EXPERIMENTAL STUDY ON THE SWELLING BEHAVIOUR IN EXPANSIVE SOILS USING GROUTING TECHINIQUE

[1]D.HARIKA, [2] K.SAI KRISHNA, [3] B.KARUN, [4] G. SRINIVAS, [5] K.USHA SRI SAI, [6] M.SRINIVAS PHANI KUMAR
[1]UG Student, NRI INSTITUTE OF TECHNOLOGY, Agiripalli, Vijayawada
[2]UG Student, NRI INSTITUTE OF TECHNOLOGY, Agiripalli, Vijayawada
[3]UG Student, NRI INSTITUTE OF TECHNOLOGY, Agiripalli, Vijayawada
[4]UG Student, NRI INSTITUTE OF TECHNOLOGY, Agiripalli, Vijayawada
[5]UG Student, NRI INSTITUTE OF TECHNOLOGY, Agiripalli, Vijayawada
[6]Associate professor, NRI INSTITUTE OF TECHNOLOGY, Agiripalli, Vijayawada
[1]Harikadodda223@gmail.com,[2]kesanasaikrishna@gmail.com,[3]boyapatikarun.bk@gmail.com,[4] Srinugandham147@gmail.com,[5]kunchamusha142@gmail.com

ABSTRACT- **In construction expansive soils plays a major Problem. Large number of research studies are carried out by using waste material in construction purpose .In this project we using natural waste material which is economical and eco-friendly. Soil stabilization is done by using EGG SHELL POWDER and FLY ASH by using Grouted columns and Mixing. An attempt is made to reduce the swelling behaviour in expansive soils using Grouted columns and Mixing. Soil containing the clay mineral for most MONTMORILLONITE shows the expansive property. GEOTECHNICAL tests like Free swell test, Moisture content, Atterberg limits, Sieve analysis, Consolidation, Unconfined compressive test, Swell pressure test are conducted to know soil properties. ESP (EGG SHELL POWDER) (5%) and FLY ASH (20%,25%,30%) of slurry mix concentration is used for grouted columns. Different concentrations of grout mixers are used to reduce the heave of expansive soil. Oedometer tests were performed to get swell pressure of different grouted specimens. Index properties, free swell, particle size distribution and compaction tests have also been conducted to know the soil properties. The results clearly indicate that ESP, Fly Ash, grouted columns in expansive soils can reduce the expansive characters of such soils.**

Keywords: **Black Cotton Soil, Egg Shell Powder, Flyash**

I. INTRODUCTION

Natural expansive soils are very common in the India and all over the world. Annually large amount of money is spent to repair the damages caused to infrastructures built on expansive soils. It contains high percentage of clay mineral like montmorillonite. The problematic sub grade soils, usually within the seasonal moisture fluctuations zone at approximately 2 to 4 m depth below ground surface. Those soils are swelling considerably and exhibit low shear strength when wet whereas, such soils shrink and exhibit high shear strength in dry condition. The seasonal moisture variation in soil creates a major damage to the structures. Expansive soils are clays of high plasticity and it exhibits low shear strength. Those soils are highly compressible and they contain low bearing capacity. Several treatment methods are currently available for stabilizing the expansive soils, such as mechanical stabilization, chemical stabilization, electrical stabilization, stabilization by geo synthetics, reinforced earth walls, and stabilization using bio enzymes etc.

II. PROBLEMS WITH EXPANSIVE SOILS

Expansive soil contains high swelling and shrinkage properties. These properties creates major problem to all civil engineering structures. The major problem caused due to expansive soils are cracking of concrete, foundation and basement, water leaking into basements, broken pipes and water lines, cracks in interior drywalls and sticking doors and windows. Those soils can also damages the roads, retaining structures and canal lining, etc.

III. IDENTIFICATION AND CLASSIFICATION OF EXPANSIVE SOILS

Expansive soils can be identified using two method, those are direct method and indirect method. In direct method, by using oedometer test and free swell test it can be identified that either the soil have expansive properties nor don't have the expansive property. In indirect method the expansive soils can be identified from physical, chemical and physico-chemical properties of soil.

The classification of expansive soils depends upon their expansion potential.

IV. FACTORS AFFECTING EXPANSIVE SOILS

The expansive property or swelling property depends upon the following factors.

- The type and amount of cay present in the soil and the nature of the clay mineral.
- The initial water content and dry density.
- The nature of pore fluid.
- The stress history of the soil including the confining pressure.
- Cycles of drying and wetting.

V. METHODS TO CONTROL HEAVE IN EXPANSIVE SOILS

Different methods are also available for reduction of heave of the expansive soil, they are

- Soil stabilization.
- Soil reinforcement.
- Providing sand cushion between foundation and soil.
- Providing CNS soil layer between foundation and soil.

A. EGG SHELL POWDER

Egg shell consists of calcium carbonate a common form of calcium. The rest is made up of protein and other minerals. Egg shells are roughly 40%calcium, with each gram providing 381-401 mg. A study in isolated cells found that calcium absorption was up to 64% greater from egg shell powder compared to pure calcium carbonate .It is also acts as a replacement of artificial lime. Egg shell consists of 96%-97%of (caco3) calcium carbonate concentration and 3-4%of organic matter Egg shells are rich in calcium and contain protein associated with the albumen residue, egg shell membrane, and shell matrix, which can be utilized by chickens .The limited information on the nutritional value of egg shell waste indicates there may been economic advantage over other calcium sources. The waste shell must be dried and powdered before being used for soil stabilization.

B. FLY ASH

Fly ash consists of primarily of oxides of silicon, aluminum, iron, calcium, magnesium, potassium, sodium & min content of sulphur. Fly ash has been used successfully in manyprojects to improve the strength characteristics of soils. Fly ash is used in grout and flow able fill production, embankments and other structural fills stabilization of soils. Fly ash is a group of materials that can vary significantly in composition. It is residue left from burning coal, which is collected on an electrostatic precipitator or in a bag house. It mixes with flue gases that result when powdered coal is used to produce electric power. Since the oil crisis of the 1970s, the use of coal has increased. In 1992, 460 million metric tons of coal ash was produced worldwide. About 10 percent of this was produced as fly ash in the United States. In 1996, more than 7 million metric tons were used in concrete in the U.S. Economically, it makes sense to use as much of this low-cost ash as possible, especially if it can be used in concrete as a substitute for cement. Most fly ash is pozzolanic, which means it's a siliceous or siliceous-and-aluminous material that reacts with calcium hydroxide to form cement. When port-land cement reacts with water, it produces a hydrated calcium silicate (CSH) and lime. The hydrated silicate develops strength and the lime fills the voids. Properly selected fly ash reacts with the lime to form CSH–the same cementing product as in Portland cement. This reaction of fly ash with lime in concrete improves strength. Typically, fly ash is added to structural concrete at15-35 percent by weight of the cement, but up to 70 percent is added for mass concrete used in dams, roller-compacted concrete pavements, and parking areas.

C. STABILIZATION

Stabilization is a process in which soil alerted by different methods in order to improves the strength of soil. Soil is stabilized to increase the strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design conditions and designed strength.

D. STABILIZATION WITH BAGASSE ASH:

Bagasse ash may be used or in combination with any material .due to potential use of sugarcane bagasse ash as stabilizing agent leads to decrease in plasticity index of high plasticity soils, optimum moisture content and increase in maximum dry density. Due to high silica content in bagasse ash strength and durability of soil increases.

E. STABILIZATION WITH CERAMIC TILE DUST:

In this study, potential of ceramic dust as stabilizing additive to expansive soil is evaluated. The evaluation involves the determination of swelling potential of expansive soil in its natural state as well as mixed with varying proportions of ceramic tile dust. The ceramic tile dust in experimental program is experimental program is obtained from breaking of ceramic tiles. Due to presence of silica content it is used as stabilizing agent.

IV. METHODS OF STABILIZATION

A. MECHANICAL METHOD:

In this category, soil stabilization is achieved by physical process such alternation and mechanical machines. By grading of soil particle s i.e., changing composition of soil by adding or removing different soil particles. By compaction using devices such rollers, tampers, rammers.

B. CHEMICAL METHOD:

In this category, soil stabilization depends on chemical reaction between stabilizer and soil mineral. It is done to reduce permeability of soil, increase shear strength and enhance bearing capacity by using chemical agents such as calcium chlorides, sodium silicates, cement, lime, bitumen.

C. *GEO-SYNTHETICS STABILIZATION:*

Geo-synthetics are latest techniques used to stabilize soil strata, made from various types of polymers (Polyethylene, Polypropylene, Polyester, Nylon, Polyvinyl, chloride)

ADVANTAGES OF STABILIZATION

1. It improves the strength of the soil, thus increasing the soil bearing capacity.
2. Stabilization improves the workability and the durability of the soil.
3. It is non-destructive, facilitates monitoring soil moisture content for the same site overtime, covers a large soil volume, and monitors volume of soil moisture.
4. Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.

D. FACTORS AFFECTING SOIL STABILIZATION

Organic matter:

Large amount of organic matter can lower the pH of the soil to be stabilized after reaction with the additives in the materials that are being used in the process. So there is necessary to determine the percentage of organic matter in the soil.

Moisture content:

Different soil stabilization products such as quick lime and cement require various amounts of moisture to produce the desired results. The level of moisture found may influence the choice of product to use. Failure to do so can result in unsatisfactory results due to incomplete reactions between the soil and the products that have been used to stabilize the soil.

Temperature:

The reaction between the soil and binders used during the stabilization process has temperature requirements. For example cement will take long time to gain strength

VI. GROUTING

Controlled Injection of slurry in to the soil is called grouting.

VARIOUS APPLICATIONS OF GROUTING

Grouting technique can be used in various applications:

- Filling the void between the lining and rock face in tunnel works.
- Fixing the tendons in pre-stressed post tensioned concrete.
- Defects on building masonry or pavement.
- Fixing ground anchors for sheet pile was, concrete pile was, retaining was tunnels etc.
- Soil strengthening to reduce lateral support requirement.
- Soil strengthening to increase lateral and vertical resistance of pile.
- Stabilization of loose sand against liquefaction.
- Slope stabilization.

VII. SCOPE OF PROJECT

Soil stabilization materials help helps in increasing the load bea**G**ring capacity, tensile strength & overall performance of soil. Soil stabilization materials modify the physical and chemical properties of soil and aggregates by improving its engineering properties, either temporarily or permanently. Authentication problem provides a challenge to balance high level of security with appropriate level of usability

To grout bearing, machine foundation, columns joints in precast construction etc., .To grout anchors in concrete. To grout cavities, gaps and voids in concrete can be installed adjacent to existing walls. Used for slab jacking to lift or level distorted foundation. Very useful for confined spaces and low head room applications. Improvements to ground formations can be measured. So user interface provided needs improvement

OBJECTIVES OF PROJECT

1. The main objective is to strengthen the soil by using various materials with different proportions.
2. To study the change in properties of un-stabilized and stabilized soil.
3. Grouting fills the empty space present below the ground surface.
4. Reduces swelling & shrinkage in expansive soils.
5. Density of the expansive soil increases.
6. OMC of the soil decrease.
7. Improves shear strength of the soil.
8. Increases bearing capacity in foundation works
9. To improve the engineering properties of the soil by using ESP & FLYASH.
10. To increase UCS and angle of internal friction increased with increased in FLYASH &ESP content.
11. To increase the life of structure.
12. To make it as economic stabilization of soil

VIII. LITERATURE REVIEW

EXPERMENTAL STUDY FOR STABILIZING CLAYEY SOIL WITH EGG SHELL POWDER.

by **Mohammed NJ Alzaidy**

ABSTRACT: Using of chemical admixtures lime, cement bitumen etc., are highly expansive. Egg shell powder is economical and eco-friendly. Egg shell powder (2%,5%,8%) and waste plastic (0.25%,0.5%,1%) are added in these proportions. Due to this curing duration also significantly improved.

CONCLUSION: Engineering properties varies from mixing proportions of ESP and PW and its curing duration .shear strength parameter and swelling potential increases due to increasing of curing duration.

STABILIZATION OF EXPANSIVE SOIL WITH EGG SHELL POWDER & QUARRY DUST

By **M.Samuthiram**

ABSTRACT: For dams& Reservoirs plays a major role problem in the construction site. Long number of research studies is carried out by using waste materials in construction purpose. This project is eco-friendly & economical. we are using 4% paper combination of admixtures are required to suitable soil.70%soil+30%Quarry dust+4%ESP. we can combine both mixtures of ESP+5% of Quarry dust for good result .

CONCLUSION: By mixing of ESP and quarry dust improves shear strength and swelling potential. Mixing of ESP and quarry dust separately cannot give the effective results.

LABORATORY INVESTIGATION OF THE EFFECT OF EGG SHELL POWDER ON PLASTICITY INDEX IN CLAY AND EXPANSIVE SOIL.

By ArashBarazesh,HamidrezaSaba,MehdiGharib,Moustafa Yousefi Rad

ABSTRACT: Utilization of such refuse and industrial wastes and their subsidiary products as alternative to construction materials may effectively contribute to environmental preservation and minimization of their adverse effects on the environment. In the present study, eggshell powder was used as a waste to combine with soil so that the plasticity properties of clay soil were investigated in different mixture proportions. Then the plasticity properties of soils including liquid and plasticity limits as well as plasticity index, already measured, were compared with those of the experimental specimens mixed with eggshell powder in different proportions.

CONCLUSION: Variations in the liquid limit of primary soil specimen decreased as the proportion of eggshell powder increased in the mixture; however, the addition of different percentages of the additive did not significantly affect this decrease.

IMPROVEMENT OF CLAYEY SOIL BY USING EGG SHELL POWDER QUARRY DUST

By **GeethuSaji, Nimisha Mathew**

ABSTRACT: Egg Shell Powder (ESP) and Quarry Dust (QD) were used to study the effect on the properties of clayey soil. Eggshell primarily contains calcium, magnesium carbonate and protein and the quantity of lime in eggshell is almost the same as in limestone on ton for ton basis. 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.

CONCLUSION: OMC increases and maximum Dry Density decreases with increase in percentage of ESP. With addition of varying percentage ESP Cohesion decreases and Angle of Internal Friction increases. Shear Strength increases with increase in percentage of ESP and after 20% strength is almost constant. Permeability increases with increase in ESP. 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

EFFECT OF EGG SHELL POWER IN THE INDEX AND ENGINEERING PROPERTIES OF SOIL

M

ABSTRACT: In egg consumption, Tamilnadu stands second place in India. Hence a huge amount of eggshell wastes are produced every year. In the absence of an effective waste disposal, the utilization of eggshell for soil improvement will be a welcome development. Soil samples were collected and stabilized with eggshell powder in proportions of 0.5% to 5.5% at 0.5% interval by dry weight. The maximum unconfined compressive strength was attained at 3% eggshell powder stabilization. The use of eggshell powder as an additive will therefore improve the strength of soils; however, using eggshell powder quantities in excess of 3% may not yield sample results.

CONCLUSION: We can utilize the eggshell waste as a useful soil stabilizing material. By using the eggshell powder as a soil stabilizer, we can minimize the waste disposal problem of eggshell. The optimum usage of eggshell powder added to the soil was 3%.The delayed compaction effect leads to increase in unconfined compressive strength of soil when compared to the without delay in compaction

ASH INJECTION FOR LANDFILL STABILISATION

ByL. ANDREAS, K. WIKMAN,M. BERG R. SJOBLOM AND A. LAGERKVIST

ABSTRACT: The division of Waste Science and Technology at Lulea University of Technology has been testing the injection of fly ash from the incineration of RDF for this purpose in two test areas at a landfill. As a total, about 100 tonnes of fly ash were injected. The work was performed on behalf of, and in co-operation with TelgeAtervinningAB – a recycling company in Sodertalje, south of Stockholm, AF-Energi&Miljo AB, Stockholm, and Tekedo AB, Nykoping, Sweden.

CONCLUSION: Ash is miscible with water to pump able slurry that can be injected without hardening inside the equipment. Fly ash worked better than bottom ash mostly because of its finer consistency. From the reinvestigations only minor differences could be observed for fresh and aged fly ash. Neither the waste nor the grouting material caused a backpressure during the injection and nothing indicated that the injected ash deforms the landfilled waste. The ash-water-slurry flows through the voids in the waste easily and may thus dispread quite far from the injection holes

Sl.no	No. of blows	Empty wt (w1) (gm)	Empty + wet sample (w2)(gm)	Empty + dry sample (w3)(gm)	Water content (%)
1	35	20.70	29.99	26.79	52.54
2	34	24	36	32.35	43.71
3	20	24	37.84	31.45	85.77

RHEOLOGICAL PROPERTIES OF ALKALINE ACTIVATED FLYASH USED IN JET GROUTING APPLICATIONS

By

NunoCristelo,EdgarSoares,IvoRosa,TiagoMiranda,Daniel V. Oliveira

ABSTRACT: The application of alkaline activated fly ash to soil stabilisation has been recently studied, and although the structural behaviour was adequate, some concerns were raised regarding its apparent viscosity, which proved to be an important issue in jet grouting applications. Six different grout compositions, defined based on Na2O (alkali) / ash and activator / ash ratios, were analysed. Results show that the fluidity of the grouts correlate very well with UCS, with an increase of the former resulting in a decrease in the latter, which is a concern in jet grouting applications since this parameter controls the velocity of the grout at the nozzle and the soil / grout mixing capability

Sl.no	W1 (gm)	W2 (gm)	W3 (gm)	Mould wt with soil (b)
1	21.7	53.59	49.01	4.85
2	21.7	54.88	49.34	4.96
3	21.7	60.64	53.03	4.99
4	21.7	68.77	57.68	4.87

CONCLUSION: The properties of the injection grout assessed, when in its fresh state, control the behaviour of the soil-grout mix after the hardening process takes place. It was shown that a very significant correlation exists between fluidity and UCS and between density and UCS. To improve fluidity without compromising strength, it is necessary to increase the alkali / ash ratio of the grout, in order to maintain Na2O concentration.

TEST RESULTS

FOR SOIL1, FREE SWELL OF 70%:

Sl.no	Weights	Trail1 (gm)	Trail2 (gm)	Trail 3 (gm)
1	W1	604	604	604
2	W2	835	852	857
3	W3	1580	1602	1589
4	W4	1500	1488	1488
	Sp.gravity	1.57	1.85	1.66

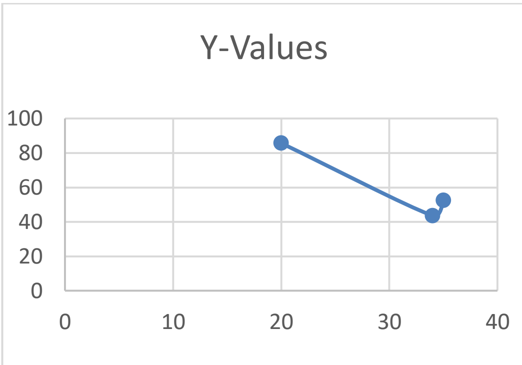
The specific gravity of soil1, is taken as 1.69.Repeat the test twice or more to get more accuracy.

Liquid limit (w_L)

Liquid limit is the water content at which a part of soil, cut by a groove of standard dimension, will flow together for a distance f 12mm under the impact of 25 blows given at the rate of 2 blows per second with a drop of 1 cm in a standard liquid limit device (Casagrande's device).

CALCULATIONS

FOR SOIL, FREE SWELL INDEX OF 70 %:



AVERAGE LIQUID LIMIT FOR NATURAL SOIL=60.67%

Plastic limit (w_p)

It is defined as the minimum water content at which soil will just begin to crumble when rolled into a thread approximately 3mm in diameter.

FOR SOIL1, FREE SWELL INDEX OF 70%:

Sl.no	Empty wt (w1) (gm)	Empty + wet sample (w2) (gm)	Empty + dry sample(w3)(gm)	Water content (%)
1	36.38	62.96	56.48	31.73
2	37.89	57.9	52.85	33.756
3	36.9	58.43	53.15	32.6

AVERAGE PLASTIC LIMIT FOR NATURAL SOIL=32.69%

plasticity index, (I_P)

- It is a range of moisture in which a soil remains in a plastic state while passing from a semisolid state to liquid state.

Plasticity Index = Liquid Limit - Plastic Limit.
=60.67-32.69
=27.98%

Compaction test:

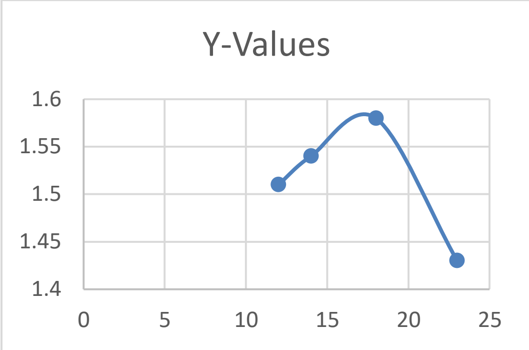
compaction is the densification of a soil expelling air by means of mechanical equipment. Compaction curve is the curve showing the relationship between water content and corresponding dry density of a soil for a given compactive effort. Optimum moisture content (O.M.C) is the water content at which the soil is compacted to maximum dry density with a given compactive effort. Dry density of a soil is the ratio of weight of solids to the total volume of soil.

FOR SOIL1, FREE SWELL OF 70%:

Empty weight of the mould (a) =1.931kg
Weight of sample taken = 3kg
Volume of the mould = 943.89c

Maximum dry density = 1.58. g/cc
Optimum moisture content = 20%

GRAPH:



DRY DENSITY:

Volume of the mould V= 1000cc
Bulk density =a-b/V
= (4850-3000)/(1000)
= 1.85gm/cc.
Dry density = bulk density /(1+water content)
= 1.85/(1+0.1677)
= 1.51

Similarly for other water contents also bulk density and dry density are calculated.

Free swell test

Differential free swell is the difference in volume of soil in water and kerosene expressed as percentage of volume of soil in kerosene.

FOR SOIL1,

Free Swell Index, (%) = $(V_d - V_k)/(V_k) \times 100$
Free swell index= (17-10) /10 x 100
= 70%

Grain size analysis

(a) Mechanical method

Sl .no	IS sieve size	Particle size	Weight retained	% weight retained	Cumulative % weight retained	Cumulative % weight passing
1	4.75	0	0	0	0	100

	mm					
2	2mm	100	100.142	20.0284	20.0284	79.9716
3	1mm	114.5	114.642	22.9284	42.9568	57.0432
4	425µ	130.5	130.642	26.1284	69.0852	30.9148
5	300µ	79.5	79.642	15.9284	85.0136	14.9864
6	150µ	43.5	43.642	8.7284	95.742	6.258
7	75µ	21	21.142	4.2284	97.970	2.0296
8	Pan	10	10.418	2.0284	100	0

From the PSD Curve:

D60 =1.09

D30 =0.425

D10 =0.23

Co-efficient of uniformity = Cu = (D60) / (D10)

=4.739

Coefficient of curvature = Cc = (D30)2 / (D60*D10)

=0.72

UNCONFINED COMPRESSIVE STRENGTH

The unconfined compressive strength is defined as the ratio of failure load to cross sectional areaof the soil sample when it is not subjected to any lateral pressure.

Qu=P/Ac

CALCULATIONS:

Deformation dial reading =1 Revolution 20′

Proven ring = 17.6

Axial deformation ΔL = 6.9mm

Strain = ΔL / L∘

= 0.0547

Corrected area at failure Ac = A∘ / (1-ε)

=11.996

Qu = P / A∘

= 230.693

SWELL PRESSURE TEST

EFFECT OF CONCENTRATION OF GROUT MATERIALS IN EXPANSIVE SOILS

- The influence of vertical grouted columns on swell behaviour was studied in this project. The concentration of grout material shows major influence in the expansive soils.

For soil-1:

- The measured heave value was 0.66mm and the corresponding swell pressure value 130 kN/m^2. The number of vertical columns 7 and the area of grouted columns 0.000049m^2. Here the variable was concentration, it can be varies from 100% to 50%.

	Heave(MM)	Swell preesure(kn/m^2	%Reduction of heave
NATURAL SOIL	0.66	130	85.8

TEST RESULTS

SWELL PRESSURE TEST

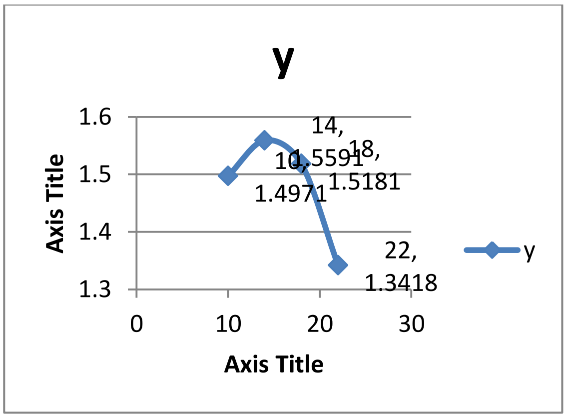
	Heave(MM)	Swell pressure (kn/m^2	%Reduction of heave
NATURAL SOIL	0.66	130	85.8
5%ESP+20% FLY ASH	0.54	105	56.7
5%ESP+25% FLY ASH	0.42	80	43.6
5%ESP+30% FLY ASH	0.28	55	35.4

COMPACTION TEST:

Calculation of optimum moisture content and maximum dry density for 5% ESP&20% FLY ASH

SL.NO	W1 (gm)	W2 (gm)	W3 (gm)	Mould wt with soil
1	36.7	110.82	101.03	7.38
2	36.43	109.8	98.26	7.505
3	36.98	133.05	115.64	7.510
4	36.95	107.24	89.94	7.495

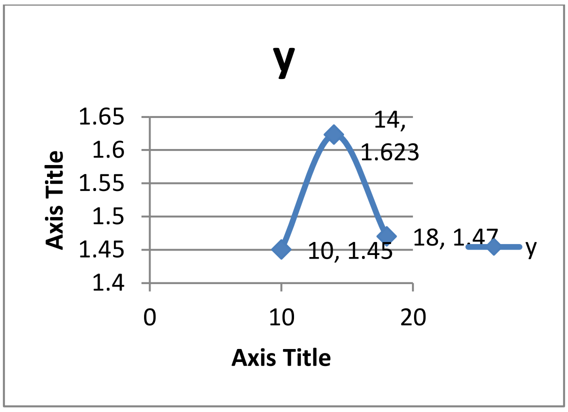
Graph:



Calculation of optimum moisture contant and maximum dry density for 5% ESP&25% FLY ASH

SL.NO	W1 (gm)	W2 (gm)	W3 (gm)	Mould wt with soil
1	36.95	99.24	90.25	7.140
2	36.98	115.8	101.90	7.410
3	36.43	131.67	112.14	7.290

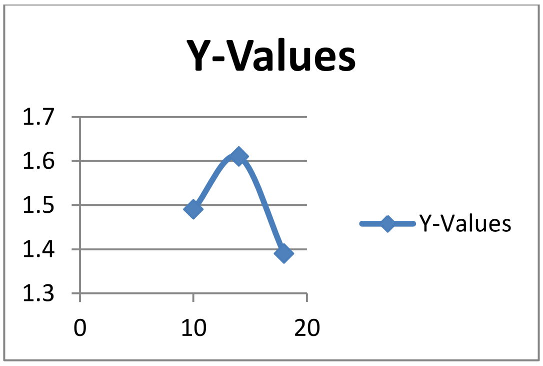
Graph:



Calculation of optimum moisture content and maximum dry density for 5% ESP&30% FLY ASH

SL.NO	W1 (gm)	W2 (gm)	W3 (gm)	Mould wt with soil
1	36.41	111.44	100.79	7.400
2	37.51	99.25	88.27	7.620
3	36.98	109.36	94.00	7.430

Graph:



UNCONFINED COMPRSSIVE STRENGTH:

SL. NO	NATU RAL SOIL	5%ESP+20 %FLY ASH	5%ESP+25 %FLY ASH	5%ESP+30 %FLY ASH
1	230.69	243.40	253.22	349.71

SPECFIC GRAVITY:

SL. NO	NATU RAL SOIL	5%ESP+20 %FLY ASH	5%ESP+25 %FLY ASH	5%ESP+30 %FLY ASH
1	1.679	2.1739	2.009	2.106

CONCLUSIONS

From the above experimental results swell pressure test of the expansive soil is 130 KN/m2 and heave is 0.66.With the vertical grouted columns, the measured heave has been observed to reduce for all concentrations of grout mix.

- For 5%ESP and 20% FLYASH: The reduction of heave the concentration of grout material 0.54 for 25% and the Swell pressure test is 105 KN/m2 (5 soil grouted columns).
- For 5% ESP and 25% FLYASH: The reduction of heave concentration of grout material 0.42 for 30% and the swell pressure test 80 KN/m^2(5 soil grouted columns).
- For5%ESP and 30% FLYASH: The reduction of heave concentration of grout material 0.28 for 35% and the swell pressure test is 55 KN/m^2(5 soil grouted columns).
- This type of grout material shows a major influence in heave. In this project two types of grout materials are used i.e., ESP, FLY ASH. For 5% ESP, 30% FLYASH shows more influence of heave.
- For expansive soil the unconfined compressive strength is 230.693 KN / m2. For 5%ESP and 20%FLYASH concentration the unconfined compressive strength is 240.93 KN/m2. For5%ESP and 25% FLYASH concentration the unconfined compressive strength is 253.22KN/m2. For 5%ESP and 25% FLYASH concentration the unconfined compressive strength is 1349.71KN/ m2
- For concentration of 5%ESP and 30%FLYASH the unconfined compressive strength is more when compared to other to concentrations.

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10. Soil stabilization using flyash and rice husk ash by anil kumar singhai1, sudhanshushekhar singh2
11. Geotechnical properties of fly ash and its application on soft soil stabilization by emillianianakgeliga
12. Geotechnical properties and microstructure of lime-flyash phosphogypsum-stabilized soil by tebogopilgrenemashifana
13. Recent experiences with lime-flyash stabilization of pavement subgrade soils,base,and recycled asphalt by joel h beeghly
14. Soil stabilization with flyash and rice husk ash by dr.robert