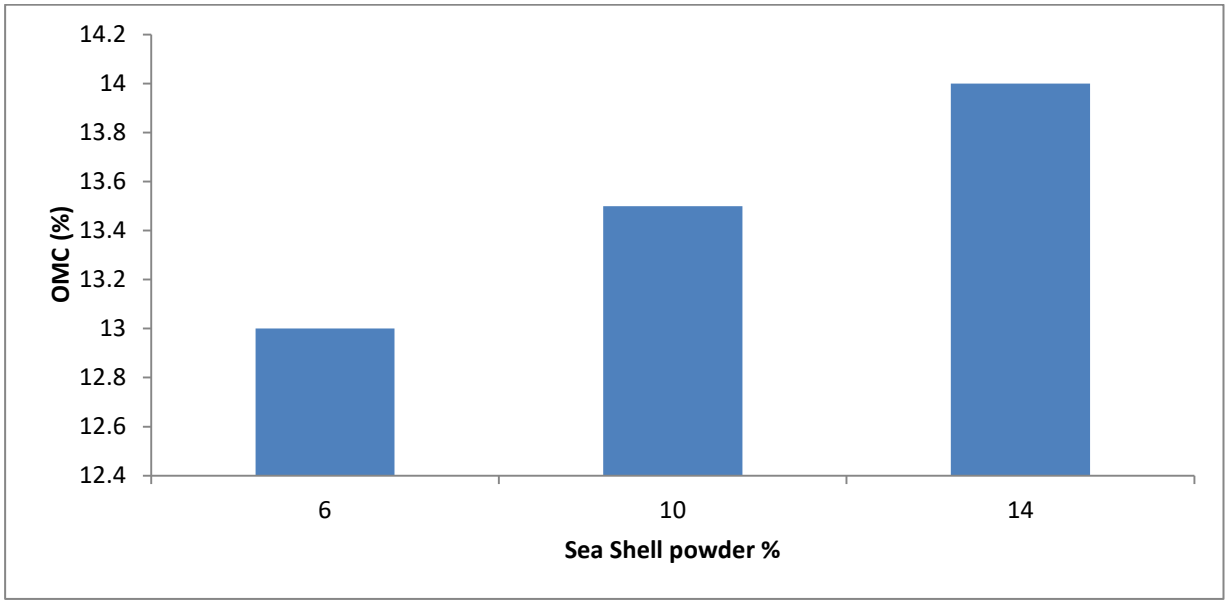

Fig 6: Effect of Seashell on OMC

Effect of Leaf Ash on CBR:

Seashell powder is natural waste materials to improve the strength of clayey soil as it contain calcium in large amount. To investigate the effect of seashell powder on the strength parameter of clayey soil, CBR tests were carried out in the lab by adding seashell powder in the mix of clayey soil and optimize fly ash. The load penetration curves of various mixes of clayey soil, fly ash and seashell powder were shown in figure.7.

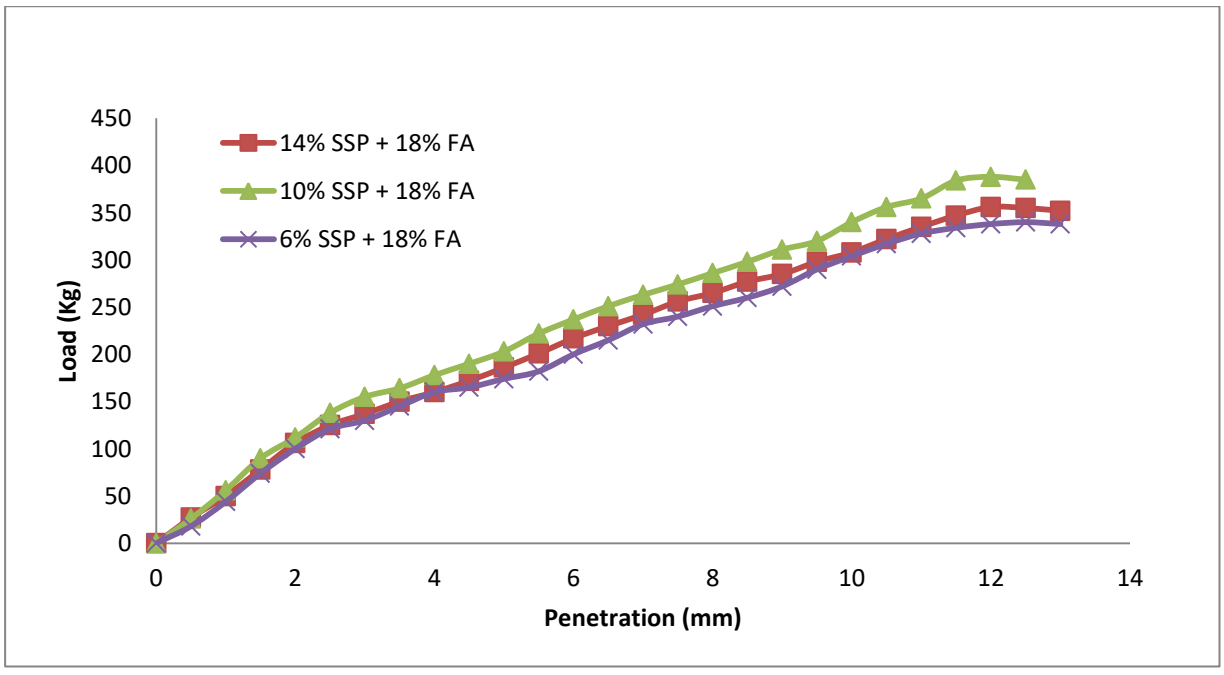

Fig 7: Load penetration curves for different mixes

The CBR values observed from the above graph depict that the CBR value is high for a mixture of 10% seashell powder and 18% fly ash i.e.10.07 and 9.87 for 2.5mm and 5mm respectively. This increase in CBR may be contributed to

pozolanic reaction of seashell powder due to presence of high amount of calcium in seashell powder. This reaction results in stronger bond and hence increases the strength of clayey soil. The decrease in the CBR value after adding seashell powder more than 10% is due to the free availability of seashell powder in the mix. Therefore 10% may be considering as the optimum dose of seashell powder in the mix of clayey soil and 18% fly ash.

UCS Behavior:

In case of construction and filling of embankment for road construction unconfined strength of soil also need to be investigated. Therefore in the present study, UCS test of clayey soil in the laboratory was carried out. Fly ash and seashell powder was also mixed into different proportion to observe the effect of these materials on UCS

SOIL:FLYASH:SEASHELL POWDER	UCS ($N/mm^{2)}$
100:0:0	0.197
90:10:0	0.195
82:18:0	0.206
78:22:0	0.176
76:18:6	0.227
72:18:10	0.254
68:18:14	0.238

Fig 8: UCS values for different mixes of fly ash and seashell powder in clayey soil

It was observed that the UCS value increases with the increase in fly ash content and it is observed highest when 18% fly ash is mixed with clayey soil. Further when seashell powder is added with the optimum dose of fly ash mixed with clayey soil, the UCS value increases to a value of 0.254 N/mm^2 when 10% seashell was added to the admixture. By further adding more seashell powder the amount of calcium in the mixture increases and the value starts decreasing. From the above values of UCS test it can be concluded that 18% fly ash and 10% seashell powder is the optimum proportion for attaining maximum value for UCS.

4. CONCLUSIONS

- OMC of clayey soil increases with increasing the dose of fly ash in the clay. About 3% increase in OMC was observed when 18% fly ash was blended with the soil.
- No significant effect of sea shell on OMC was observed. By mixing 14% of sea shell in the clay, the OMC remains constant at 14%.
- A small decrease in MDD was observed with the addition of Fly ash in soil. Maximum Dry Density of soil(virgin) is 15.70 $KN/m^{3,}$ and when 18 % of Fly ash was mixed in the soil, MDD reduces to 15.20 $KN/m^{3.}$
- On the contrary, MDD increases with the increases in dose of sea shell. MDD increased to 17.48 kN/m^3 from 15.7 kN/m^3, if 10% sea shell powder was mixed in the clayey soil.
- Unsoaked CBR increases with the increase in the dose of fly ash. Maximum CBR was noticed at 18% dose of fly ash. A 96% increase in CBR was observed when clayey soil was mixed with 18% of fly ash. CBR was further improved by 30% if 10% sea shell powder was blended in the mix of clay and 18% fly ash. A overall 180% increase in CBR can be achieved by blending 18% fly ash and 10% sea shell powder.
- The soaked CBR increased to 7.53% if 18 % of Fly ash was mixed in the clay. It further increased to 8.79% if the mix of clay and 19.5% fly ash was mixed with 10% sea shell powder.
- In UCS test, the value increases from 0.197 to 0.206 (N/mm^2) when 18% Fly ash is mixed with the clayey soil. Further with the addition of 10% Sea Shell powder with 18 % Fly ash the value increases to 0.254 (N/mm^2). Improving the UCS value by 30%

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