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Studies on Improvement of Clayey Soil Using Egg Shell Powder and Quarry Dust

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ABSTRACT
Nowadays, considerable attention has been paid to the utilization of alternative materials, which bear higher engineering quality than traditional materials and are financially affordable. Soil is one of the most important materials used in a variety of construction projects including earth canals and earth dams. The fact that soil may provide all the resistance characteristics necessary for a project illustrates the importance of various methods used to improve soil quality. Clay soil is widely used in most of the construction projects. Clay soils, particularly soft clay soils, have good plastic properties so that increased moisture results in their decreased shear strength, compressive strength and volume changes. These damages typically take an irreparable toll on structures, which further clarifies the importance of soil improvement. Considering millions of tons of waste produced annually across the country, which not only poses the problem of disposal but also adds to environmental contamination and health risks, utilization of such refuse and industrial wastes and their subsidiary products as alternatives to construction materials may effectively contribute to environmental preservation and minimization of their adverse effects on the environment. In the present study, eggshell powder and quarry dust was used as the wastes, to combine with soil so that the properties of clay soil were investigated in different mixture proportions. Then the properties of soils including liquid and plasticity limits as well as plasticity index, dry density, optimum moisture content, permeability, consolidation coefficients, and shear strength, which were already measured, were compared with those of the experimental specimens mixed with eggshell powder and quarry dust in different proportions. Since the introduction of egg shell powder and quarry dust improves the engineering behavior of soils, this review work exposes those qualities and applications that make quarry dust and egg shell powder a good replacement or admixture during soil improvement and for a more economic approach. The conclusion drawn from this investigation is that the combination of quarry dust and egg shell powder is more effective than the addition of quarry dust/ egg shell powder alone for the improvement of properties of clay.
Keywords : Clay, Waste, Eggshell Powder, Quarry Dust.

I. Introduction

In situ improvement of soil properties using additives is commonly referred to as soil stabilization, which is often used with fine soils. Indeed, soil stabilization is a process whereby natural or synthetic materials are added to soil improving soil properties. It is typically used to modify and improve low-quality materials, which brings about changes in soil properties including decreased rate of subsidence, decreased adhesion coefficient in soils with high cohesion (clay), increased adhesion coefficient in soils with low cohesion (sand), reduced percentage of water absorption and prevention of soil expansion, reduced cost of earth structures (transport), speeded road construction operations, resistance to frost and defrost, improved ductility, reduced rigidity of earth structures, lack of weed growth in the surface of earth structures such as roads and reduced thickness of bearing layer.

Over the last years, environmental issues have prompted human to use industrial wastes as alternatives to some construction materials. Both earthwork researchers and engineers have paid considerable attention to using wastes in soil stabilization and improving physical and mechanical properties of soils. This may help both remove environmental problems and contribute to the economy. Industrial wastes such as fly ash, iron slag, wood ash, plastic wastes and iron filings show considerable potential to stabilize soils, which are occasionally used to improve geotechnical properties of poor soils. Expansive soils shrink when they lose their moisture but swell when they absorb water. Moisture absorption may occur as a result of raining, torrents, leaking pipes of water or sewage, and impeded surface water evaporation due to the built structures adjacent to water reservoirs. Clay soils are highly vulnerable to swelling.

One of the most common methods of fine soil improvement is to stabilize it using additives that improve soil properties through physical and chemical changes. It is, however, worth noting that fine soils behavior should be well studied before deciding on the method of improvement. Soil modification or stabilization is usually carried out to achieve the following goals:

- Increasing soil strength, geotechnical properties and bearing capacity
- Preventing structure subsidence
- Reducing adhesion in highly adhesive soils
- Increasing adhesion in soils with low adhesion (sands)
- Increasing safety factor against slope, levees and earth dam sliding
- Reducing soil plasticity index.

In the present study, Egg Shell Powder (ESP) and Quarry Dust (QD) were used to study the effect on the properties of clayey soil. An improvement in the strength properties of soil by addition of ESP and QD will help to find an application for waste materials to improve the properties of clayey soil and can be used as a better stabilizing agent.

II. Literature Review

F.Z. Aissiou1, A. Nechnech1, and H. Aissiou, had a which work consists of the presentation of the results of a laboratory study on the treatment of a clay soil in the area of the Inhabitant of Algiers by incorporation of various contents extinct lime. For that, physical and mechanical tests such as (unconfined compression test, classification tests of the grounds in 1st place and shear test) were carried out and the results obtained highlight an unquestionable and definitely better improvement of the characteristics geotechniques such as the resistance of compression, resistance of shearing (angle of friction and cohesion) etc.

As an example, studies have been conducted on the use of eggshell powder to stabilize non-adherent soils in Japan. Stabilizing agents such as lime and pitch are expensive and need to be replaced economically. Research has shown that eggshell is a rich source of lime, calcium and protein so that it may be used as an alternative to such soil stabilizers as lime because it contains lime-like ingredients. Used as source of lime in agriculture, eggshell proved to contain a considerable amount of lime. In the present study, eggshell powder was used as an alternative to stabilize expansive soils. To this end, various laboratory experiments were carried out on soil specimens mixed with different percentages of additives (1-25% weight percent) and the effect of eggshell powder was examined on Atterberg properties of the specimens.

O.O. Amu et al studied the effect of eggshell powder on the Stabilizing Potential of Lime on an Expansive Clay Soil. He conducted series of tests to determine the optimal quantity of lime and the optimal percentage of lime-ESP combination. The optimal quantity of lime was gradually replaced with suitable amount of eggshell powder. Results indicated that lime stabilization at 7% is better than the combination of 4% ESP + 3% lime.

Okonkwo, Odiong, and Akpabio, had a study, and aimed at determining the effect of eggshell ash on the strength properties of cement-stabilized lateritic soil. All proportions of cement and eggshell ash contents were measured in percentages by weight of the dry soil. The Compaction test, California Bearing Ratio test, Unconfined Compressive Strength test and Durability test were carried out on the soil-cement eggshell ash mixtures. The increase in eggshell ash content increased the Optimum Moisture Content but reduced the Maximum Dry Density of the soil-cement eggshell ash mixtures. Also the increase in eggshell ash content considerably increased the strength properties of the soil-cement eggshell ash mixtures up to 35% in the average but fell short of the strength requirements except the durability requirement was satisfied.

The studies on the Influences of Fly-Ash and Eggshell Powder on Some of Engineering Properties of Al-Umara Soil, by Najwa Wasif Jassim showed that as the percentages of adding fly –ash and eggshell powder increases, the reduction in the plasticity index amount for all soil samples increases too at different rates. The values of cohesion decreased when the soil samples mixed with fly-ash, while there was an increase in the values of internal angle of friction. In case of using eggshell powder, there was a small increase in cohesion values, but there was a small decrease in the internal angle of friction values for the tested soil.

According to Onyelowe Ken C, Okafor F and Nwachukwu D. G, revealed that the use of quarry dust in soil stabilization is to improve engineering properties of soil. Quarry dusts are considered as one of the well accepted as well as cost effective ground improvement for the stabilization of weak soil deposits. When quarry dust is added with expansive soil it is expected that it will make it more porous, less durable, reduce cohesion etc, and also quarry dust has rough, sharp and angular particles and as such causes a gain in strength due to better interlocking.

A study of the influence of compactive effort on the properties (i.e., *MDUW, OMC, CBR, Sp* and *Ps*) of quarry dust-black cotton soil mixtures has been conducted by *Charles M. O. Nwaiwu,1* Samson H.*

Mshelia,2 and Joshua K. Durkwa . Maximum dry unit weight as well as *CBR* increased with quarry dust content while *OMC* decreased at higher quarry dust content. These effects were more pronounced at the heavy compaction which yielded the highest compactive effort. Free swell strain, swell potential and swelling pressure decreased as quarry dust content increased. However, the highest values of *Sf* and *Ps* were obtained at the *BS* heavy compaction effort for each percent of quarry dust added.

Results on the Effect of Stone Powder and Lime on Strength, Compaction and CBR Properties of Fine Soils by *Nabil Al-Joulani* , revealed that the addition of 30% stone powder has increased the angle of internal friction (φ) by about 50% and reduced cohesion by about 64%. The addition of 30% of lime has decreased the friction angle and cohesion by 57% and 28%, respectively. The maximum dry density and optimum moisture content decreased slightly by addition of 30% stone powder, however, the addition of 30% lime decreased the maximum dry density and optimum moisture content by 19% and 13.5%, respectively. The CBR values have increased from 5.2 to 16 and 18 by the addition of 30% stone powder and lime, respectively.

III. Objective of the Study

The aim of this work is to study the improvement on the properties of clayey soil with addition of Egg Shell Powder and Quarry Dust at varying percentages.

IV. Materials and Method

4.1 Methodology

- General Study of the properties of Clayey Soil.
- Study on Soil Properties using varying percentages of Egg Shell Powder and determine the optimum percentage of Egg Shell Powder.
  Tests Performed are:

  Proctor Test
  Consolidation
  Atterberg Limits
  Permeability
  Direct Shear Test

  Percentages of Eggshell Powder used:

  1, 3, 5, 10, 15, 20, 25, 30
- Study on Properties of soil using optimum percentage of Eggshell Powder and varying percentages of Quarry Dust.
  Percentages of Quarry Dust used:

  10, 20, 30

4.2 Materials Used

4.2.1 Clay

The soil used in this study was collected from a piling site at Kalamasery, Ernakulam. The sample was thoroughly oven dried, weighed and stored in sacks at room temperature. The general property of the soil was thoroughly studied in the laboratory. The soil was tested for liquid limit, plastic limit optimum moisture content, maximum dry density, permeability etc.
For the soil, the general properties obtained were tabulated as follows:

TABLE 1: General Soil Properties

PROPERTIES	RESULT
Water Content (%)	28.3%
Specific Gravity of Soil	2.78
Permeability (cm/s)	7.1×10^{-5}cm /s
Liquid Limit (%)	52%
Plastic Limit (%)	30.67%
Plasticity Index	21.33%
Optimum Moisture Content	26%
Maximum Dry Density	1.51g/cc
Effective size, D_{10}	12μ
Uniformity coefficient, C_U	5.83
Coefficient of curvature,C_c	0.744

The gradation curve shown in figure 1,the values of D_{10}, D_{30} and D_{60}, are 12μ, 25μ and 5.85μ respectively. Percentage of clay fraction is 4%. Percentage silt and clay obtained as 87% and that of sand is 13%.From the gradation curve it was found that the soil is free from any gravel fraction.

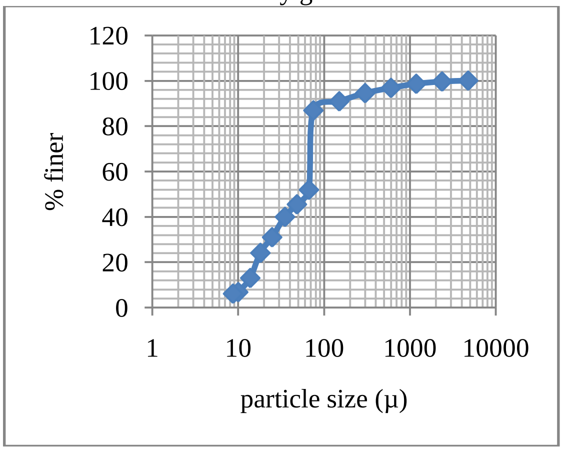

FIG 1: Grain Size Analysis

4.2.2 Egg Shell Powder (ESP)

Eggshell powder (ESP) has not being in use as a stabilizing material and it could be a good replacement for industrial lime, since it's chemical

composition is similar to that of lime. Chicken eggshell is a waste material from domestic sources such as fast food joints and homes. Literature has shown that eggshell powder primarily contains CaO (99.83%) and the remaining consists of Al2O3, SiO2, Cl, Cr_2O_3, MnO and CuO. The eggshell waste was washed and dried before grinding. The eggshell powder was sieved using IS Seive No.200 (75μ), and the powder passing the sieve was used. This sieve was chosen in order to achieve a uniform powdery.
Specific Gravity of Egg Shell Powder used= 1.32

4.2.3 Quarry Dust (QD)

Quarry dust/crusher dust is obtained as soil solid wastes during crushing of stones to obtain aggregates. Quarry dust exhibits high shear strength which is highly beneficial for its use as a geotechnical material. It has a good permeability and variation in water content does not seriously affect its desirable properties. Quarry dust proved to be a promising substitute for sand and can be used to improve the engineering properties of soils. The dry density increased with the addition of quarry dust with attendant decrease in the optimum moisture content. The Quarry Dust used was collected from a crusher near Pareekanni, Ernakulam, and was sieved through IS Seive No. 200(75μ) before use.
Specific Gravity of Quarry Dust used= 2.89

V. RESULTS AND DISCUSSIONS

From the experiments conducted with ESP, 20% was obtained as optimum percentage of ESP. Then experiments were conducted with optimum percentage of ESP and varying percentage of QD and the obtained results were shown below.

5.1 ATTERBERG'S LIMITS
TABLE 2: Influence ESP on Atterberg's limits

ESP %	L.L (%)	P.L (%)	P.I (%)
0	52	30.67	21.33
1	49.2	29.72	19.48
3	47.6	28.64	18.96
5	45	28.07	16.93
10	43	29.6	13.4
15	42.4	30.13	12.27
20	39.6	30.47	9.13
25	40	30.56	9.44
30	40	30.78	9.22

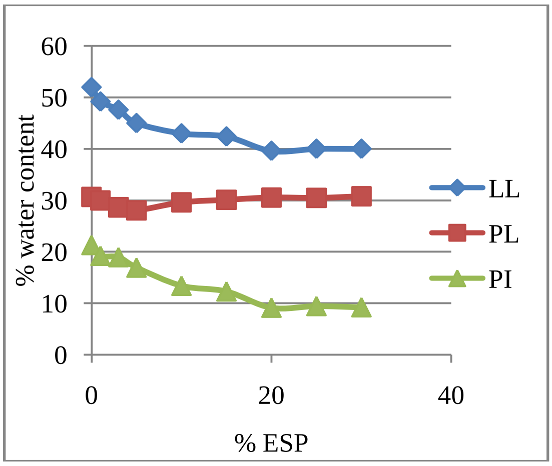

FIG 2: Variation of LL, PL & PI with Varying Percentage of ESP

Fig 2 shows that, up to 20% of ESP is added, there is a considerable decrease in PI, and after that the value seems to be almost constant. Result of L.L & P.I tests on clay treated with ESP & QD are shown in the Figure 3, it is observed that as the percentage of additives increases, there is a reduction in liquid limit and plasticity index of clay tested. From this, it can be deduced that the plastic characteristics of the soil sample are gradually decreasing with increase in the percentage of ESP & QD.

TABLE 3: Influence on Atterberg's Limits with optimum % of ESP and varying % of QD

% QD WITH OPTIMUM % ESP	LL%	PL%	PI%
20 % ESP+10% QD	36	28.75	7.25
20 % ESP+20% QD	32	26.216	5.784
20 % ESP+30% QD	30	24.6	5.4

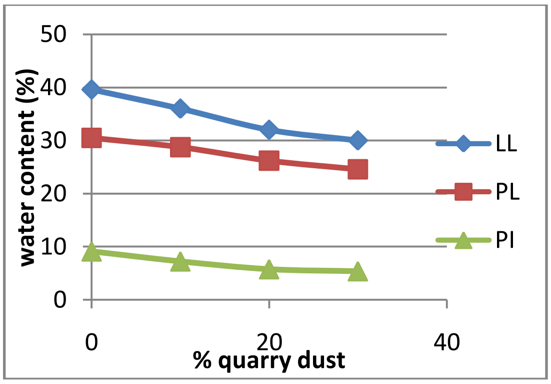

FIG 3: Variation of LL, PL & PI with optimum percentage of ESP and varying percentage of QD

5.2 STANDARD PROCTOR TEST

It can be inferred from figure 4 that there is increase in OMC with increase ESP. The increase is due to the addition of ESP, which decreases the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed (these processes need water to take place). This implies also that more water is needed in order to compact the soil-ESP mixture. The MDD decreases by increasing the content of ESP. The decrease in the MDD can be attributed to the replacement of soil by the ESP which has relatively lower specific gravity (1.32) compared to that of the raw soil which is 2.78. The MDD increases by increasing the content of QD. This increase in MDD may be explained by considering the replacement of clay with higher specific gravity QD (2.89).With increase in percentage of quarry dust the OMC of soil goes on decreasing. This is attributed to the reduction in clay content of soil by replacement with quarry dust which has less attraction for water molecules.

TABLE 4: Influence of ESP on OMC and Dry Density

% ESP	OMC (%)	MDD (g/cc)
0	26	1.51
1	26	1.49
3	26.5	1.46
5	27	1.45
10	28	1.41
15	28.5	1.395
20	29	1.39
25	29	1.375
30	30	1.34

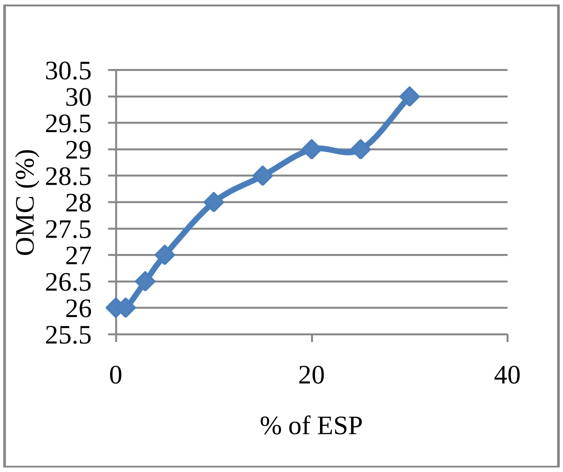

FIG 4: Variation of OMC with ESP

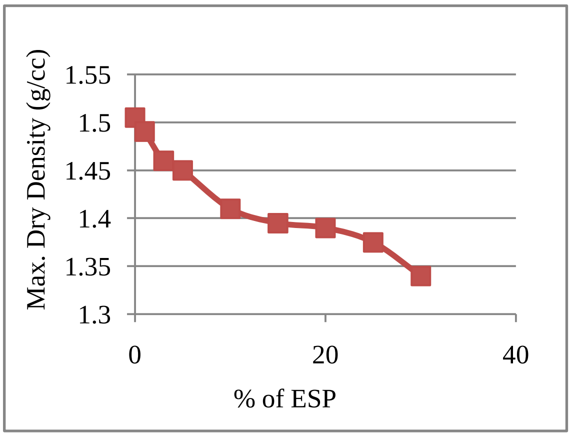

FIG 5: Variation of Max. Dry Density with ESPjj

TABLE 5: Influence of ESP & QD on OMC & Max. Dry Density

% QD WITH OPTIMUM % ESP	OMC (%)	MDD (g/cc)
20% ESP+10%QD	27	1.61
20% ESP+20% QD	21	1.72
20% ESP+30 % QD	18	1.84

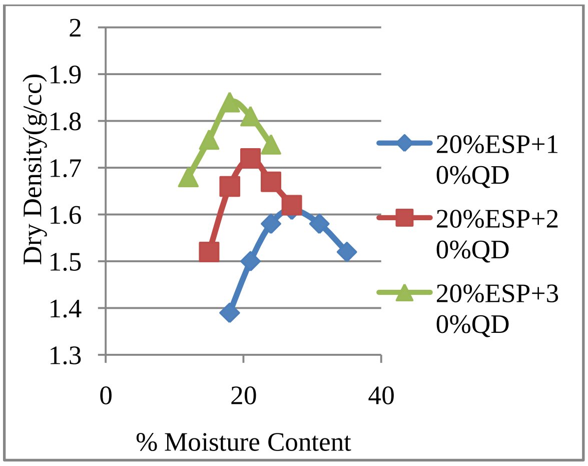

FIG 6: Variation of OMC & Max Dry Density on ESP&QD

5.3 DIRECT SHEAR TEST

TABLE 6: Influence of ESP on Direct Shear Test

ESP (%)	COHESION (c) (kg/cm^2)	ANGLE OF INTERNAL FRICTION (ϕ)	SHEAR STRENGTH (kg/cm^2)
0	0.382	16.75	0.591
1	0.381	17.11	0.596
3	0.38	17.84	0.611
5	0.378	19.13	0.618
10	0.371	20.75	0.655

15	0.351	23.02	0.68
20	0.331	27.2	0.773
25	0.324	27.65	0.772
30	0.232	28.2	0.77

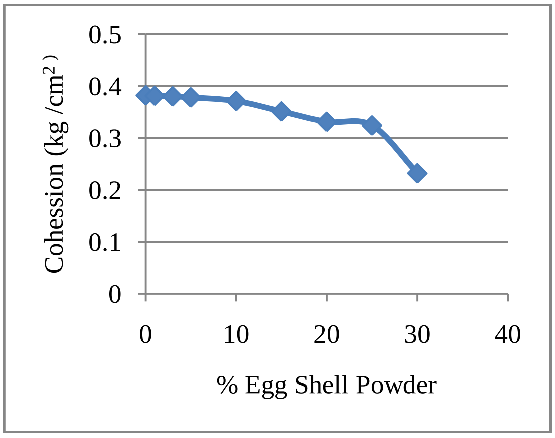

FIG 7: Variation of Cohesion with Varying % of ESP

From the figures 7 & 10 it has been found that with the increase in the percentage of ESP & QD, the cohesion of the soil goes on decreasing. From the figures 8 & 11 it has been found that with the increase in the percentage of ESP & QD, the angle of internal friction of the soil goes on increasing. This is attributed to the reduction in clay content of soil with increase in ESP & QD percentage, ESP & QD mixes have higher angle of internal friction values than the soil. By using Mohr – Coulomb's equation shear strength was calculated. It was found from figure 9 that with increase in percentage of ESP the shear strength increased, later on there is slight decrease in graph at 25% ESP. Hence the optimum value of shear strength was around 20%.From figure 12 it is clear that with increase in ESP-QD mixes shear strength increases.

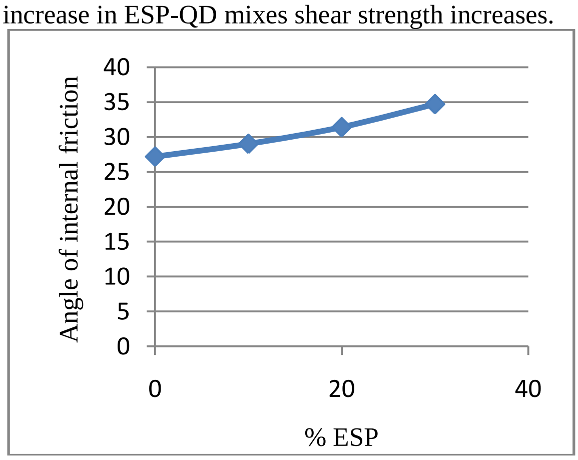

FIG 8: Variation of Angle of Internal Friction with Varying % of ESP

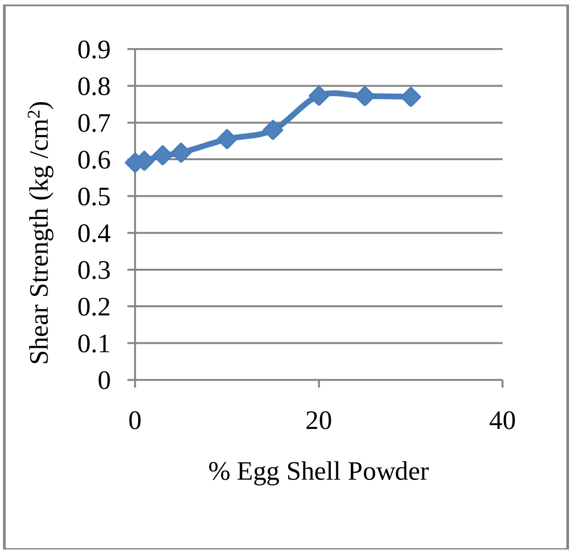

FIG 9: Variation of Shear Strength with Varying % of ESP

TABLE 7: Influence of ESP and QD on Direct Shear Test

%QD WITH OPTIMUM % ESP	COHESION(C) (kg/cm^2)	ANGLE OF INTERNAL FRICTION (Φ)	SHEAR STRENGTH (kg/cm^2)
20%ESP +10 QU	0.308	29.03	0.795
20%ESP +20 QU	0.288	31.42	0.853
20%ESP +30 QU	0.256	34.72	0.942

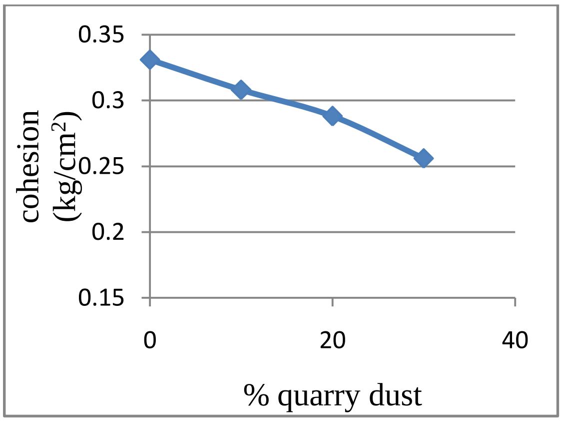

FIG 10: Variation of cohesion with optimum % of ESP and varying % of QD

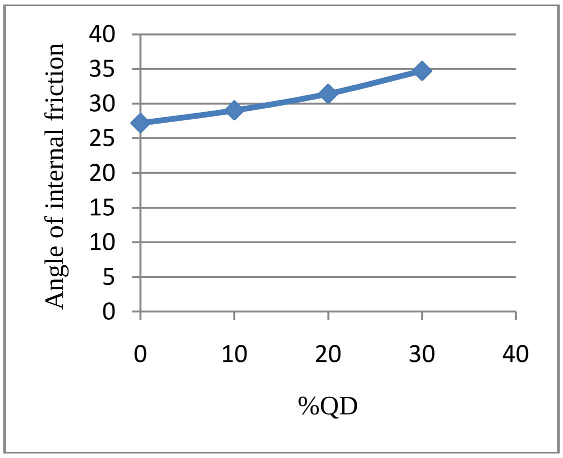

FIG 11: Variation of Internal angle of friction with optimum % of ESP and varying % of QD

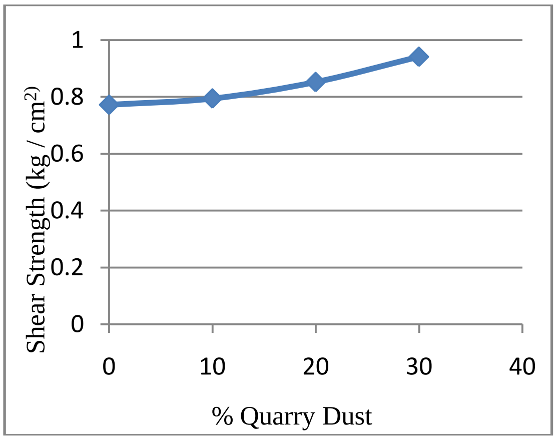

FIG 12: Variation of shear strength with optimum % of ESP and varying % of QD

5.4 PERMEABILITY

TABLE 8: Influence of ESP on Permeability

ESP %	AVG. PERMEABILITY (cm/s)
0	7.1×10^{-5}
1	7.4×10^{-5}
3	7.99×10^{-5}
5	8.63×10^{-5}
10	9.58×10^{-5}
15	2.4×10^{-4}
20	4.85×10^{-4}
25	5.51×10^{-4}
30	6.14×10^{-4}

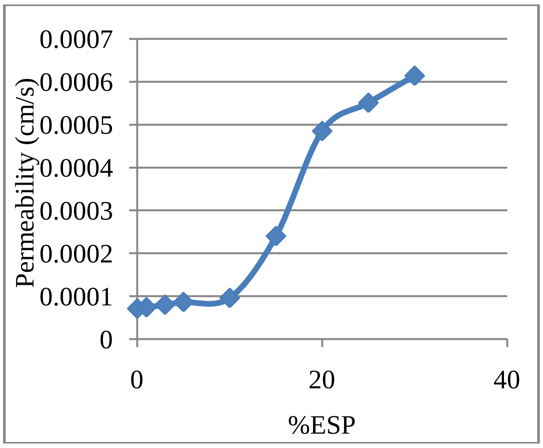

FIG 13: Variation of Permeability with ESP

TABLE 9: Influence of optimum % of ESP and varying % of QD on permeability

% QD WITH OPTIMUM % ESP	AVG. PERMEABILITY (cm/s)
20% ESP+10% QD	6.73×10^{-4}
20% ESP+20% QD	8.4×10^{-4}
20% ESP+ 30% QD	9.1×10^{-4}

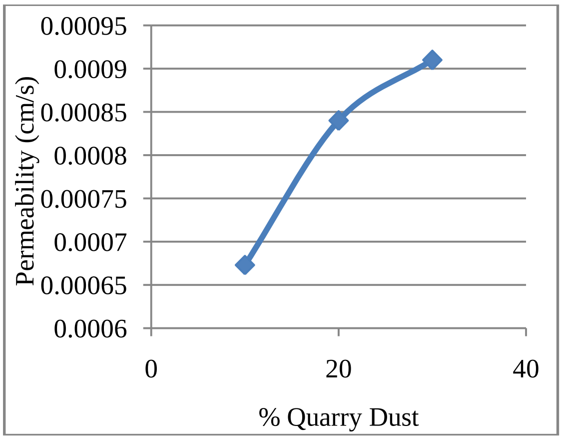

Fig 14: Variation of Permeability with Optimum % of ESP and varying %s of QD

It can be inferred from figure 13 & 14 that the permeability goes on increasing with increase in percentage of ESP & QD. Addition of ESP & QD on expansive clayey soil increases the porosity which led to increase in permeability.

5.5 CONSOLIDATION

TABLE 10: Influence of ESP on coefficient of consolidation and compression index

%QD WITH OPTIMUM ESP	COEFFICIENT OF CONSOLIDATION (C_V) Kg/cm^2	COMPRESSION INDEX (C_C)
20%ESP+10 %QD	0.24	0.620
20%ESP+20 %QD	0.25	0.595
20%ESP+30 %QD	0.32	0.586

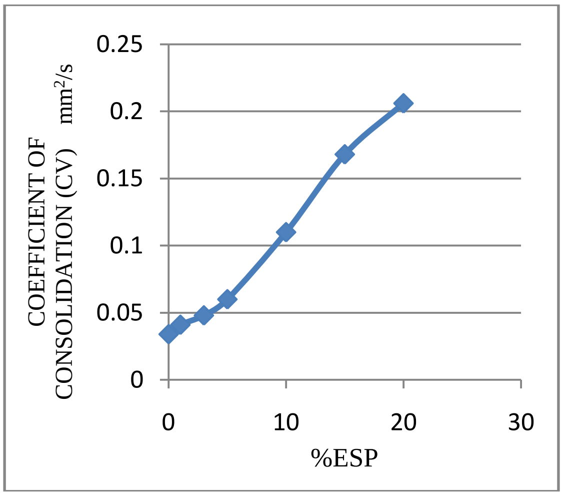

FIG 15: Variation of Cv with ESP

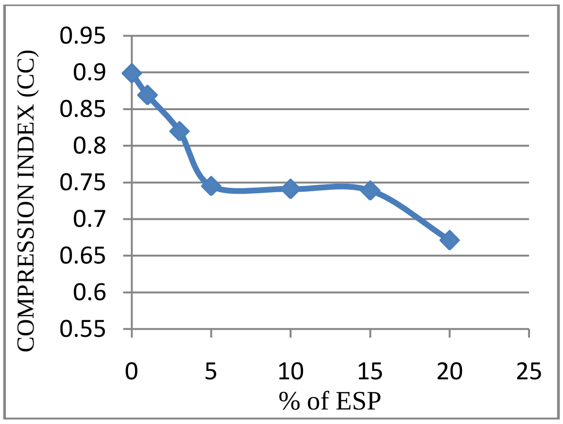

FIG 16: Variation of compression index with ESP

It can be inferred from figure 15 & 17 that the coefficient of consolidation increases with increase in percentage of ESP & QD and from figures 16 &18 coefficient of compression decreases with increase in percentage of additive. This is due to the increase in porosity with addition of admixture.

TABLE 11: Influence of optimum percentage ESP and varying percentage QD on Cv & Cc

ESP (%)	COEFFICIENT OF CONSOLIDATION (C_V)	COMPRESSION INDEX (C_C)
0	0.034	0.899
1	0.041	0.869
3	0.048	0.820
5	0.060	0.745
10	0.110	0.741
15	0.168	0.739
20	0.206	0.671

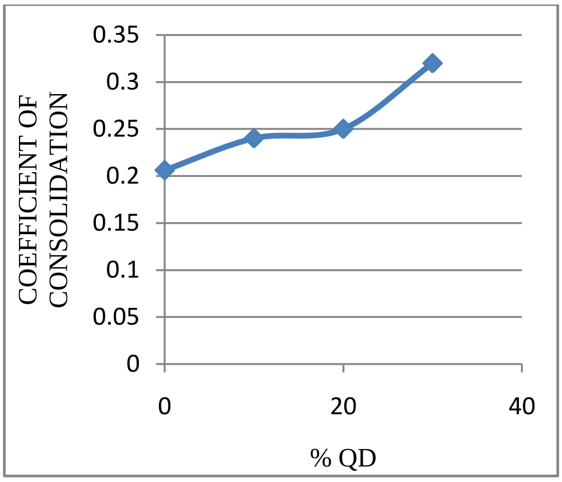

FIG 17: Variation of coefficient of consolidation with optimum % ESP and varying % of QD

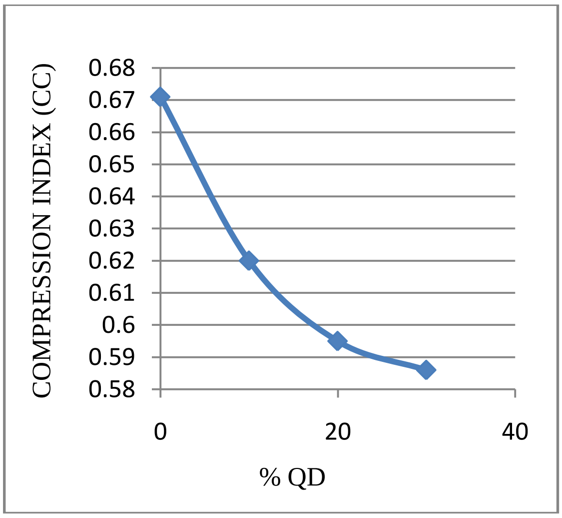

FIG 18: Variation of compression index with optimum percentage of ESP and varying percentage of QD

VI. Conclusions

The following conclusions can be drawn on the basis of the result obtained and discussion made in this study.

1. With addition of ESP, there is a considerable decrease in Atterberg's Limits, and after 20% the value seems to be almost constant.
2. OMC increases and maximum dry density decreases with increase in percentage of ESP.
3. With addition of varying percentage ESP cohesion decreases and angle of internal friction increases.
4. Shear strength increases with increase in percentage of ESP and after 20% strength is almost constant.
5. Permeability increases with increase in ESP.
6. Coefficient of consolidation increases and compression index decreases with increase in percentage of ESP.
7. From the analysis it is obtained that 20% of ESP gives considerable improvement in properties of clay soil. So 20% selected as optimum percentage.
8. Maximum dry density increases and optimum moisture content decreases considerably with addition of optimum percentage of ESP and varying percentage of QD.
9. Shear strength and angle of internal friction increases and cohesion decreases with addition of optimum percentage ESP and increase in percentage of QD.
10. Atterberg's limits decreases considerably with addition of optimum percentage of ESP and QD. PI is almost constant for 20% and 30% QD with optimum percentage of egg shell. Hence 20% ESP & 30% QD is selected as optimum percentage.

In the light of above observation we come to a conclusion that ESP along with QD used in combination with clay possessed certain properties which enables it to be used economically for improvement of clayey soil. Since Egg shell and Quarry dust are waste products, usage of same reduces the environmental problems.

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