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Stabilization of High Swelling Soil by Using Quarry Dust and Egg Shell Powder

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Abstract— Soil is one of the most important materials used in a variety of construction projects including earth canals and earth dams. Nowadays, considerable attention has been paid to the utilization of alternative materials, which bear higher engineering quality than traditional materials and are financially affordable. High swelling soils have good plastic properties so that increased moisture results in their decreased strength and increased volume. 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 glass powder were 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 and unconfined compressive 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 glass powder improves the engineering behaviour 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 or egg shell powder alone for the improvement of properties of clay.

I. INTRODUCTION

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 soil. Foundations in expansive soils, popularly known as black cotton soils in this country, undergo alternate swelling and shrinkage upon wetting and drying due to seasonal moisture fluctuations. Usually, moisture and water vapor migrates from the high temperature zones around the building. The difference in water contents between the interior and the exterior zones of the building causes uplift of the interior portion and results in mound – shaped heave of the floor of the building. Black cotton soils are a worldwide problem that creates challenges for Civil Engineers. They are considered as potential natural hazard, which can cause extensive damage to structures if not adequately treated. The disadvantages of black cotton soil can be overcome by stabilizing with suitable material. Development of any country can be closely monitored by the improvement in infrastructural facilities in which transportation plays a key role. The quality and durability of a pavement is greatly affected by the type of sub grade soil over which such pavements are to be constructed. Pavement structure response is very sensitive to the characteristics of the sub grade, which provides the support base for such pavement structure. Problems associated with pavement construction further become far more critical, particularly in regions where the sub grade consists of expansive soils. In India these soils cover about 0.8x106 Sq. Km. area which is more than one fifth of its surface area and extend over the states of Maharashtra, Gujarat, parts of Uttar Pradesh, Madhya Pradesh, Rajasthan, Andhra Pradesh and Tamil Nadu. In recent years reinforced earth technique has been gaining popularity in the field of geotechnical engineering due to its highly versatile and flexible nature and is being widely used for the construction of retaining walls, embankments, earth dams, foundation beds for heavy structures on soft grounds, viaducts and other applications.

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II. SOIL STABILIZATION

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, increased adhesion coefficient in soils with low cohesion, reduced percentage of water absorption and prevention of soil expansion, reduced cost of earth structures, 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.

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

III. OBJECTIVE OF THE STUDY

For developing a good and durable road network in high swelling clay soil areas, the nature of soils shall be understood. High swelling soils absorb water heavily, swell, become soft and lose strength. These soils are easily compressible when wet and possess a tendency to heave during wet condition. High swelling soils shrink in volume and develop cracks during summer. They are characterized by extreme hardness and cracks when dry. The stability and performance of the pavements are greatly influenced by the sub-grade and the embankment as they serve as foundation for pavements. On such soils, suitable construction practices and sophisticated methods of design are to be adopted.

The aim of this work is to study the improvement on the properties of a high swelling soil with addition of Egg Shell Powder and Glass powder at varying percentages.

IV. MATERIALS USED

- HIGH SWELLING SOIL

The soil used in this study was collected from Reddiyarpatti, Tirunelveli. The sample was thoroughly 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, etc.

- EGG SHELL POWDER (ESP)

Eggshell powder (ESP) can be a good replacement for industrial lime, since its 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, Cr2O3, MnO and CuO. When lime is added to expansive clay, complex chemical reactions take place. At the colloidal level, Base Exchange occurs with the strong calcium ions of lime replacing the weaker ions such as sodium on the surface of the clay particle. Further adsorption of non-exchanged calcium ions also leads to an increase in ion density. This results in a change of soil texture that reduces clay content and increases the percentage of coarse particles. The eggshell waste was washed and dried before grinding. The eggshell powder was sieved using 425µ sieve 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 = 2.09

- 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 chennai, and was sieved through 425µ sieve before use. Specific Gravity of Quarry Dust used = 2.65

V. EXPERIMENTAL INVESTIGATION

EXPERIMENTS CONDUCTED

1. Grain size Distribution
   i. Sieve analysis
   ii. Hydrometer analysis
2. Specific gravity test
3. Atterberg limits
   i. Liquid limit
   ii. Plastic limit
   iii. Shrinkage limit
4. Standard proctor compaction test
5. Soaked CBR test
6. Unconfined compression test
7. Swell test
   i. Free swell index
   ii. Swell pressure

GRAIN SIZE DISTRIBUTION

SIEVE ANALYSISZ

In the BS and ASTM standards, the sieve sizes are given in terms of the number of the inch. The complete sieve analysis can bedivided into two parts – the coarse analysis and fine analysis. Since black cottonsoil is an expansive soil, wet sieve analysis is used. It is advisable to wash the soil portion passing through 4.75 mm sieve over 75-micron sieve so that the siltand clay particles sticking to the sand particles may be dislodged. Washing should be continued until the water passing through 75-micron sieve is substantially clean. The fraction retained on 75- m i c r o n sieve is dried in the oven. The dried portion is sieved through various sieves. Sieving is performed by arranging the various sieves one over the other in the order of their mesh openings. The largest aperture sieve being kept at the top and the smallest aperture sieve kept at the bottom. A receiver is kept at the bottom and the coveris kept at the top of the whole assembly. The soil sample is put on the top sieveand the whole assembly is fitted on a sieve shaking machine. The amount of shaking depends on the shape and the number of particles. At least 10 minutes of shaking is desirable for soils with small particles. The portion of the soil sample retained on each sieve is weighed. The percentage of soil retained on each sieve is calculated on the basis of the total mass of the soil.

The retained soil particles on each sieve are classified on the basis of the following:

Coarse sand - 4.75mm to 2mm Medium sand - 2mm to 0.425mm

Fine sand - 0.425mm to 0.075mm

Clay and silt

- <0.075mm

Sieve sizes used:

4.75mm, 2.36mm, 1.18mm, 600μ, 300μ, 150μ and

sieve analysis test

- HYDROMETER ANALYSIS

Mix 50g of soil with 100ml of sodium oxalate or sodium hexameter phosphate per liter. The mixture is well stirred witha glass rod and allowed to stand. Next day the mixed is passing through 0.075mmsieve and washed. The passing is taken for hydrometer analysis. After stirring themixture for 5 minutes the suspension is transferred to the measuring cylinder andmade upto exactly 1000ml with distilled water. The measuring jar is now shakenvigorously and then allowed to stand and the stop watch is started. The hydrometer is carefully inverted and the first reading taken after a period of 0.5minute. It is usual for convenience, when recordings the hydrometer readingsto omit the one and more the decimal point three places to the right. Further readings are taken at 1 and 2 minutes and hydrometer is removed. Immersion andwithdrawal of hydrometer should be done carefully. After each removal, the hydrometer should be wiped dry with a clean rag. Further readings should be taken after periods of 4, 8, 15, 30 minutes and 1, 2, 3 hours. Subsequently readings may be taken at convenient intervals.

- SPECIFIC GRAVITY TEST

Specific gravity is defined as the ratio of weight of given volume of soil solids at a given temperature to the weight of an equal volume ofdistilled water at that temperature. The specific gravity is determined using a 500ml flask. The mass M_1 of the dry empty bottle is first taken. The sample is put on the bottle and the mass M_2 is taken. The bottle is then filled with water and the entrapped air is removed by applying vacuum. The mass M_3 of the bottlewith soil and water is taken. Finally, the bottle is completely emptied, thoroughlywashed and clean water is filled to top and mass M_4 is taken.

The specific gravity can be computed as $G = (M_2-M_1)/((M_4-M_1)-(M_3-M_2))$

- SHRINKAGE LIMITS

About 50 grams of the sample passing through 425 micron IS sieve is mixed with distilled water sufficient to fill the voidscompletely and to make the soil pasty enough to be readily worked into the shrinkage dish without the inclusion of air bubbles. Some sample is put in its center and the soil is caused to flow to the edges by tapping it gently on a hardsurface. The dish is gradually filled by adding more soil in installments followed by gentle tapping's to exclude the air intrusions. The excess soil is struck off with straight edge and all soil adhering to the outside of the dish is wiped off. thw dish filled with soil is immediately weighed. The dish is then placed in the oven. The dry soil pat is placed on the surface of the mercury of the cup and is carefully forced down by means of glass with prongs. The massof the mercury so displaced divided by its density gives the volume of the dry soil pat. Shrinkage limit is calculated using the relation

$W_s = (V_d - V_s)\rho_W/M_d$

- SWELL PRESSURE

The pressure which the expansive soil exerts, if the soil is not allowed toswell or the volume change of the soil is arrested is known as swell pressure. The specimen ring with the specimen is kept between two porous stones saturated in boiling water. The loading block is positioned centrally on the topof the porous stone. This assembly is placed on the platen of the loading unit. The load measuring proving ring tip attached to the load frame is placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is inundated with distilled water and allowed to swell.

- FREE SWELL INDEX

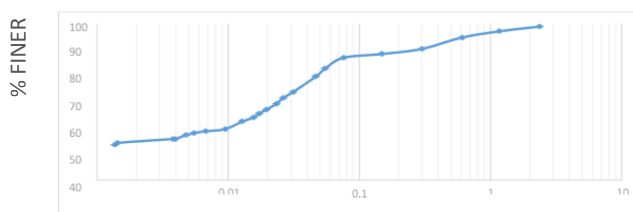
10 g of soil specimens of oven dry soil passing through 425-micron IS Sieve is taken. The soil specimen is poured in a glass graduated cylinder of 250ml capacity.

VI. RESULTS AND DISCUSSIONS

GRAIN SIZE DISTRIBUTION

Particle size	%finer
4.75	99.2
2.36	98.36
1.18	95.36
0.6	91.25
0.3	84.04
0.15	80.79
0.075	78.32

Table Particle Size Distribution



SPECIFIC GRAVITY

Specific gravity (G) is defined as the ratio of the weight of the given volume of the soil solids at a given temperature to the weight of an equal volume of distilled water at that temperature, both weights being taken in air. The IS specifies 27°C as the standard temperature for reporting the specific gravity.

Materials	Specific Gravity
Soil specimen	2.38
Quarry Dust	2.65
Egg Shell Powder	2.09

The consistency limits are the water contents at which the soil mass passes from one state. The Atterberg limits which are most useful for engineering purposes are liquid limit, plastic limit and shrinkage limit. These limits are expressed as percentage water content.

Liquid limit
Liquid limit is defined as the minimum water content at which the soil is still in the liquid state

Plastic limit
Plastic limit is defined as the minimum water content at which the soil willjust begin to crumble when rolled into a thread approximately 3mm

UNCONFINED COMPRESSION TEST
The unconfined compression test is a special case of triaxial compression test. The unconfined compressive strength of clayey soil is determined using controlled strain.

From the value of unconfined compressive strength test result, upto 4% addition of eggshell powder to the soil, the UCS value increased and a sudden decrease was observed at 4.5% addition of eggshell powder to the soil

% ESP	UCS $\times 10^{-3}$ N/mm^2
0	7.16
0.5	8.98
1	11.21
1.5	13.67
2	15.92
2.5	18.36
3	20.27
3.5	21.84
4	23.73
4.5	20.9
5	18.56
5.5	17.42

Table Influence of ESP on UCS

From the above results, it is concluded that 4% addition of egg shell powderto that of the soil sample showed best results with the increased OMC, dry densityand unconfined compressive strength. Addition of egg shell powder alone with expansive soil does not increase the strength and hence quarry dust is used to improve the geotechnical properties of the soil. Egg shell powder – Quarry dust stabilization is cheap and is a method with considerable scope for construction of low-cost roads and where quarry dust and egg shells are available as waste products.

Liquid limit

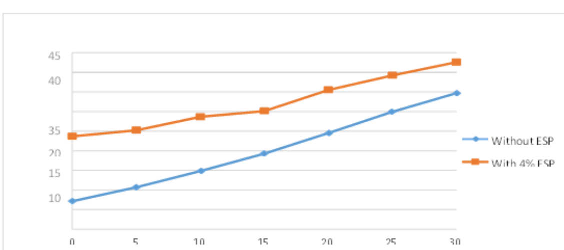
Proportion	Liquid Limit	
	Without ESP	With 4% ESP
100% soil + 0% QD	60	52.4
95% soil + 5% QD	58.1	50.9
90% soil + 10% QD	56.4	49.4
85% soil + 15% QD	53.7	46.8
80% soil + 20% QD	50.3	43.5
75% soil + 25% QD	47.6	40.9
70% soil + 30% QD	44.9	38

Influence of varying % of QD on Liquid Limit with andwithout optimum % of ESP

UNCONFINED COMPRESSIVE STRENGTH (UCS)

Proportion	UCS Without ESP $\times 10^{-3}$ N/mm^2	UCS With 4% ESP $\times 10^{-3}$ N/mm^2
100% soil + 0% QD	7.16	23.73
95% soil + 5% QD	10.7	25.28
90% soil + 10% QD	14.86	28.69
85% soil + 15% QD	19.29	30.17
80% soil + 20% QD	24.54	35.54
75% soil + 25% QD	29.97	39.26
70% soil + 30% QD	34.7	42.6

Influence of varying % of QD on UCSwith and without optimum % of ESP



Comparison of UCS for varying % of QD with and without optimum % of ESP

CONCLUSION

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

1. Increase in the addition of QD decreases the liquid and plastic limits whileincrease in addition of ESP to the soil sample decreases the liquid limit but increases the plastic limit.
2. OMC decreases and maximum dry density increases up to 4% of ESP by weight.
3. From the analysis, it is obtained that 4% of ESP gives considerable improvement in UCS of clay soil. So 4% selected as optimum percentage.
4. OMC decreases and maximum dry density increases with increase in QD percentage.
5. Maximum dry density increases and optimum moisture content decreases considerably with addition of optimum percentage of ESP and varying percentage of QD.
6. The optimum mix proportion was found to be 70% soil + 30% Quarry dustadded with 4% Egg Shell Powder.
7. The swell pressure reduces by almost 85% for the optimum mix proportion.
8. The combination of quarry dust and egg shell powder is more effective than the addition of quarry dust or egg shell powder alone for the improvement of properties of clay.

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 high swelling soil. By using the eggshell powder as a soil stabilizer, we can minimize the waste disposal problem of eggshell. Since Quarry dust is also a waste product, usage of same alsoreduces the environmental problems

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