An Experimental Behavior of Different Percentages of Palm Oil Fuel Ash (POFA) And Shredded Rubber on The Strength Properties of Black Cotton Soil

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Abstract- *Soil Stabilization means alteration of soil properties to meet the specified engineering requirements. Construction of engineering structures on weak or soft soil is considered as unsafe. Improvement of load bearing capacity of soil may be undertaken by variety of ground improvement techniques. From the recent studies it is observed that solid waste materials such as Palm oil fuel ash and waste tires are used for improving the properties of soil. In the present investigation, shredded rubber tire from waste has been chosen as the reinforced material and the Palm oil fuel Ash (POFA) and Lime as binding agents. The Optimum replacement of soil by POFA can be determined by conducting Compaction test with proportions 5%, 10%, 15%, 20% by weight of soil. Shredded rubber which is included in to the soil mix (in which Optimum soil is replaced by POFA) at 3 different percentages of fibre content that is 1%,2%,3% by weight of the soil . The investigation has been focused on the strength behaviour of the soil reinforced with randomly included optimal rubber fibre, optimal replacement of POFA by soil and 2% lime as constant. The samples were subjected to California bearing ratio (CBR) test and unconfined compression test. The test results were noted and compared to virgin soil properties and determining the optimum content of stabilizers to improve the properties of soil.*

Keywords- Black cotton (BC) soil, Shredded rubber, Palm oil fuel ash (POFA), California bearing ratio (CBR), Unconfined compressive strength (UCS).

I. INTRODUCTION

Soil is defined as sediments or other accumulation of mineral particles produced by the physical or chemical disintegration of rocks plus the air, water, organic matter and other substances that may be included. Soil is typically a non-homogenous, porous, earthen material whose engineering behavior is influenced by the changes in moisture content and density.

TYPES OF SOILS Based on the origin: a) Organic soils b) Inorganic soils

Organic soils These soils are mixture derived from growth and decay of plant life and also accumulation of skeleton or shell of small organism. **Inorganic soils** These soils are derived from the mechanical or chemical weathering of rocks. Inorganic soils are again classified in to two types. They are **Transported soils** Inorganic soil that has been moved to another location by gravity, water or wind. Residual soils Inorganic soil that is still located at the place where it was formed. These are also known as sedentary soils. Example for residual soil is Black cotton soil. Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as Black cotton soils.

IMPORTANCE OF SOIL STABILIZATION

Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. Stabilization in broad sense incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance. Stabilization is being used for a variety of engineering works, the most common application being in the construction of roads and airfield pavements, where the main objectives is to increase the strength or stability of soil and to reduce the construction cost by making best use of locally available materials.

PROPERTIES OF BLACK COTTON SOIL

ENGINEERING PROPERTIES The main engineering properties of soil are permeability, plasticity, compaction, compressibility and shear strength.
PERMEABILITY: The permeability is defined as the property of a porous material which permits the passage or seepage of water through its interconnecting voids.
PLASTICITY: It is defined as the property of a soil which allows it to be deformed rapidly, without elastic rebound, without volume change.

COMPACTION: Compaction is a process by which the soil particles artificially rearrange and packed together into a closer state of contact by mechanical means in order to decrease the porosity of the soil and thus increase its dry density.

COMPRESSIBILITY: The property of soil mass pertaining to its susceptibility to decrease in volume under pressure is known as compressibility.

SHEAR STRENGTH: This is the resistance to deformation by continuous shear displacement of soil particles or on masses upon the action of a shear stress.

INDEX PROPERTIES The properties of soil, which are not of primary interest to the geotechnical engineering, but are indicative of the engineering properties are called index properties. This includes

PARTICLE SIZE ANALYSIS: This is method of separation soils into different fraction bases on particles present into soils. It can be shown graphically on a particle size distribution curve. The coal ashes can be classified as sandy silt to silty sand as per this classification.

SPECIFIC GRAVITY: It can be classified as the ratio of the weights of a given volume of soil solid at a given temperatures of the weight of an equal volume of distilled water at that temperature both weight being taken in air.

ATTERBERG'S LIMITS The water content at which the soil changes from one state to other state are known as consistency limits or Atterberg's limit .The Atterberg's limit which are useful for engineering purposes are; Liquid limit, plastic limit and shrinkage limit. These limits are expressed as percent water content.

LIQUID LIMIT: It is defined as the minimum water content at which the soil is still in liquid state but has a small strength against flowing which can be measured by standard available means.

PLASTIC LIMIT: It is defined as minimum water content at which soil will just begin to crumble water rolled into a thread approximately 3mm in diameter, Plasticity index is determined as difference of L.L. and P.L.

SHRINKAGE LIMIT: It is defined as the maximum water content at which a reduction in water content will not cause a decrease in the volume of soil mass.

II. REVIEW OFLITERATURE

Ghatge Sandeep Hambirao,Dr.P.G.Rakaraddi e-ISSN: 2278-1684,p-ISSN: 2320-334X Volume 11, Issue 1 Ver. V (Feb. 2014), PP 20-27 In this journal shredded rubber from waste has been chosen as the reinforcement material and cement as binding agent. The tests results were clearly shown a significant improvement in shear strength and bearing capacity parameters of the soil. The low strength and high compressible soft clay soils were found to improve by addition of waste rubber and cement. The tests are conducted for black cotton soil with 2% and 4% cement with the varying rubber percentages i.e.; 0%, 5%, 10%, and 15% and the results are noted. The unconfined compressive strength and CBR ratios increases with the increases in cement content at an optimum fiber content of 5%.The unconfined compressive strength has been increased from 15kpa to 74kpa for 2% of cement content and 246kpa for 4%cement content for black cotton soil. It can be concluded that shredded rubber fiber can be considered as a good earth reinforcement material

S Sameer, K Giridhar, Y Murali Krishna ,ISSN 0973-4562 Volume 13, Number 22 (2018) pp. 15944-15950 Here rubber is taken in three different dimensions 15mm*25mm, 20mm*40mm,25mm*50mm is mixed with various percentages 2.5%, 5%, 7.5%, 10%.Modified proctor test is conducted to determine the compaction characteristics like optimum moisture content, max dry density. When 5% of rubber of dimension 25mm*50mm , the CBR has got the improvement of 66.28% with comparison of plain soil 26.01%.

M. Siva Parvathi ,B. Anusha , G. Vimalatha , B. Shayam Kumar,Volume 4, Issue 6, June 2019 Quarry Dust shall be used as a partial replacement for sand in concrete works Washed samples of Quarry Dust satisfied the criteria for fine aggregates as per the BIS specifications.

The optimum replacement for natural sand by quarry sand is60%. Washed quarry dust can be used for reinforced concrete works

Jagtarsingh, ER. Jasvir Singh Rattan. Volume 06, Issue 09 (September 2017) The journal soil stabilization of soil is done by use of shredded rubber of sizes 10mm, 20mm, 30mm, in width and 20mm, 40mm, 60mm in length are used for experimental work. The percentages used are 1%, 2%, 3%. Modified proctor test and unconfined compression strength (UCS) tests were performed on the soil. It is found that when soil mixed with 1% of shredded tire with size 10mm*20mm its UCS value increases to 7.83% than the virgin soil. Shredded rubber tire has water absorption capacity.

Prof. P Vandana Rao, Prof. G Sudheer Kumar and Prof. G Prasanna Kumar, Volume 2, Issue 22, PP: 01-10, April-June 2018 conducted a research on stabilization of black cotton soil using rice husk ash. As per the research and analysis this paper represents that, Husk is a by-product in rice milling industries. It is used as a fuel in rice mills which contains 75% of volatile matter and 25% converted to ash known as rice husk ash RHA. RHA contains 85-90% amorphous silica, 10-15% iron oxide. In a manner conforming to experiments on black cotton soil MDD is decrease with increasing dose of RHA, OMC increases with RHA contains, UCS value and CBR value is increase up to RHA contains is 10% after that it decrease. The optimum dose of RHA is 10%. In 2016, Gaus Makandar (3) conducted a research on stabilization of black cotton soil using waste foundry sand and lime. As per the research and analysis, this paper represents that the pozzolanic properties of the waste foundry dust and lime can be utilized in the construction industry. In metal casting industry, metal foundries require large quantity of sand. This sand is recycle and reused many times but after that, this sand is removed as a waste foundry sand. It contents more than 80% of high quality silica, 5-10% of bentonite clay, 2-5% of water and sea coal less than 5%. As per the estimate, around 100 million tons foundry sand produced annually. When WFS and hydrated lime added to black cotton soil, it reacts with clay particles and converted into strong cementious matrix. CBR increases whith constant percentage of WFS and increasing percentage of lime. Combination of WFS and lime is beneficial for control on OMC of the soil. Liquid limit is decrease and increase in dry strength of black cotton soil. WFS and lime is a good compound for stabilization and improving engineering properties of black cotton soil.

III. METHODOLOGY

DETERMINATION OF MOISTURE CONTENT BY OVENDRYING METHOD (IS: 2720 PART-2)

AIM: Determine the natural moisture content of the given soil sample.

NEED AND SCOPE OF THE EXPERIMENT:

In almost all soil test natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To cite a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

DEFINITION: The natural water content also called the natural moisture content is the ratio of the weight of the water to the solids in a given mass of soil. The ratio is usually expressed as percentage.

PLANNING AND ORGANIZATION:

APPARATUS:

1. Non-corrodible airtight container.
2. Thermostatically controlled electric oven with interior of non-corroding material to maintain the temperature between 105°C to 110°C
3. Desiccator with any suitable desiccating agent other than sulphuric acid.
4. Balance of sufficient sensitivity to weigh soil samples to an accuracy of 0.004per cent of the weight of all soil.

PROCEDURE:

1. Clean the container with lid, dry it and weight it (W1).
2. Take a specimen of the sample in the container and weight with lid (W2).
3. Keep the container in the oven with lid removed. Dry the specimen to constant weight, maintaining the temperature between 105°C to 110°C for a period varying with the type of soil but usually 16 to 24 hours.
4. Record the final constant weight (W3) of the container with dried soil sample. Peat and other organic soils are to be dried at a lower temperature (say 60°C) possibility for a longer period. Certain soils contain gypsum, which on heating loses its waste of crystallization. If it is suspected that gypsum is present in the soil sample used for moisture content determination it shall be dried at not more than 80°C and possibly for the longer time

CALIFORNIA BEARING RATIO TEST

NEED AND SCOPE: The California bearing ratio test is penetration test meant for the evaluation if subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavements and its components layers. This is the most widely used method for the design of flexible pavements.

This instruction sheet covers the laboratory method for the determination of C.B.R of the undistributed and remoulded/compacted soil specimen both in soaked as well as unsoaked state

THEORY: Definition of C.B.R: it is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25mm/min. to that required for the corresponding penetration of a standard material.

C.B.R= (test load/standard load)*100

The test may be performed on undistributed specimens and remoulded specimens which may be compacted either statically or dynamically.

PREPARATION OF TEST SPECIMEN

- Undistributed specimen
- Attach the cutting edge to the mould and push it gently into the ground. Remove the soil from the outside of the mould which is pushed in. When the mould is full of soil remove it from weighing the soil with mould or by any field method near the spot.
- Determine the density
- Remoulded specimen
- Prepare the remoulded specimen at proctor’s maximum dry density or any other density at which C.B.R is requires. Maintain the specimen at optimum moisture content or the field moisture as required. The material used should pass 20mm I.s sieve but it should be retained on 4.75mm I.S sieve. Prepare the specimen either by dynamic compaction or by static compaction.

Dynamic compaction

- Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water
- Fix the extension collar and the base plate to the mould. Insert spacer disc over the base. Place the filter on the top of the spacer disc.
- Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows by the 4.89 kg rammer.
- Remove the collar and trim off soil.
- Turn the mould upside down and remove the base plate and the displacer disc.
- Weigh the mould with compacted soil and determined the bulk density and dry density. Put filter paper on the top of the compacted soil (collar side) and perforated base plate on to it.

Static compaction Calculate the weight of the wet soil at the required water content to give the desired density when occupying the standard specimen volume in the mould from the expression

W=desired dry density*(1+w) V Where W=weight of the wet soil
w=desired water content
V=volume of the specimen in the mould=2250 cm3

Take the weight W of the mix soil and place it in the mould. Place a filter paper and the displacer disc on the top of soil.

Keep the mould assembly in static loading frame and compact by pressing the displacer disc till the level of disc reaches the top of the mould.

Keep the load for some time and then release the load. Remove the displacer disc. The test may be conducted for both soaked as well as unsoaked conditions.

If the sample is to be soaked in both cases of compaction put a filter paper in the top of the soil and place the adjustable stem and perforated plate on the top of the filter paper.

Put annular weights to produce a surcharge equal to weight of base material and pavement expected in actual construction. Each 2.5kg weight is equivalent to 7 cm construction. A minimum of two weights should be put.

Immerse the mould assembly and weights in a tank of water and soak it for 96 hrs. Remove the mould from tank.
Note the consolidation of the specimen

IV. RESULTS AND DISCUSSIONS

DETERMINING THE PROPERTIES OF THE BLACK COTTON (BC) SOIL:- Experiments were conducted to determine the properties of black cotton soil. The experiments included are specific gravity test, free swell index test, Standard proctor test, Atterberg’s limits determination, California bearing ratio test, unconfined compressive strength test.

Table 4.1.3 MDD and OMC for 100% soil

S.No.	S 1 (14%)	S2 (16%)	S 3 (18%)	S 4 (20%)	S 5 (22%)	Sample6 (24%)
Weightof Compacted soilinmould (gm)	1645	1835	1925	1985	1988	1955
Volume ofmould(cc)	943.6 9	943.69	943.69	943.69	943.69	943.69
Bulk density(g/cc)	1.74	1.94	2.03	2.1 0	2.11	2.07
Weightofw etsoil(gm)	36.13	42.02	42.39	42.99	44.22	49.28
Weight of drysoil(gm)	34.69	39.63	39.96	40.2 0	42.4 9	44.48
Weightofw ater(gm)	1.44	2.39	2.43	2.79	1.73	4.8
Waterconte nt(%)	4.15	6.03	6.08	6.94	4.07	0.79
Dry density(g/cc)	1.67	1.83	1.91	1.96	2.02	1.86

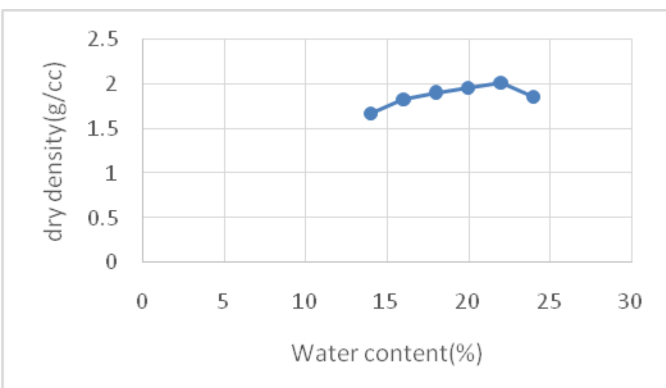

Fig. 4.1.3 Compaction curve for 100% soil

Optimum moisture content = **22 %**
Maximum dry density=**2.02g/cc**

Table 4.1.4 Results of Atterberg's limits

LIQUIDLIMI T	PLASTI C LIMIT	SHRINKAGE LIMI T	PLASTICI TY INDEX
42%	21.38 %	17.10 %	20.62%

CALIFORNIA BEARING RATIO TEST:-

Table 4.1.5 CBR readings for100% soil

Penetrationinm m	Provingring reading	Load inkg
2.5	1 7	17*1.176=19.99 2
5.0	2 3	23*1.176=27.04 8

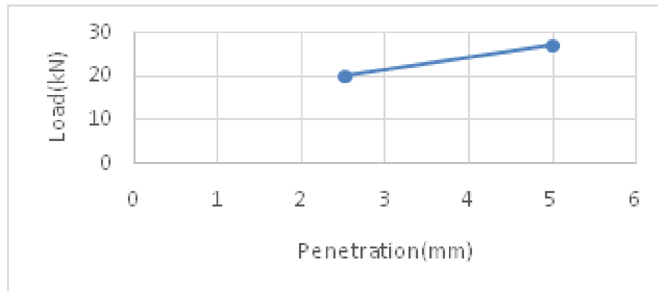

Fig.4.1.5 Load vs Penetration curve for 100% soil

CBR at 2.5 mm penetration=**1.46%**
CBR at 5.0 mm penetration=**1.31%**

UNCONFINED COMPRESSIVE STRENGTH OF SOIL:-

Table 4.1.6 UCC values for100% soil

Deflection (mm)	Provingri ngreading	Load(kg)	Strain	Corrected area(cm2)	UCC (kg/cm2)
0.25	1.2	0.4032	0.0034	10.20	0.039
0.50	2.8	0.9408	0.0066	10.24	0.092
0.75	3.6	1.2096	0.0104	10.28	0.118
1.00	4.2	1.4112	0.0138	10.31	0.136
1.25	9.00	3.024	0.0173	10.35	0.292
1.50	14.6	4.9056	0.0208	10.39	0.472
1.75	13.8	4.6368	0.0243	10.42	0.445
2.00	14.8	4.9728	0.0277	10.46	0.475
2.25	14.2	4.7712	0.0312	10.50	0.454
2.50	9.4	3.1584	0.0347	10.53	0.299
2.75	12.2	4.099	0.0382	10.57	0.387
3.00	10.8	3.628	0.0416	10.61	0.342

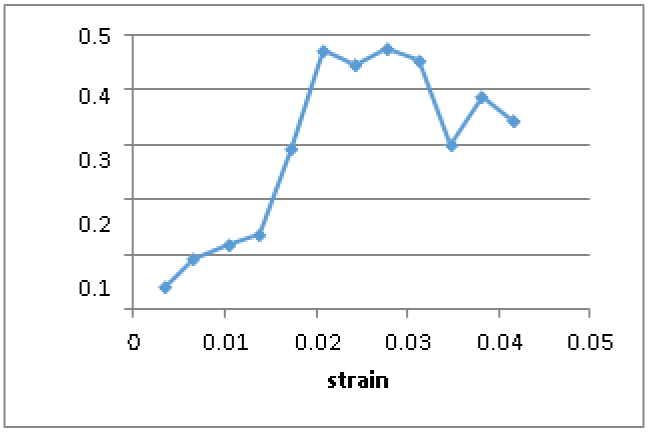

Fig. 4.1.6 Stress vs Strain curve for 100% soil

qc =unconfined compressive strength=0.475kg/cm^2
c= cohesive strength=(0.475/2)= 0.23kg/cm2

DETERMINATION OF OPTIMUM REPLACEMENT OF SOIL BY POFA:-

To assess an amount of compaction and water content required the compaction tests are done on the expansive soils in the laboratory. The test provide a relationship between the water content and the dry unit weight. The water content at which the maximum dry unit weight is obtained from the relationship provided by the tests. The compaction curve for soil and POFA percentages ranging from 5% to 20% are presented from fig 4.4 – 4.7. The MDD and OMC values are observed from the compaction curves for all different mix proportions of expansive soil and POFA are given in table 4.4. It is noticed that the optimum MDD and OMC values are obtained at 15% of POFA by weight of soil.

SOIL +15%POFA

Table4.2.3 MDD and OMC values for15% POFA

S.No.	Sample1 (16%)	Sample2 (18%)	Sample 3 (20%)	Sample4 (22%)
Weightof Compacted soilinmould(gm)	1760	1835	1920	1885
Volume ofmould(cc)	943.69	943.69	943.69	943.69
Bulk density(g/cc)	1.86	1.94	2.03	1.99
Weightofwet soil(gm)	50.62	44.90	60.63	47.8
Weight of drysoil(gm)	43.94	40.67	58.27	43.68
Weightofwater(gm)	6.68	4.23	2.36	4.15
Watercontent(%)	15.20	10.42	4.05	9.50
Dry density(g/cc)	1.61	1.76	**1.95**	1.81

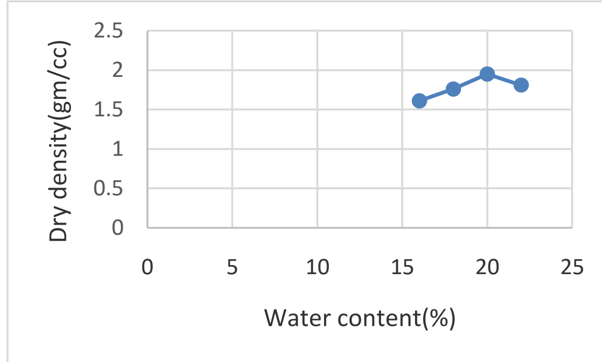

Fig. 4.2.3 Compaction curve for 15% POFA

Optimum moisture content = **20%** Maximum dry density = **1.95 g/cc**

Table 4.2.5 Summary of results for Optimum amount of POFA

S.No	Description	Optimum moisturecontent(%)	Maximum drydensity(g/cc)
1	For100%Soil	22	2.02
2	For 95%Soil+5 % POFA	18	1.53
3	For90% Soil+10%POFA	20	1.76
4	For85% Soil+15%POFA	**20**	**1.95**
5	For80% Soil+20%POFA	22	1.67

From the result,The optimum soil content replacement by Palm oil fuel ash (POFA) is 15% by the weight of the soil.

DETERMINATION OF OPTIMUM ADDITION OF RUBBER TO THE SOIL:-To assess an amount of compaction and water content required the compaction tests are done on the expansive soils in the laboratory. The test provide a relationship between the water content and the dry unit weight. The water content at which the maximum dry unit weight is obtained from the relationship provided by the tests.

The compaction curves are drawn for soil with replacement by POFA and with addition of percentages of waste rubber shreds 1%, 2%, 3% by weight for getting an optimum values respectively are presented from fig 4.8 – 4.10. The MDD and OMC values are observed from the compaction curves for all different mix proportions of expansive soil and POFA are given in table 4.5. It is noticed that the optimum

MDD and OMC values are obtained at 15% replacement of soil by POFA and with 2% of addition of rubber by weight of soil. **Optimum soil mix is: - 85% soil + 15% POFA + 1% of rubber by weight of soil.**

Table 4.3.4 Summary of results for optimum amount of Rubber

S.No	Description	Optimum moisturecontent(%)	Maximum drydensity(g/cc)
1	For100%Soil	22	2.02
2	For85%Soil+15%POFA+0%Rubber	20	1.95
3	For85%Soil+15%POFA+1% Rubber	18	2.05
4	For85%Soil+15%POFA+2% Rubber	**16**	**2.43**
5	For85%Soil+15%POFA+3%Rubber	16	2.40

From the result,The optimum amount of addition of rubber to soil mix is **2% of rubber by weight of soil.**

CONDUCTING TESTS ON OPTIMUM MIX OF SOIL

For the optimum soil mix, taking 2% lime as constant due to lack of cementitious properties of POFA, samples were prepared and subjected to California bearing ratio test and unconfined compressive strength test

CALIFORNIA BEARING RATIO TEST:-

Table 4.4.1 CBR values for Optimum mix of soil

Penetrationinmm	ovingring reading	Load inkg
2.5	38	38*1.176=44.688
5.0	53.5	53.5*1.176=62.916

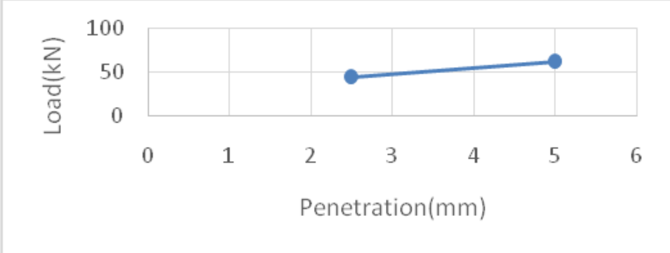

Fig. 4.4.1 Load vs Penetration curve for optimum mix of soil

CBR at 2.5mm penetration = **3.26%**
CBR at 5.0mm penetration = **3.06%**
CBR = 3.26%

UNCONFINED COMPRESSIVE STRENGTH OF SOIL (OPTIMUM MIX):-

Table 4.4.2 UCC values for optimum soil mix

Deflection (mm)	Provingringreading	Load(kg)	Strain	Corrected area(cm2)	UCC (kg/cm2)
0.25	3.6	1.2096	0.0034	10.20	0.118
0.50	4.2	1.4112	0.0066	10.24	0.137
0.75	6.4	2.1504	0.0104	10.28	0.209
1.00	8.8	2.9568	0.0138	10.31	0.286
1.25	12.2	4.099	0.0173	10.35	0.396
1.50	10.6	3.5616	0.0208	10.39	0.343
1.75	14.4	4.838	0.0243	10.42	0.464
2.00	16.6	5.577	0.0277	10.46	0.533
2.25	18.4	6.182	0.0312	10.50	0.588
2.50	22.6	7.593	0.0347	10.53	0.721
2.75	24.2	8.131	0.0382	10.57	0.77
3.00	26.8	9.004	0.0416	10.61	0.848
3.25	20.8	6.988	0.0451	10.65	0.656
3.50	19.6	6.586	0.0486	10.69	0.616

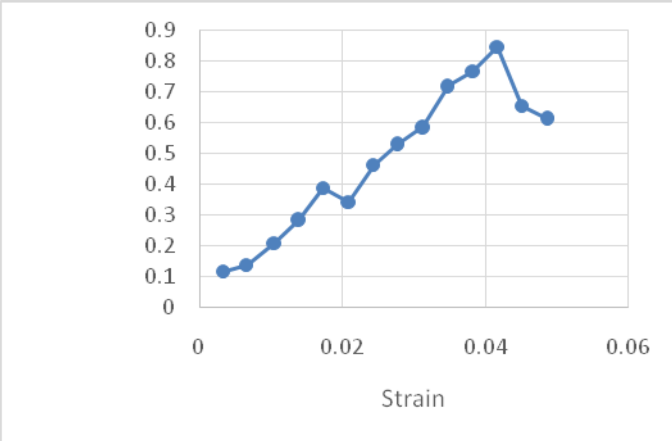

Fig. 4.4.2 Stress vs Strain curve for optimum soil mix

qu= unconfined compressive strength = 0.848 kg/cm^2
c=cohesive strength=(0.848/2)=0.424kg/cm^2

SUMMARY OF RESULTS

Table 5.1 Summary of results

S.No	Experiment	Symbol	100%soil	Optimumsoilmix
1	Standardproctor test	MDD OMC	2.02 g/cc 22%	2.43g/cc 16%
2	Californiabearing ratiotest	CBR	1.46%	3.26%
3	Unconfinedcompressive strengthof soil	quC	0.475kg/cm^2 0.237kg/cm^2	0.848kg/cm^2 0.424kg/cm^2

V. CONCLUSIONS

From the results of the investigation carried out within the scope of study, the following conclusions can be drowned.

1. Swelling potential of clay gets reduced with the addition of Admixtures. Thus the compressibility of soil also gets reduced with the addition of POFA and lime.
2. Maximum dry density of virgin soil is 2.02 g/cc, for optimum soil mix it is increased by 20% i.e., 2.43 g/cc.
3. Optimum moisture content of virgin soil is 22%, for optimum soil mix it is decreased by 27% i.e., 16%.
4. California bearing ratio of virgin soil is 1.46%, for optimum soil mix it is increased by 123% i.e., 3.26%
5. Unconfined compressive strength of virgin soil is 0.475 kg/cm^2, for optimumsoil mix it is increased by 78% i.e., 0.848 kg/cm^2.

REFERENCES

[1] Ajay, K., and Jawaid, S.M. (2013) “Soil Modification Using Shredded Scrap Tires”. International Journal of Biological Sciences & Technological Research (IJBSTR) Research Papers, Vol. 1, pp.10-13.

[2] Amin, E.R. (2012) “A Review on the Soil Stabilization Using Low-Cost Methods”. Journal of Applied Sciences Research, pp.2193-2196.

[3] Ayothiraman, R., and Abilash, M. (2011) “Improvement of subgrade soil with shredded waste tyre chips”. Proceedings of Indian Geotechnical Conference Kochi, Paper no H –033, pp.365–368.

[4] Mandeep Singh., and Anupam Mittal. (2014) “A Review On the Soil Stabilization with Waste Materials”. International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 National Conference on Advances in Engineering and Technology, pp.11-16.

[5] A N Ramakrishna and A V Pradeep Kumar (2006), “Stabilization of Black Cotton Soil Using Palm oil fuel Ash and Cement ” , in Proceedings of National conference Civil Engineering meeting the challenges of tomorrow, pp. 215-220

[6] Ali M. srinivasulu V. (2004) An experimental study on the influence of Palm oil fuelash and Lime on properties of Bentonite.

[7] Chandra S. kumar. Anand R.K (2005) Soil stabilization with Palm oil fuel ash andlime sludge.

[8] Muntohar, A.S., Hantoro, G., Influence of the Palm oil fuel ash and lime on theengineering properties of clayey subgrade.