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Effect of Egg Shell Powder on Index and Engineering Properties of Clayey Soil

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Abstract: **Eggshell powder is used as an additive to combine with clayey soil so that properties like compaction and shear strength of clayey soil are investigated at 0%,3%,5%& 10% to the weight of soil. It is more efficient & economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for different deep foundations.**

Index Terms: **Egg shell powder-ESP, Clayey soil, Index properties, Engineering properties, Optimum Moisture content-OMC, Maximum dry density-MDD.**

I. Introduction

Construction on Clayey Soil Appears to be difficult, as it possesses low strength and high compressibility when water content increases with the advancement of science, materials, and equipment, soil stabilisation has begun to take on a new form, where egg shell powder is one among them. It is becoming a common and cost-effective soil improvement technique. "Ref. [1]" To investigate the properties of the soil in terms of liquid limit, plastic limit, optimal moisture content, maximum dry density, and direct shear strength, as well as to see how eggshell powder in different percentages affects these properties such as Liquid limit, Plastic limit, Optimum moisture content, maximum dry density, direct shear strength.

II. Materials used and Methodology Adopted

A. Black Cotton Soil

Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. Most of the expansive soils are rich in montmorillonite and a few amounts in illite. The black cotton soil is collected from Ibrahimpatanam, Ranga Reddy, Hyderabad.

B. Egg Shell Powder

"Ref. [3]" Eggshell powder primarily contains CaO (99.83%) and the remaining consists of Al2O3, SiO2, Cl, Cr2O3, MnO andCuO. ESP has not been used as stabilizing material, but it could be a good replacement for industrial lime. Egg shell waste was washed and dried before grinding. Egg shell powder was sieved using IS Sieve No.200 (75μ), and the powder passing the sieve 75μis used.

Egg shell powder

C. Methodology Adopted

Different tests are conducted on virgin soil to determine its index & Engineering properties. "Ref. [5]" Then after, tests are done by adding Egg shell powder at 3%, 5% and 10% to the dry weight of soil. Results from the above-mentioned tests are compared and analyzed the effect of ESP on soil.

D. Tests Performed on Soil Samples

1)Atterberg'sLimits

"Ref. [4]" The measure of essential water contents of a fine-grained soil is described by Atterberg's limits. Soil can appear in a variety of forms depending on its water content. They are solid, semi-solid, plastic and liquid.

a) *Liquid Limit:*

Liquid Limit is the water content at which soil changes from a plastic to a liquid state when the soil specimen is just fluid enough for a groove to close when jarred in a specified manner.

b) *Plastic Limit:*

The moisture content of a soil at the boundary between the plastic and semi-solid states of consistency is expressed as a percentage of the weight of the oven-dry soil. When rolled into a thread, it's the moisture content at which a soil starts to crumble.

2) Standard Proctor Test

The Proctor compaction test is a laboratory method for determining the optimum moisture content at which a particular soil type will become most dense and reach its maximum dry density.

Calculations:

Bulk density of soil: $\Upsilon = (W_2 - W_1)/ 1000$

Dry density of soil: $\Upsilon_d = \Upsilon / (1+w)$

Where w = moisture content present in soil.

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III. Experimental Results of Samples

A. Atterberg's Limits

(1) Liquid Limit:
Table 1 show the Liquid limits values for natural soils which is done in four trials.

TABLE I.
LIQUID LIMIT VALUES FOR NATURAL SOILS

Trials	1	2	3	4
W1(g.)	38.97	38.19	37.6	28.18
W2(g.)	47.11	48.58	47.73	38.11
W3(g.)	43.55	44.3	43.65	34.18
(W2-W3) (g.)	3.46	4.28	4.08	3.93
(W3-W1) (g.)	4.68	6.11	6.05	6.0
W(%)	73.93	70	67.4	65.5
N	16	20	26	32

Where
W1=Weight of container
W2=Weight of container+Wet soil
W3=Weight of container+Dry soil
(W2-W3)=Weight of water
(W3-W1)=Weight of dry soil
w(%)=Moisture content
N=Number of blows

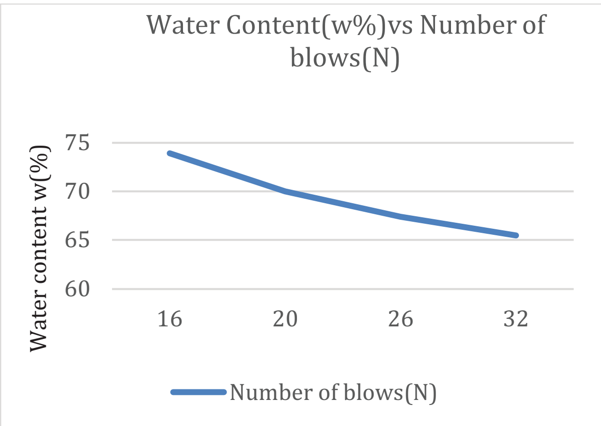

Figure 1. Liquid limit graph for natural soils

The variation of liquid limit can be observed from figure 1 which shows the variation of blows with water content.

Values of Liquid limit for soil with addition of 3% Egg Shell powder is shown in table II.

TABLE II.
LIQUID LIMIT VALUE OF SOIL ADDED WITH 3% OF ESP

Trials	1	2	3	4
W1(g.)	27	28	37.8	27
W2(g.)	63	57	77	38.9
W3(g.)	48.56	45.72	61.64	34.29
(W2-W3) (g.)	14.44	11.28	15.36	4.61
(W3-W1)	21.56	17.72	23.84	7.29
w(%)	66.9	63.48	64.4	63.23
N	10	23	30	41

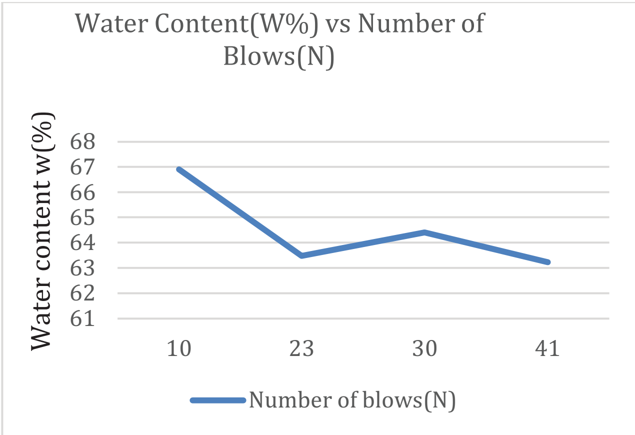

Figure 2. Liquid limit variation for soil with 3% of ESP

Figure 2 shows the variation of blows with water content by the addition of ESP at 3%.

TABLE III.
LIQUID LIMIT VALUE OF SOIL ADDED WITH 5% OF ESP

Trials	1	2	3	4
W1(g.)	39.06	38.5	33.1	27.2
W2(g.)	61.09	60.53	55.3	48
W3(g.)	53.75	53.1	47.8	41
(W2-W3) (g.)	7.34	7.43	7.5	7
(W3-W1) (g.)	14.69	14.6	14.7	13.8
w(%)	50.1	50.8	51.02	50.7
N	15	21	35	42

Table III shows the Liquid limits values for soil added with 5% ESP done in four trials. We can observe the reduction in Liquid limit value with increase in ESP.

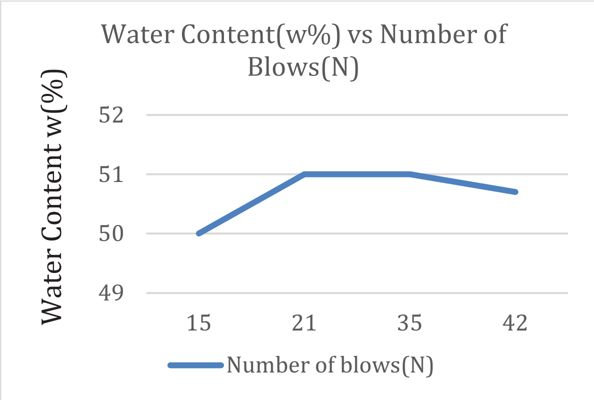

Figure 3. Liquid Limit Variation for Soil With 5% Of ESP

The variation of blows with water content can be seen from fig 3. Reduction of blows can be seen with increase in ESP.

Variation of Liquid limit with addition of 10% ESP can be seen from table IV.

TABLE IV.

LIQUID LIMIT VALUE OF SOIL WITH 10% OF ESP

Trials	1	2	3	4
W1(g.)	13.24	12.56	13.53	13.26
W2(g.)	54.92	53.02	53.06	45.12
W3(g.)	42.00	40.68	41.28	35.74
(W2-W3) g.)	28.76	28.12	27.75	22.53
(W3-W1) g.)	12.92	12.34	11.78	9.33
w(%)	44.95	43.91	42.45	41.40
N	18	23	30	35

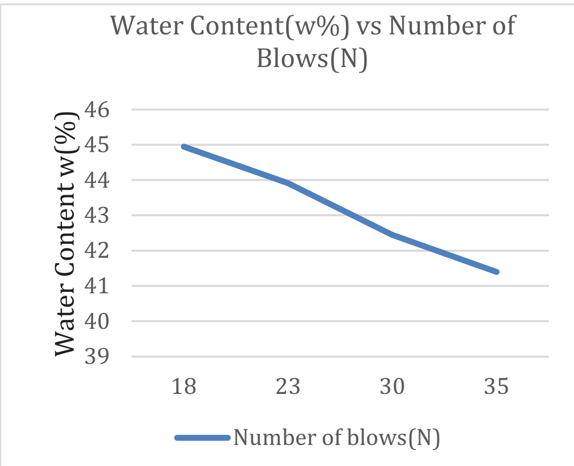

Figure 4. Liquid limit variation for soil with 10% of ESP

Figure 4 shows the variation of blows with water content and we can see the reduction of blows with the addition of ESP.

(2) Plastic Limit:

Plastic limit values for natural soil

W1(g)	W2(g)	W3(g)	w(%)
25.54	29.4	28.7	22.38

Plastic limit values of soil with 3% ESP

W1(g)	W2(g)	W3(g)	w(%)
37.9	40.7	40.1	27.27

Plastic limit values of soil with 5% ESP

W1(g)	W2(g)	W3(g)	w(%)
38.8	43.2	42.14	31.73

Plastic limit values of soil with 10% ESP

W1(g)	W2(g)	W3(g)	w(%)
26.6	28.6	28.1	33.33

(3)Plasticity Index:

Plasticity index values for natural soils

PI = LL-PL

=67.61%-22.38%

=45.23%

Where PI=Plasticity index

LL=Liquid limit

PL=Plastic limit

Plasticity index of soil added 3% ESP

PI = LL-PL

=63.8%-27.27%

=36.53%

Plasticity index of soil added 5% ESP

PI = LL-PL

=51%-31.73%

=19.27%

Plasticity index of soil added 10% ESP

PI = LL-PL

=43.2%-33.33%

=9.87%

B. Standard Proctor Test

The soil to be tested is oven dried to remove the natural moisture content in the soil. To the oven dried sample fixed ESP and water content ranging from 12% to 21% (i.e,12%,15%,18%,21%)are added to the dry weight of soil.

Table V shows the values of optimum moisture content(OMC) and maximum dry density for natural soils. Four trails are done to get the average valuesw of OMC and max. dry density.

TABLE V.
VARIATION OF DRY DENSITY FOR NATURAL SOIL

Details	1	2	3	4
Water to be added(%)	20	23	26	29
Weight of water (g)	500	575	725	800
Weight of compacted soil(g)	1655	1672	1744	1765
Water content(%)	24.9	27.2	30.06	32.4
Wet density(g/cc)	1.655	1.744	1.806	1.827
Dry density(g/cc)	1.325	1.360	1.388	1.379

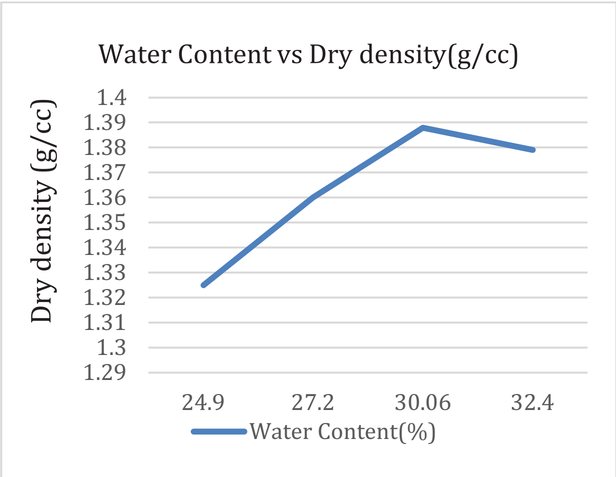

Figure5. Variation of Dry density with water content for natural soil

The variation of dry density and OMC can be seen from the figure 5. Dry density goes on increasing with increase in water content up to 30.06% and it falls gradually with further increase in water content.

TABLE VI.
VARIATION OF DRY DENSITY FOR SOIL WITH 3% ESP

Details	1	2	3	4
Water to be added(%)	18	21	24	27
Weight of water (g)	450	525	600	675
Weight of compacted soil(g)	1595	1619	1745	1735
Water content(%)	23	24.2	28.6	31.4
Wet density(g/cc)	1.65	1.67	1.807	1.796
Dry density(g/cc)	1.347	1.348	1.404	1.369

The variation of dry density and OMC with addition of 3% ESP can be seen from Table 6. The value of OMC is increased with decrease in water content and can be seen from figure 6.

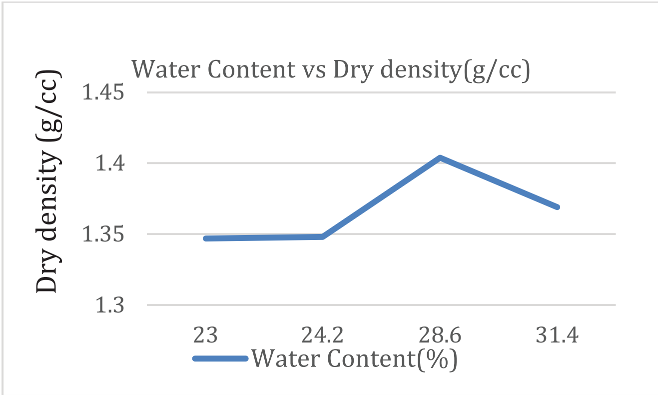

Figure 6. Variation of Dry density with water content for soil with 3% of ESP

TABLE VII.
VARIATION OF DRY DENSITY FOR SOIL WITH 5% ESP

Details	1	2	3	4
Water to be added(%)	15	18	21	24
Weight of water (gm)	375	450	525	600
Weight of compacted soil(gm)	1477	1619	1745	1735
Water content %)	19.2	22.19	25.6	28.6
Wet density(g/cc)	1.501	1.688	1.829	1.796
Dry density(g/cc)	1.282	1.256	1.456	1.43

Table 7 shows the values of water content and dry density after the addition of 5% ESP to the soil.

The variation of dry density and OMC with addition of 5% ESP can be seen from the figure 7.

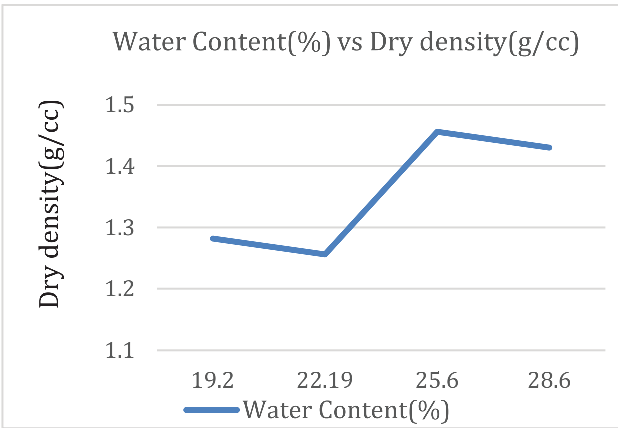

Figure 7. Variation of Dry density with water content for soil with 5% of ESP

TABLE VIII.

VARIATION OF DRY DENSITY FOR SOIL WITH 10% ESP

Details	1	2	3	4
Water to be added(%)	12	15	18	21
Weight of water (g)	300	375	450	525
Weight of compacted soil(g)	1500	1713	1542	1520
Water content (%)	17.24	19.95	21.6	23.39
Wet density(g/cc)	1.48	1.691	1.522	1.501
Dry density(g/cc)	1.26	1.41	1.33	1.217

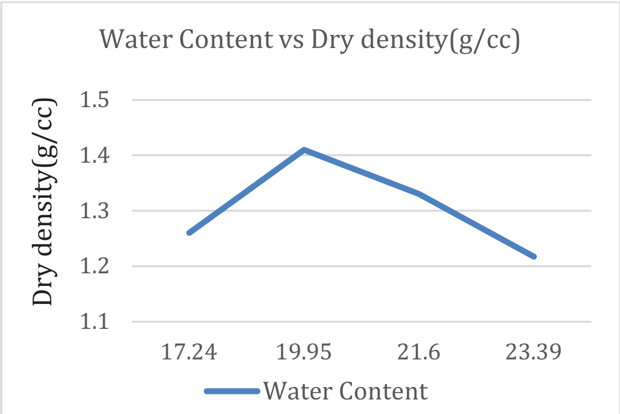

Figure 8. Variation of Dry density with water content for soil with 10% of ESP

IV. EXPERIMENTAL ANALYSIS OF SAMPLES

A. Influence of ESP on Atterberg's limits

Atterberg limits got altered after the addition of ESP at various percentages. The variation of Atterberg limits with different percentages of ESP is shown in Table IX. Noticeable reduction in Liquid limit, Plastic limit & Plasticity index can be seen from Figure 9.

TABLE IX.

VARIATION OF ATTERBERG'S LIMITS OF SOIL WITH DIFFERENT ESP %

ESP(%)	**Liquid limit(%)**	**Plastic limit(%)**	**Plasticity index(%)**
0	67.6	22.38	45.23
3	63.8	27.27	36.53
5	51	31.73	19.27
10	43.2	33.33	9.87

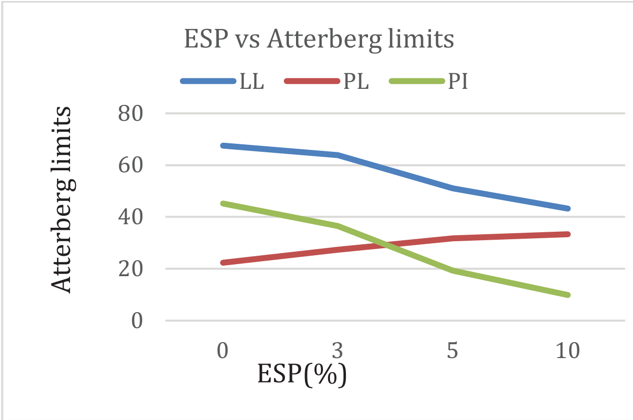

Figure 9. Variation of Atterberg limits with 0%,3%,5%,10% of ESP to the soil

Table X shows the variation of OMC and MDD with the variation of ESP in percentages and the considerable rise in MDD with reduction in OMC can be observed.

TABLE X.

VARIATION MOISTURE CONTENT AND MAXIMUM DENSITY AT DIFFERENT PERCENTAGES OF ESP

ESP(%)	Optimum moisture content (%)	Maximum dry density(g/cc)
0	30.6	1.383
3	28.6	1.404
5	25.6	1.376
10	19.95	1.41

It can be clearly seen from Figure 10 that OMC of soil is decreased with increase in ESP.

Figure 11 shows the variation of MDD with increment in ESP. An initial rise in MDD is observed with addition of ESP. It started to fall with the increment of ESP and reached the maximum value at 10% of ESP.

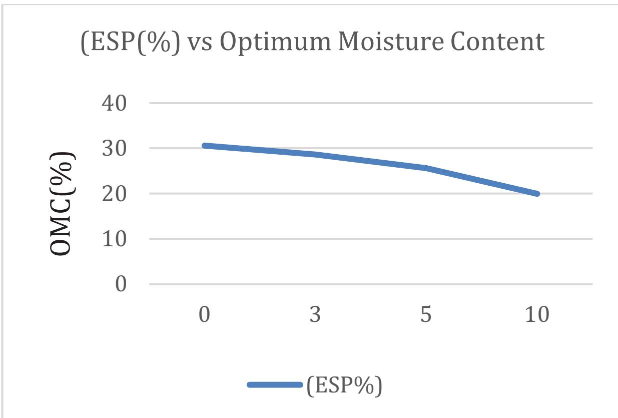

Figure 10. Variation of Optimum moisture content in soil with different percentages of ESP

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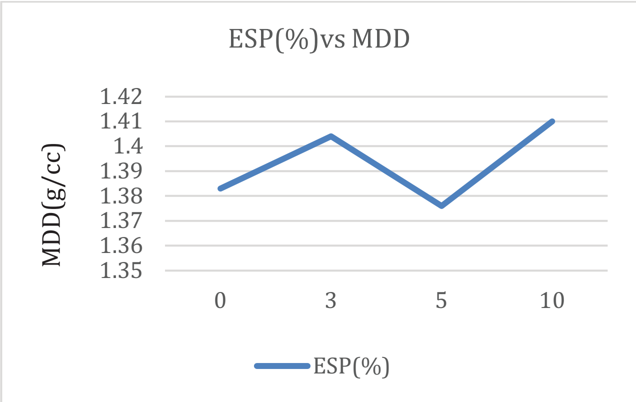

Figure11. Variation of Maximum dry density in soil with different percentages of ESP

V. CONCLUSIONS

- The liquid limit value decreased gradually due to the increase in the porous property of eggshell powder when the eggshell powder is added. The plastic limit value increased gradually when the eggshell powder is added to the soil that consequently resulted in the reduction of plasticity index, which is an indication of improvement of soil property.
- The initial increase in the dry density indicates the improvements in the soil properties and further resulted in the enhancement of soil properties with the application of eggshell powder.
- The initial decrease in OMC is due to the absorption capacity of the eggshell powder due to its porous properties. The subsequent increase is a result of the pozzolanic action of eggshell powder with addition of varying percentages of ESP.
- Thus, the use of ESP can improve both index & engineering properties of soil.

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