Performance Study of Expansive Soil using Stabilizers

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Abstract - *Improvisation of soil properties is one of the key aspects of geotechnical engineering that has been considered by researchers across the globe. Expansive soil is problematic due to their alternate swelling and shrinking properties resulting in cracks and undulations in roads, differential settlement in foundation of buildings and also reduction in the strength of the soil to withstand the structural load. Black cotton soil being one of the major soil groups in India covering more than 20 % of the total soil mass is one such soil. In this paper, a study on the swelling parameters of black cotton soil by conventional treatment using lime and by non-conventional treatment using Condor and TerraZyme are carried out. Lime is increased in dosages of 2% and Condor and TerraZyme are increased in dosages of 0.01% over the course of this study. Upon analysis, a conclusion is drawn on which of these methods work best on black cotton soil for treatment, reducing its swelling parameters efficiently thereby solving the crisis experienced by geotechnical and highway engineers on these types of expansive soils. This paper involves a performance study on the swelling parameters by admixing the soil with conventional and non – conventional stabilizers.*

Key Words: **Expansive soil, Differential settlement, Swelling parameters, Stabilizers**.

1. INTRODUCTION

Rapid Industrialization has taken the world by a storm. Availability of land is diminishing significantly with surge in demand. The problem of expansive soils is widespread throughout the world. Major countries facing the problem with expansive soils are Australia, Canada, China, Egypt, India, Israel and the United States. The clay mineral that is mostly responsible for the expansiveness belongs to the Montmorollinite group. The six major natural hazards are cyclones, earthquakes, floods, landslides, tsunamis and expansive soils. According to a study, expansive soils tie with hurricane for the second place among America's most destructive natural hazards in terms of dollars losses to buildings. According to a study by Chen (1988), it was predicted that global annual loss due to expansive soils would exceed 4.5 billion dollars by the year 2000 itself. Consider how manifolds it would have grown by the year 2020 and how much the economy of the country would be affected. In the wake of this scenario to leave no stone unturned, even problematic soil is being utilized for construction activities. Black cotton soil with swelling characteristics is one type of expansive soil.

1.1 Mechanism of Soil Stabilization

Enzymes are carbon group and built up of proteins. A typical enzyme consists of 300 amino acid residues and a metal cation. Enzymes acts as catalysts to speed up a chemical reaction. Enzymes combines with large organic molecules to form a reactant intermediary thereby exchanging the ions with the clay structure and breaking the clay lattice and providing a cover up effect which further prevents water to penetrate through the soil and ultimately prevents the loss of density. The enzymes are initially absorbed by the clay lattice and later when exchanged with metal cations they are released. Enzymes have two effects on reaction with clay lattice. Initially it causes the clayey soil to expand and later it causes them to tighten.

When added to clay, the enzymes increase the wetting and bonding capacity of the clay particles. It also improves the Cohesion between the soil particles thereby making the structure permanent and resistant to weathering. Dipole moment of water molecule is lowered by dissociating the water molecule as hydroxyl (OH^-) and hydrogen (H^+) ions. The hydroxyl ion further dissociates into oxygen and hydrogen where the hydrogen atom is transformed into hydronium ion (H_3O^+) when it reacts with water. Normally, outer most layer of the clayey soil consists of negatively charged particles. The water surrounded around the soil consists of positively charged metal ions like Potassium, Calcium, Sodium, Aluminium and Magnesium. As a result of this phenomena, the electrostatic barrier is broken. When such a reaction takes place, the positively charged metal ions migrate into free water which can be later removed as a result of evaporation thereby the film of the absorbing water molecule is minimized .The clay particles thereby reduce the swelling capacity. It is a known fact that increase in the swelling capacity decreases the baring capacity of the soil.

Due to the reduction in the swelling capacity by the bio - enzymes, the bearing capacity of the soil will not be affected. Another point is that the moisture content of the soil affects the surface tension which is a major factor in increasing its degree of compaction. But upon the usage of enzymes in soil, the surface tension gets reduced thereby making the soil to get compacted easily. Once the water film surrounding the soil is reduced, the clay particles tend to agglomerate and as a result of relative movement between the particles, the surface area is reduced and less absorbed water is retained in the soil which in turn reduces its swelling capacity.

In other terms, the cohesion of the clay particles increases with increase in the quantity of bio – enzyme, as a result of which the voids in the soil gets reduced which would ultimately resist the water entering the layer through its pores.

2. LITERATURE REVIEW

2.1 Experimental study of Expansive Soil Stabilized using TerraZyme

A. Gowshik, et, al. (2016) studied the stabilization of expansive soil using TerraZyme. In this study, TerraZyme was added to the soil in concentrations of 200ml / 3m^3, 200ml / 2.5m^3, and 200ml / 2m^3 of soil. Atterberg's limit test, Standard proctor test, CBR test, and Unconfined Compression (UCC) test were carried out. The CBR and UCC test were done on 0, 7, 14 and 28 days and the results were plotted in the form of a graph. The results show that the CBR value increased from 1.20 % to 5.67 %, optimum moisture content considerably increased, swell pressure and liquid limit decreased significantly. The study was concluded by stating that the properties of expansive soil could be improved by adding TerraZyme.

2.2 Use of PET and Condor SS in Black Cotton Soil

Mangesh A. Kulkarni, et. al. (2017) deals with the treatment of highly expansive and plastic black cotton soil with polyethylene fibre (PET)as reinforcement with Condor as chemical. For PET they have collected strayplastic bottles and cut them into strips of various aspect ratios of 1:1, 1:2, 1:3. The PET and Condor has been added in percentages of 0.25%, 0.5% and 0.75%. Various PET properties such as Young's Modulus, Elastic limit, Tensile strength and Density were determined. Soil samples were tested for Modified Proctor Test and UCS with variation with percentage of waste plastic and plastic with Condor and results has been tabulated. The results show that maximum dry density occurs at aspect ratio 2 at 0.5% of PET in both cases of test with and without Condor and the optimum moisture content get decreased with increase in the percentage of PET

2.3 The Effect of Lime Stabilization on Black Cotton Soil

Nadgouda K.A. & Hegde R.A. (2010) studied the swelling and strength characteristics of black cotton soil mixed with lime. Sieve analysis, Atterberg's limit test, standard proctor test, CBR test, Differential free swellindex (DFSI) test and swell pressure test were conducted. The liquid limit decreased from 59.8% to 53.2% on adding lime to 4.5% after which increasein lime increased the liquid limit. The plastic limit increased from 33% to 40% and the plasticity index decreased from 25.9% to 15.1% upon additionof lime. The DFSI decreased from 39% to 34.6%. According to **Huang (1987) 'Identification and classification of clays in China'** any soil having DFSI less than 40% is said to be non-expansive. Here the DFSI of virgin soil is 39% which falls under non- expansive category and hence there was no necessity for concluding the effect of lime on the free swell index of the soil. The swell pressure decreased with increase in lime content up to 3.5% beyond which it goes on increasing. It decreases from 1.06 kg/cm^2 to 0.22 kg/cm^2. The CBR value of soil decreased with increase in lime up to 3.5% and after which lime had no significance. With these values as reference, conclusion was drawn that 3.5% to 4.5% lime content.

3. MATERIALS USED

3.1 Black cotton soil

Black cotton soil is a highly plastic clay mineral which has Montmorillonite structure. It is generally light to dark grey in colour. The most important characteristic of the soil is, when dry, it shrinks and is hard like stone and has very high bearing capacity. It's very easily available everywhere in India. Also called as **Regur soil**, it's called black cotton soil because it's very favorable for growing cotton trees. It's very clayey in nature and develops cracks in summers in drought conditions. This crack evolving nature allows self tilling of soil that aerates it naturally.

3.2 Lime

Calcium hydroxide is an inorganic compound with the chemical formula Ca $(OH)_2$. It is a colourless crystal and is produced when quicklime is mixed, or slaked with water. Also called calcium hydroxide and slaked lime, hydrated lime is highly caustic and can burn skin and eyes. Lime used in building materials is broadly classified as "pure", "hydraulic", and "poor" lime; can be *natural* or *artificial*; The Romans used two types of lime mortar to make Roman concrete, which allowed them to revolutionize architecture, sometimes called the Concrete revolution.

3.3 Condor

Condor is a soil stabilizer made from buffered sulphuric acid which is dark brown in colour and is harmful upon contact with body. It enhances the characteristics of the expansive soil. Condor SS brings the clay, present in the soil, to a balanced state. This is referred to as the 'Condor Effect.' The electrical charges in the clay are equally balanced and distributed, eliminating the attraction to water and the problems associated with it, such as, capillary pumping, swelling, contracting, lateral expansion, and poor bearing strength amongst others. Once treated with Condor SS, the clay releases the water. With the absence of this water, the weight of the structure, road or compactor, causes the clay structure to collapse, closing the tiny capillaries, thus providing a much stronger and stable building surface with exceptional bearing capacity.

3.4 TerraZyme

TerraZyme is a natural, non-toxic, liquid enzyme formulation that alters the physical and chemical properties soil. This enzymatic process improves the engineering qualities in the soil facilitating resistance to water absorption. When TerraZyme is added to soil, it catalyzes the breakdown of organic materials and increases the wetting and bonding capacity. It allows soil materials to become more easily wet and more densely compacted. Also, it improved chemical bonding helps to fuse the soil particles together, creating a more permanent structure that is more resistant to weathering, wear and water penetration Road compaction requires less mechanical effort.

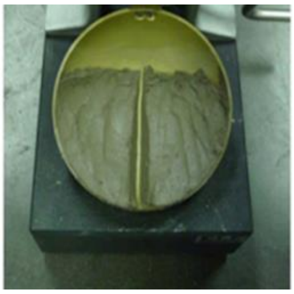
4. TESTS CONDUCTED

4.1 Specific Gravity

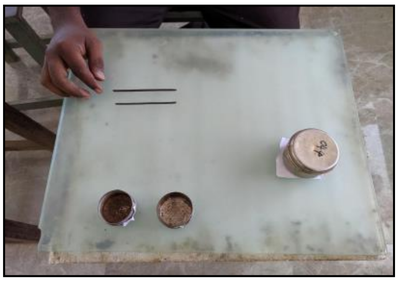
Specific gravity is defined as the ratio of unit weight of soil to the unitweight of distilled water at standard temperature of 27°C.The name specificgravity can cause confusions as soil has got so many different particles and each of it has its own separate gravity measurements. But as such, specific gravity is taken as the average of specific gravity of all the particles present in the soil. The specific gravity of the soil lies in the range of 2.65 and 2.80 with finer particles having greater specific gravities. Specific gravity test can be done by two procedures. One is by density bottle method and the other isby pycnometer. Specific gravity helps engineers to identify the voids present in soil, how porous and saturated the soil is thereby helping them to identify whether the soil will withstand the structure and allow proper drainage.

4.2 Atterberg limits

Liquid limit is the water content at which soil changes from plastic to liquid state, when the soil specimen is just fluid enough for a groove to close when jarred in a specified manner. Water plays a significant important role in triggering landslides and slope failures. Increase of water content reduces the stability of slope. When the moisture content exceeds plastic limit, the slope begins to deform. The theory behind liquid limit is based on Slope stability. This is the main reason why the number of blows keeps decreasing considerably upon increase in water content. From liquid limit test, compression index can be determined which is used in settlement analysis. If the natural moisture content is higher than the liquid limit, the soil can be considered as soft and if the liquid limit is higher than the moisture content then the soil can be considered as brittle and stiffer



Plastic limit The water content at which soil sample change from plastic state to semi-solid state (i.e.) the water content at which soil loses plasticity and starts behaving like a brittle material is known as plastic limit of the soil. Plastic limit value is used to classify fine grained soil and calculate activity of clays and toughness index of soil. Moreover, it also gives us information regarding the state of consistency

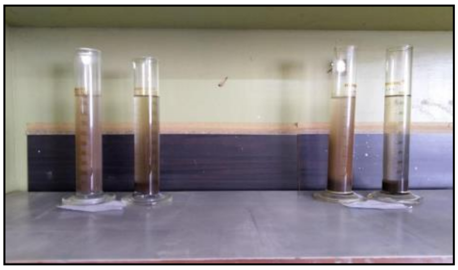


of soil on site. In addition, it also can be used to predict the consolidation properties of soil while calculating allowable bearing capacity and settlement of foundation. Plasticity index plays a crucial role as it is one amongst the two properties on which the study of swelling parameter of soil depends. Plasticity index depends on liquid limit and plastic limit of the soil

Shrinkage Limit of the soil is the water content where furtherloss of moisture will not result in any more volume reduction or in other words the water content of the soil when the water is just sufficient to fill all the pores of the soil and the soil is just saturated. The volume of the soil doesnot decrease when the water content is reduced below the shrinkage limit. The greater the value of shrinkage limit, greater is the ability of soil to withstand without undergoing shrinkage. Upon treatment, the shrinkage limit value of the soil gradually increases indicating that the swelling characteristic of soil has been improved

4.3 Differential swell index

Free swell index is defined as the increase in the volume of soil without applying any external constraints on submergence in water. According to Huang (1987) 'Identification and Classification of soil in China' any soil having free swell index value greater than 40% is termed as expansive soil. So, the major point is to bring the free swell index of the soilto a value less than 40%. Upon treatment, the FSI keeps decreasing initially and after a certain point, the effect will subside and the soil will start to behave as the parent soil itself. This point after which there is no significant change has the possibility of becoming our optimum content of stabilizer to be added to improve the swelling characteristics of so



4.5 Optimum moisture contenet

The Optimum Water Content of soil is the water content at which a maximum dry unit weight can be achieved after a given compaction effort. A max dry unit weight would have no voids in the soil. If you were trying to compact a hard dry soil to make it denser, you might want to get it wet. The Optimum Moisture Content is the water content of the soil in which you could compact it the most. If there is too much water you would have too much pore water pressure during compression to compact any further. If there is too little water the soil would naturally resist compaction via shear strength/friction/effective stress. The determination of the Optimum Moisture Content is important because if tillage is carried out on fields that are wetter or drier than the many problems can be caused, including soil structural damage, through the production of large clods, and an increase in the content of readily dispersible clay which is indicative of the soil stability

4.4 Direct shear

The Direct Shear Test is an experimental procedure conducted in geotechnical engineering practice and research that aims to determine the shear strength of soil materials. Shear strength is defined as the maximum resistance that a material can withstand when subjected to shearing. Generally, the Direct Shear Test is considered one of the most common and simple tests to derive the strength of a soil and can be performed on undisturbed or remoulded samples

4.5 Vane shear

Vane shear test is used to determine the undrained shear strength of soils especially soft clays. This test can be done in laboratory or in the field directly on the ground. Vane shear test gives accurate results for soils of low shear strength (less than 0.3 kg/cm^2). Vane shear test is easyand quick. This test can be performed either in laboratory or in the field directly on the ground. In-situ vane shear test ideal for the determination of undrained shear strength of non-fissured, fully saturated clay. Shear strength of soft clays at greater depths can also be found by vane shear test. Sensitivity of soil can also be determined using vane shear test results of undisturbed and remolded soil samples

4.6 Unconfined Compressive Strength

The unconfined compression test is by far the most popular method of soil shear testing because it is one of the fastest and cheapest methods of measuring shear strength. The method is used primarily for saturated, cohesive soils recovered from thin-walled sampling tubes. The unconfined compression test is inappropriate for dry sands or crumbly clays because the materials would fall apart without some land of lateral confinement. To perform an unconfined compression test, the sample is extruded from the sampling tube. A cylindrical sample of soil is trimmed such that the ends arereasonably smooth and the length-to-diameter ratio is on the order of two. The soil sample is placed in a loading frame on a metal plate; by turning a crank, the operator raises the level of the bottom plate. The top of the soil sample is restrained by the top plate, which is attached to a calibrated proving ring. As the bottom plate is raised, an axial load is applied to the sample. The operator turns the crank at a specified rate so that there is constant strain rate.The load is gradually increased to shear the sample, and readings are taken periodically of the force applied to the sample and the resulting deformation.The loading is continued until the soil develops an obvious shearing plane or the deformations become excessive. The measured data are used to determine the strength of the soil specimen and the stress-strain characteristics. Finally, the sample is oven dried to determine its water content.

5. RESULTS AND DISCUSSION

CHARACTERISATION OF UNTREATED SOIL SAMPLE

S.NO	PROPERTY	VALUE
1.	SPECIFIC GRAVITY	2.65
2.	NATURAL MOISTURE CONTENT	16 %
3.	DIFFERENTIAL FREE SWELLINDEX (DFSI)	70 %
4.	LIQUID LIMIT	60 %
5.	PLASTIC LIMIT	23 %
6.	PLASTICITY INDEX	37 %
7.	SOIL CLASSIFICATION	CH
8.	SHRINKAGE LIMIT	5 %
9.	DIRECT SHEAR TEST	$C=14.5KN/m^2$ $\Phi=13^{\circ}$
10	VANE SHEAR TEST	$S=37KN/M^2$
11	UNCONFINED COMPRESSION TEST	$Q_u=69\ KN/M^2$

CHARACTERIATION OF LIME TREATED SOIL

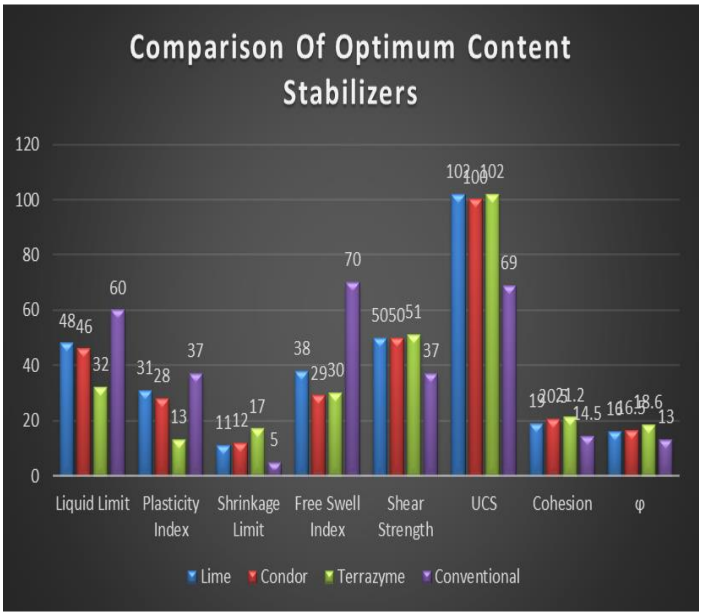
PROPERTY	LIME CONCENTRATION				
	0.01%	0.02 %	0.03%	0.04%	0.05%
LIQUID LIMIT	56%	51%	48%	52%	57%
PLASTIC LIMIT	21%	19%	17%	20%	25%
PLASTICITY INDEX	35 %	32 %	31 %	32 %	32 %
SHRINKGE INDEX	6 %	8 %	11 %	10 %	9 %
DIFFERENTIAL FREE SWELL INDEX	64 %	54 %	38 %	68 %	65 %
DIRECT SHEAR	C=15.3 ASR=14	C=16 ASR = 15	C=17 ASR=16	C=18.9 ASR=17	C=19 ASR=18
VANE SHEAR	37.5	38.6	39	41	42.3
UNCONFINED COMPRESSIVE STRENGTH	70	73	85	97	102

CHARACTERISATION OF CONDOR TREATED SOIL

PROPERTY	LIME CONCENTRATION				
	0.01%	**0.02%**	**0.03%**	**0.04%**	**0.05%**
LIQUID LIMIT	53 %	51 %	46 %	50 %	53 %
PLASTIC LIMIT	22 %	20 %	18 %	23 %	25 %
PLASTICITY INDEX	31 %	31 %	28 %	27 %	29 %
SHRINKGE INDEX	6 %	9 %	12 %	10 %	9 %
DIFFERENTIAL FREE SWELL INDEX	68 %	54 %	29 %	65 %	73 %
DIRECT SHEAR	C=16.2 ASR=16.5	C=16.5 ASR=17.3	C=17.8 ASR=16.5	C=18.6 ASR=18.2	C=20.5ASR=16.5
VANE SHEAR	38	38.5	39.2	40.2	42.3
UNCONFINED COMPRESSIVE STRENGTH	72	75	87	99	100

CHARACTERISATION OF TERRAZYME TREATED SOIL

PROPERTY	TERRAZYME CONCENTRATION				
	0.01%	0.02%	0.03%	0.04%	0.05%
LIQUID LIMIT	47	53	32	41	48
PLASTIC LIMIT	22	20	19	24	26
PLASTICITY INDEX	25	23	13	17	22
SHRINKAGE INDEX	9	10	17	15	12
DIFFERENTIAL FREE SWELL INDEX	59%	44 %	30 %	64 %	73 %
DIRECT SHEAR	C=16.2 ASR=17.6	C=18.2 ASR=15.6	C=18.9 ASR=18.6	C=19.9 14.3	C=21.2 ASR 14.5
VANE SHEAR	38.5	38.9	40.2	41	51
UNCONFINED COMPRESSIVE STRENGTH	75	78	89	99	102



6. CONCLUSIONS

[1] Liquid limit and plasticity index are the two major factors which influence the swelling properties of soil. Based on these results, the degree of swelling is Low for TerraZyme when compared to critically high untreated black cotton soil.

[2] Based on the results obtained from shrinkage limit test, the degree of swelling is medium for

TerraZyme indicating that TerraZyme works better for critically high swelling soil.

[3] Based on the results obtained from various shear tests per- formed, the shear strength shows a great increase for Terra- Zyme as compared to Condor and Lime.

[4] Taking the afore-mentioned significant factors into consideration in determining the swelling parameters and shear strength parameters, TerraZyme works efficiently on black cotton soil compared to Lime and Condor.

[5] Our project will be further continued for research work, by testing the soil for 7,14,28 days post stabilization and also Field testing post stabilization.

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