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Chemical Stabilization of Black Cotton Soil

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Abstract: *This research work presented the efficiency of a nano technology based chemical named Terrasil as a modifier in improving the engineering properties of Black Cotton Soil. It discussed general details, methodology, theory, and experiments etc. involved in the project. In India about 51.8 million hectares of the land area are covered with Expansive soils (Black Cotton Soil). The Black Cotton Soils are very hard when dry, but lose its strength completely when in wet condition. Expansive soils are a worldwide problem that possess several challenges for Civil Engineers. Various methods are adopted to improve the engineering characteristics of expansive soils. The problematic soils are either removed and replaced by good and better quality material or treated using additive. By studying the literature on black cotton soil. The effectiveness of Terrasil is tested by conducting various test like UCS, proctor test etc. on Black Cotton Soil samples treated with different percentages of Terrasil 0.9%,1.1%&1.3%. It was found that compressive strength of soil treated by Terrasil increased to 40% approximately. Terrasil had a great influence on swelling behaviour of Black Cotton Soil. It reduced the free swell index from 59% to 33%. Terrasil provide to a worthwhile as a versatile stabilizer in case of expansive soil as it enhances almost all important geotechnical properties of Black Cotton Soil.*

Keywords: Black Cotton Soil

I. INTRODUCTION

Black cotton soil is spread in various part of world including India and has highly expansive nature due to the presence of montmorillonite clay mineral. The presence of montmorillonite in Black Cotton soil imparts high moisture content, low shrinkage limit & high optimum moisture content to it, thus these soil get very hard when dry but lose strength completely when gets wet. Soil stabilization is the alteration of properties of a soil to improve its response to engineering problems, like improvement in bearing capacity, stability, shear strength, swelling characteristics, shrinkage property. There are various forms of soil stabilization, commonly the conventional soil stabilization are achieved by chemical and mechanical stabilization techniques. The additives used for stabilization are termed as stabilizers. Many stabilizers such as fly ash, bitumen, lime, cement, and various chemicals are used for stabilization. A number of researchers have worked in improving the properties of soil for various engineering application which are practical and economical. B M Lekha and S Goutham (2013): conducted experimental investigation on black cotton soil and soil treated with nano chemical called terrasil. It was found that with addition of chemical the consistency limit got improved, the LL got increased and also there is decrease in PI values. The best result were obtained for dosage 1.2% terrasil by weight of soil. Also permeability of soil is found to be nil for treated soil thus making soil impermeable completely. Rintu Johnson (2015): studied the stabilization of Black Cotton soil with using terrasil and found that with increase in dosage of terrasil added into the clay soil up to 0.07% weight of soil causes the plasticity index reduces from 41% to 18%. Also there is drastic decrease in permeability due to increased dosage of terrasil into the soil. Nandan A. Patel (2015): investigated performance of CL soil and CL soil treated with 0.041% terrasil in his work. Based on the tests conducted in the laboratory, he found that the liquid limit and plastic limit of the soils decrease with the addition of 0.041% terrasil in soil. FSI value of treated soil reduces because the film of adsorbed water is greatly reduced for treated soil and the surface area reduces, resulting in decreased swelling capacity. Terrasil is a nano-chemical and is emerging as a new material for the stabilization of soil. In the present work terrasil and lime are used as admixtures. Experimental work has been carried out with 0.03, 0.05, 0.07 and 0.09% of terrasil with lime as base additive (=2% by weight of dry soil) and are tests for Liquid limit, Plastic limit, Plasticity Index and DFS test.

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FIGURE NO 1.2: BLACK COTTON SOIL

Black Cotton Soil

Expansive soils are those soils, which have a tendency to shrink and swell with the variation in moisture content. In India predominantly Black Cotton soil found in Deccan trap region of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka and Tamilnadu, Black cotton soils are also found in river valley of Godavari, Tapi, Narmada, and Krishna. The depth of black soil is very large in the north western part of Deccan Plateau and upper parts of Krishna and Godavan. Basically these soils are volcanic in origin and residual which left at the place of their formation after chemical decomposition of the rocks such as basalt and trap. These soils are rich in magnesia, lime, iron and alumina but lack in the nitrogen, phosphorus and organic matter.

Their colour varies from brown to black, and basically consists of high percentage of clay sized particles. About 20% of the total land area of our country is covered with expansive soils. Because of their moisture retentiveness, these soils are suitable for dry farming and are suitable for growing wheat, cottons, rice, jowar, cereals, vegetables, tobacco, sugarcane, citrus fruits and oilseeds.

During monsoon's, these soils absorb water, swell, become soft and their capacity to bear water is reduced, while in drier seasons, these soils shrinks and become harder due to evaporation of water. These types of soils are mainly available in arid regions of the world. Black cotton soil shows the property of high plasticity and water receptivity which makes it highly problematic due to a clay mineral called montmorillonite. More the soil will absorb the water more will be the volume change. Black cotton soil are considered as a potentially hazardous soil which if not treated well can cause extensive damages to not only to the structures built upon them but also can cause loss of human life. India is among those countries that competing in the race of globalization for the development of

Therefore stability of highway and structures became a national interest. Due to this volume changes severe distresses and excessive settlement will takes place in the structure which is very dangerous. About 100 million in the U.K., $ 1,000 million in the U.S. and billions of dollars worldwide are estimated to spend on rehabilitation of civil engineering structures that are damaged due to erratic property of Black Cotton soil. During the last few decades, damage due to swelling action has been clearly observed in the semi-arid regions in the form of cracking and breakup of pavements, roadways, building foundations, slab-on-grade members, channel and reservoir linings, irrigation systems, water lines, and sewer lines.

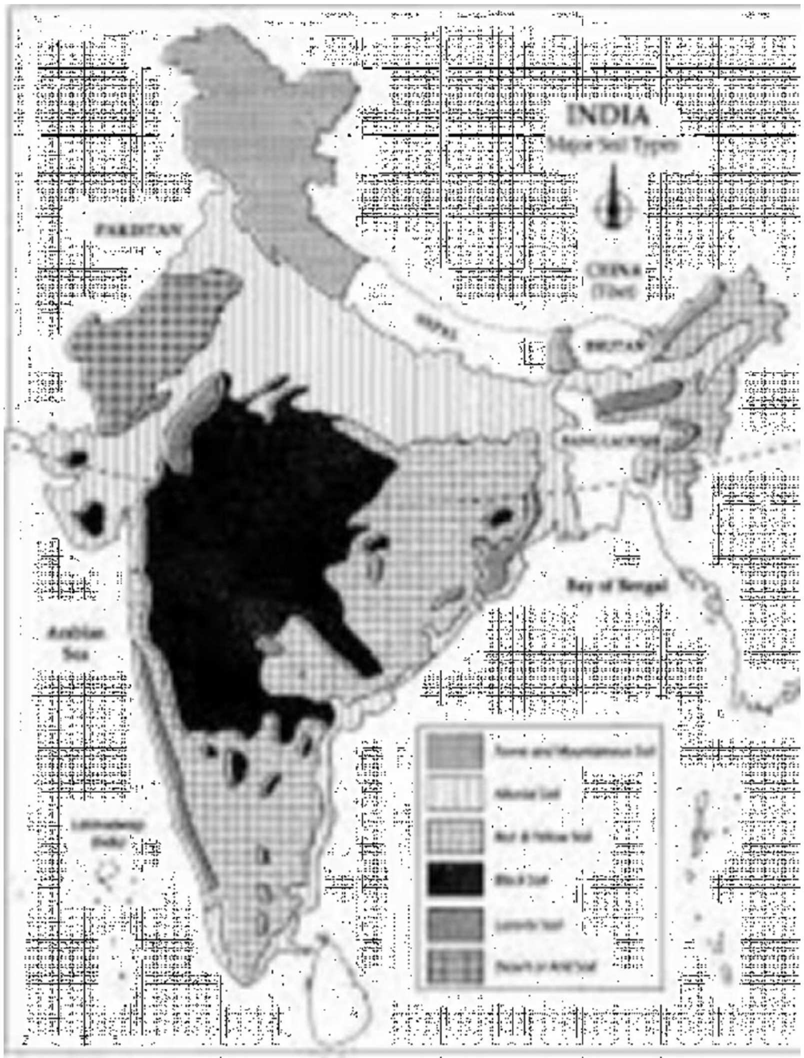

FIGURE 1.1 MAJOR SOIL TYPES IN INDIA

1.2 Soil Stabilization

It refers to various process or methods which improves the load carrying capacity of soil. Soil stabilization involves changes in properties like strength, density, swelling behaviour etc. By means of soil stabilization techniques, strength characteristics of poor soil like Black Cotton soil can be improved. Such techniques are very economical which reduces overall cost of a project.

1.2.1 Methods of Soil Stabilization

It may be grouped under two main types:

1. Modification of soil property of existing soil without using any admixtures c.g. compaction and drainage.
2. Modification of properties of soil using admixtures eg. soil stabilization with cement lime, bitumen, chemicals etc., and mechanical stabilization. 3. The choice of a particular soil stabilization techniques depends on many factors like nature and type of soil, type and importance of project and economy of project.

1.2.2 Chemical Stabilization

There are various chemicals is being used worldwide for stabilization of soil. One such stabilizer is used in this study to determine the changes in properties of parent soil. The advantage of chemical stabilization over other stabilization is setting and curing time can be controlled. However it may be proves sometimes expensive than other methods ofstabilization. Some common stabilizer are like calcium chloride, sodium chloride odium silicate etc.

1.3 Need of present study

Urbanization and development in the India have led to the a great increase in the construction activities and has necessitated the implementation of infrastructure projects such as highways, railways, air strips, water tanks, reclamation etc. These projects required a good quality earth in massive quantity. In urban areas, borrow earth is not easily available which has to be hauled from a long distance. Quite often, large areas are covered with highly plastic and expansive soil, which is not suitable for such purpose. In India about 51.8 million hectares of the land area are covered with Expansive soils. The Black cotton soils are very hard when dry, but lose its strength completely when in wet condition. Expansive soils area worldwide problem that poses several challenges for civil Engineers. Various methods are adapted to improve the engineering characteristics of expansive soils. The problematic soils are either removed and replaced by good and better quality material or treated using additive.

The stabilization of the problematic soils is very important for many of the geotechnical engineering application such as pavement structures, roadways, building foundations, channel and reservoir linings, irrigation systems, water lines, and sewer lines to avoid damage due to settlement of soft soil or to the swelling action of expansive soil. In the present investigation behaviour of black cotton soil with and without stabilization has been studied.

1.4 Scope

Determination of index properties of black cotton soil before and after addition of Terrasil.

1. Evaluation of maximum proctor density and OMC of Terrasil treated soil different dosages of Terrasil.
2. Evaluation of unconfined compression test of soil treated with Terrasil at different percentages of stabilizer.
3. Evaluation of free swell index of soil treated with Terrasil at different percentages of stabilizer.

II. LITERATURE REVIEW

Stabilization is one of the economical methods of treating the Black cotton soil to make mem suitable for construction. Generally stabilizers can be divided into three groups

Traditional stabilizers (cement, binmen etc.)

Waste products stabilizers (ty ash, phosphor-gypsum, etc.)

Chemical stabilizers (potassium compounds, polymer, ammonium chlorides etc.). Generally the rate of development of strength is higher in chemicals as compared to other two group of stabilizers. Some of the research work conducted by carbon researchers on the above has been described below

Shreyas.K(2016) is Currently working in the Dept of Civil engineering Don Bosco Institute of Technology Bangalore. Due to the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa, black cotton soil also facilitates compaction for obtaining the desired density with comparatively less effort. The characteristics of Black Cotton Soil is which it forms a very poor foundation material for road construction & also possess low strength with excessive volume changes. The properties of the black cotton soil may be altered in many ways viz, mechanical thermal, chemical and other means stabilisation, it is very important to investigate the physical and engineering properties associated with the black cotton soil. In the present study black cotton soil specimens are derived from depth of 1 to 1.5 m were studied in the laboratory for investigation of physical and engineering properties. Various tests like grain size analysis, specific gravity, atterberg's limits, standard proctor compaction, consolidation and direct shear test were conducted on the soil specimens as per the Indian Standard Codes [1]. The black cotton soil found in semi – arid regions of tropical and temperate climate zones will be having high evaporation percentage when compared to precipitation. The sticky plastic nature of black cotton soils particles will make the soil extremely difficult to extract or dislodge & the cracks measuring 70 mm wide and over 1 m deep were observed in the study also it has shown that these cracks can extend up to 3m or more in case of high deposits [2]. The effect of lime in addition with black cotton soil in an incremental manner up to 6% to a high expansive BC soil used in the laboratory for investigation in the prevailing conditions (temperature and humidity) which will enhance the strength, penetration resistance and reduce swelling & shrinkage behaviour. Quick lime can be successfully used for treatment of BC Soil, which is a cost effective when compared to other admixtures such as cement and asphalt which will provide long life to the structures with least maintenance. If the soil is non-plastic and is having low plasticity index, lime alone is not satisfactory for stabilization but an addition of fly ash is needed to improvise the necessary changes in the soil [3]. Quantity of lime is varied from 2% to 4% of BC soil to observe the corresponding physical & engineering changes in the properties of soil. The value of MDD increases with increase in percentage of lime whereas OMC decreases and Swelling pressure is lowered by 29% at 4% lime & also there is considerable reduction in compressibility value of the soil which is stabilised by fly ash [4]. The property of black cotton soil can be effectively improved by using varying percentage of lime contents from 3% to 5%. By the experimental analysis in the laboratory it was observed that on an addition of 3% of lime to the BC soil there is a considerable decreases the liquid limit by 2.70% while with 5% addition of lime reflects a decrease 15.27% also there is an increase in MDD by 6.29% and 5.59% at 3% and 5% lime content respectively. The C.B.R. values of black cotton soil is improved considerably to 3.25 times and 4.76 times with the addition of 3% and 5% lime to the BC soil respectively [5]. The Liquid Limit of black cotton Soil continuously decreases with increase in percentage of lime content and Electric arc furnace (EAF) dust content, Plasticity index of black cotton soil will also decrease with increase in EAF dust & lime fine content. Optimum moisture content increases with decrease in dry density for an increase in lime content in the soil. Whereas the Optimum moisture content decreases with increase in MDD for an 1148 | P a g e increase in EAF dust content. Unconfined compressive strength value of black cotton soil increases with increase in EAF dust content up to 6% of lime and then it decreases with increase in EAF dust content also the unconfined compressive strength value of black cotton soil increases with increase in curing period for the BC soil. Higher CBR value leads to lower total pavement thickness of flexible pavements which is economical for overall project as the materials required for construction is reduced [6].

With the presence of clayey content in soil & by conducting physical property tests there is an increase in the plasticity index by classifying the Soil specimens as A, B and C which retains almost same percentage of clay particles and have medium range of plastic indices. Whereas Liquid limit, Plastic limit, Specific Gravity and Dry Density of soil specimen A was found to be higher than the soil specimen B and C. The value of value of angle of internal friction of soil specimen C was observed to be higher than soil specimens B and A. Predicted values of the parameters viz. Plasticity index (PI), Optimum Moisture Content (OMC), Compression Index (Cc) and Angle of Internal Friction (ϕ) for the soil specimens A, B and C from empirical models derived through regression analysis were observed to be very close to the experimental values. With the increase in the plasticity index induces decrease in the angle of internal friction and the compaction Characteristics were observed to be fair for black cotton soils [8]. The liquid limit can be considered as the measure of quantity of water attracted by soil particles for a given value of shear strength thus making it possible to correlate with compressibility. The black cotton soil is very hard when it is dry but loses its strength completely in wet condition. Studies has shown that 40 to 60% of black cotton soil will have its particle size less than 0.001 mm

MIX DESIGN

The properties of natural black cotton soil (passing through 425µ IS sieve) are determined & then the soil is stabilized with M-sand (Particle size <4.75mm) by varying the proportions of Fly ash (passing through 75µ IS sieve) and cement (passing through 75µ IS sieve). The initial amount of sand for stabilization is taken in the proportion of 10% & 20% by dry weight of soil and the amount of cement was taken as 2% by dry weight of soil, further 2% cement is replaced with 5% & 8% of fly ash by its varying proportions . The proportions of mix samples were prepared and a set of laboratory tests were performed to determine the index properties with CBR values. The varying proportions of admixtures in BC soil is listed below: 1. Black cotton soil. 2. BC-Soil +10% M-Sand +2% Cement. 3. BC-Soil +20% M-Sand +2% Cement 4. BC-Soil +20% M-Sand +5%flyash. 5.BC-soil+20%M-sand +8% flyash.

JAYA PRAKASH REDDY1,S.AANDAVAN2(2015) Rich proportion of montmorillonite is found in Black cotton soil from mineralogical analysis. High share of montomoriillonite renders high degree of expansiveness. These property results cracks in soil with none warning. These cracks might generally extent to severe limit like ½" wide and 12" deep. thus building to be founded on this soil may suffer severe damage with the change of atmospheric conditions. As malleability index and

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linear shrinkage minimized with the rise of lime content, a mix of each lime and cement is critical for adequate stabilization of road bases for serious wheel masses on the black cotton soils. accidently derived results from African and Indian black cotton soils are matched with these results.

7.2.2 Structure We have already noticed that of black cotton soil of different region show considerable variation of properties.so while explaining any property, we will try to mention region where the tests were conducted. 7.1.3 Infiltration rate Black cotton soil shows high bulk density in dry condition and low worth at swollen stage. counting on wet condition bulk density of those soils is also (1~2) gm/cm3. Black cotton soil of yankee origin have bulk density starting from (1.81~2.08) gm/cm3. once more some researchers suggested to correct bulk density of black cotton soil for explicit wet content [25% w/w]. It facilitates to scale back errors ascertained attributable to initial wet content in these soils. Following table helps U.S.A. to comprehend this truth.

7.1.4 Adsorption We know water molecule behaves as electrical dipoles, of that charge is placed close to atoms 2 element and have electric charge close to gas atom. this permits water molecules to interact/attract neighbour charged particles.

7.1.5 Shrinkage Black cotton soil is sometimes glorious a pricy soil; however the mass that expand underneath wetting can shrink when drying. The shrinkage method typically related to cracking. The shrinkage method typically related to cracking. once structural issue cares shrinkage is a lot of damaging than swelling. Swelling method affects to lighter building than heavier one. As vertical growth is also lessened by mass of structure. however shrinkage is harmful to any or all style of structures and careful style and generally limitation of loading is also required to be obligatory. looking on moisture- volume relation, 3 stages shrinkage are outlined (Ritchie , 1980); these are: a. Structural shrinkage; in this stage water is lost due to air drying from large pores in soil i.e. no volume change is occurred. b. Normal shrinkage, this shrinkage facilitates us to determine COLE (coefficient of linear expansion). Water is lost due to matric potentials of (-0.3~ -15) bars
c. Residual shrinkage, admittance shrinkage potential conjointly accountable for this shrinkage however vary is -15 bars to -20 bars. Water is lost from crystal of montmorillonite. No important amendment in volume is occurred as air fills inter-crystalline areas. d. That is, initial and last stage of wet loss doesn't contribute to important volume amendment. different structural volume changes in these soils are slickensides, glasses etc.

8. METHODOLOGY The following laboratory tests have been carried out according to the specification of IS: 2720. 8.1 Moisture content test 8.2 Specific gravity test 8.3 Particle size distribution 8.4 Liquid limit test 8.5 Plastic limit test 8.6 Shrinkage limit test
8.7 Compaction test 8.8 Unconfined compression test 8.1 MOISTURE CONTENT TEST Definition: Moisture content is the ratio of the mass of water in a sample to the mass of solids in the sample, expressed as a percentage. Procedure: 8.1.1 The number of the container is recorded, cleaned, dried and weighed. (W1) 8.1.2 About 15-30 g of soil is placed in the container and the weight of soil with the sample is recorded.(W2) 8.1.3 The can with the soil is placed in oven for 24hours maintained at a temperature 1050 to 1100C. 8.1.4 After drying the container is removed from the oven and allowed to cool at room temperature. 8.1.5 After cooling the soil with container is weighed. (W3). Calculation: water content = $(W2 - W3)$ $(W3 - W1) * 100\%$ W1=Mass of container, g W2=Mass of container and wet soil, g W3=Mass of container and dry soil, g Definition: It is defined as the ratio of the unit weight of substance to that of water at constant temperature. Procedure: 8.2.1 Clean and dry the pycnometer bottle. 8.2.2Weigh the empty bottle with its cone tightly screwed on (W1). 8.2.3 Take about 200g of oven soil sample which is cooled in a desiccators. Transfer it to the bottle. Find the weight of the pycnometer bottle and soil (W2). 8.2.4 Fill the bottle completely with distilled water, place the cone and screw it and keep the bottle under constant temperature water baths.
8.2.5 Take the pycnometer bottle and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W3). 8.2.6 Now empty the pycnometer bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let the weight be W4.10.

B. MIX PROPORTION: 10.1 Black cotton soil with a varying percentage of lime stone powder: a. BC SOIL +5% LIME b. BC SOIL +10% LIME c. BC SOIL +15% LIME

Shailendra Singh1 , Hemant B. Vasaikar2 In India Black Cotton soil also known as Regurs" are found in extensive regions of Deccan Trap. They have variable thickness and are underlain by sticky material locally known as “Kali Mitti”. In terms of geotechnical Engineering, Black Cotton soil is one which when associated with as engineering structure and in presence of water will show a tendency to swell or shrink causing the structure to experience moments which are largely unrelated to the direct effect of loading by the structure. Black cotton soil is not suitable for the construction work on account of its volumetric changes. It swells and shrinks excessively with change of water content. Such tendency of soil is due to the presence of fine clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place, so the stabilization is being done for the Stabilization of black cotton soil has been done in this project work by using lime as an admixture. Problem Associated with B. C. Soil Black Cotton soils are problematic for engineers everywhere in the world, and more so in tropical countries like India because of wide temperature variations and because of distinct dry and wet seasons, leading to wide variations in moisture content of soils. The following problems generally occur in black cotton soil

III. METHODOLOGY

High Compressibility Black Cotton soils are highly plastic and compressible, when they are saturated. Footing, resting on such soils under goes consolidation settlements of high magnitude.

Swelling A structure built in a dry season, when the natural water content is low shows differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restriction on having developed swelling pressures making the structure suitable.

Shrinkage A structure built at the end of the wet season when the natural water content is high, shows settlement and shrinkage cracks during subsequent dry season. 6. Engineering Properties of B. C. Soil 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. Stabilization Lime stabilization helps in increasing the strength, durability and also minimizes the moisture variations in the soil and lime must be well compacted for obtaining sufficient strength and durability by maintaining OMC and the same assumption is made in the experimental determination of the required lime proportion. Quality of lime to be added depends upon the specific surface area of soil particles and it is more for fine grained soils even up to 15 % by weight of soil. The stabilization of black cotton soil with lime has been done in three different ratios of lime i.e. 0%, 4% and 6%. After the stabilization of soil with lime in above percentage the various tests have been performed –

Plasticity Index The plasticity index of a soil is the numerical difference between its liquid limit and its plastic limit, and is a dimensionless number. Both the liquid and plastic limits are moisture contents. Calculation: Plasticity Index = Liquid Limit – Plastic Limit PI = LL – PL

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. w s G The range of specific gravity of coal ashes varies from 1.46 to 2.66 the low values of specific gravity is because of hollow particles chemosphere the sp. Gr. Of soil solids is determined by – 1. 50 ml density bottle or 2. A 500 ml flask or 3. A pycnometer The density bottle method is most accurate and is suitable for all types of soil the flask or pycnometer method is suitable for coarse grained soil.

Brajesh Mishra (2014) Black cotton soil in India Almost 20% area of is occupied by black cotton soil. These soil are predominant in states of Andhra Pradesh, Western Madhya Pradesh, Gujrat, Maharashtra, Northern Karnataka, Tamil Nadu and some parts of Southern Uttar Pradesh (Bundelkhand area). They are mostly clay soils and form deep cracks during dry season. They are popularly known as “Black Cotton Soils” because of their dark brown color and suitability for growing cotton. They are black due to compounds of iron and aluminum. These soils are deficient in nitrogen, phosphoric acid and organic matter but rich in calcium potash and magnesium.

Characteristics of Black cotton soil Black cotton soil are generally reddish brown to black in color. They occur 0.50m to 10 m deep possessing high compressibility. Common characteristics are listed in table-1 below

Problem Associated with B. C. Soil Due to their peculiar nature Black Cotton soils are challenge for engineers everywhere in the world, and more so in tropical countries like India because of wide variation in temperature and because of distinct dry and wet seasons, leading to wide variations in moisture content of soils. The following problems generally occur in black cotton soil –

High Compressibility: Black Cotton soils are highly plastic and compressible, when they are saturated. Footing, resting on such soils under goes consolidation settlements of high magnitude. Swelling: A structure built in a dry season, when the natural water content is low shows differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restriction on having developed swelling pressures making the structure suitable. Shrinkage: A structure built at the end of the wet season when the natural water content is high, shows settlement and shrinkage cracks during subsequent dry season.

Engineering Properties of B. C. Soil 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. 2.6. Index Properties of B. C. Soil 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.

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. The range of specific gravity of coal ashes varies from 1.46 to 2.66 the low values of specific gravity is because of hollow particles chemosphere the sp. Gr. Of soil solids is determined by – 1. 50 ml density bottle or 2. A 500 ml flask or 3. A pycnometer The density bottle method is most accurate and is suitable for all types of soil the flask or pycnometer method is suitable for coarse grained soil.

Atterberg's Limit: 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.

Zihong Yin 1 , Raymond Leiren Lekalpure 1, and Kevin Maraka Ndiema etal.(2016) The construction of new railways, highways and rural roads has rapidly developed in Kenya [1,2]. This development has led to heavy construction of infrastructure projects, which has increasingly faced engineering difficulties due to black cotton soil [3]. Expansive soils form a significant percentage of soils in Kenya [4]. The depth of BCS in Kenya ranges from 0.2 to 0.3 m [5]. BCS is characterized by high swell potential, low shear, low bearing capacity, and excessive compression and dispersion [6]. Clay minerals including chlorite, vermiculite, illite and montmorillonites were found to be abundant in BCS [7]. The high content of clays minerals is the cause of high expansion in BCS [8].

BCS forms deep cracks in dry seasons and expands in wet seasons; these changes, shrinking and swelling, cause road deformation [9]. Therefore, untreated BCS does not meet the material requirements for the placement of subgrade soil and must be cut and filled with suitable material. Various methods of dealing with BCS in Kenya include excavation and replacement with suitable material, stabilization with Portland cement, confining BCS under improved subgrade by using a 300 mm capping layer or entire re- alignment of the proposed road corridor to avoid BCS areas [5]. However, substantial use of these methods dramatically increases construction budgets. Thus, it is vital to find a readily available local replacement material to deal with BCS. Mixing the materials with inherent binder properties with unstable soils to increase the engineering characteristics of such soils is referred to as soil stabilization. Stabilization greatly reduces the plasticity and swelling potential of BCS, which improves its strength and durability [10–12]. Admixtures with, e.g., Portland cement, rice husk ash, hydrated lime and cement kiln dust have been utilized as stabilizers [13–16]. Other methods include the use of bagasse ash [17]. Al-Mukhtar et al. [18,19] studied lime–soil reactions for both short and long term durations, and Al-Rawas [19] researched the effects of lime and artificial pozzolana on black cotton soil by use of Atterberg limits, swell potential, swell pressure, CBR and unconfined compression tests (UCS). They found that lime and artificial pozzolana greatly improve the engineering characteristics of BCS. F Sitepu et al.

[20] investigated the engineering characteristics of VA stabilized BCS by means of the Atterberg limit, CBR and UCS and found that VA increased UCS and CBR, and decreased the liquid limit (LL) and plasticity index (PI), but not significantly. A combination of lime and VA presented a better improvement. Karatai et al. [3] studied the influence of rice husk ash in the treatment of BCS and found that the addition of 20% rice husk ash with 2% lime increases BCS CBR by 800%, decreases soil plasticity by 90% and decreases free swell by 70%. However, rice husk ash is limited only to rice-growing areas. Volcanic ash (VA), which forms due to volcanic activity, is abundantly found in Kenya [21]. It is rich in minerals, volcanic fragments and rocks and can be used to stabilize BCS. The pozzolanic properties of VA enables it to bind with BCS clay particles and reduce clay swelling. Thus, VA-stabilized BCS decreases the expansive potential and the PI, and increases durability and strength [22]. The utilization of VA as a BCS stabilization agent is limited in Kenya. Zhang et al. [7] studied a combination of VA and BCS for use in the production of hollow clay bricks and found that the bricks exhibit an excellent compressive strength of more than 60 Mpa. This paper was written to establish the viability of the use of VA found in Kenya to stabilize BCS. The effects of natural pozzolana and natural lime on the plasticity, swell and strength of stabilized BCS were investigated. 2. Materials The materials used in these experiments included Black Cotton Soils, Volcanic Ash soils and Natural lime. 2.1. Black Cotton Soils (BCS) The BCS used in this study was obtained at Km 20 + 080 along Kapsokwony-KopsiroNamwela road, 20 Km from Kimilili town in Western Kenya. Figure 1 presents a sample of BCS used in this study. Chemical and engineering properties, in terms of Atterberg limits based on BS 1377: Part 2:1990 [23], are presented in Tables 1 and 2, respectively. With a CBR value of 1.7, a liquid and plastic limit of 70.7 and 35.7, respectively, and a plasticity index of 35, the obtained soil is classified as black cotton soil according to the Ministry of Public Works Kenya: Road material design manual [5]. Figure 2 illustrates the particle size distribution curve of the obtained BCS

2.2. Volcanic Ash The natural volcanic ash (VA) sample used in this study was obtained at the floor of the Great Rift Valley near Ewaso Kendong town situated between Mt. Suswa and Mt. Longonot, 65 km Northwest of Nairobi. The sample was scooped 0.2 m below the topsoil. Figure 3 shows VA sample used in this study. The VA's chemical properties .

2.3. Hydrated Lime Hydrated lime was procured from a local store near the laboratory. 3. Methods 3.1. Combination Scheme and Sample Preparation Volcanic ash (VA) and black cotton soil (BCS) were air-dried and grounded to pass through 0.75 and 0.5 mm sieving openings. Both VA and BCS were oven-dried for 24 h at 105 ◦C temperature. The samples were then weighed and thoroughly mixed with different lime, VA and BCS combination dosages, after which they were ready for testing. The design scheme for BCS stabilization is presented in Table 3. 3.2. Engineering Properties Measurements The engineering characteristics of black cotton soil stabilized with volcanic ash and lime were assessed in this study, including a determination of the Atterberg limits, in addition to the swell potential proctor test and CBR. 3.3. Assessment of Plasticity The plastic limit (PL) was measured per British Standard 1377-Part 2:1990 [23]. Samples of BCS and BCS with various mixtures passing through a 0.425 mm sieve were air-dried, mixed thoroughly with distilled water, and soaked for 24 h. PL is the moisture content at which a molded soil sample loop breaks when its diameter nears around 3 mm.

The liquid limit (LL) is defined as the water content that changes soil from plastic state to liquid state. The Casagrande apparatus was used to determine LL as per the British Standard 1377-Part 2:1990 [23]. Samples were prepared by passing through a 0.425 mm sieve, oven-dried, mixed thoroughly with distilled water and soaked for 24 h. The soil water content at which 25 blows caused 13 mm closure of the groove at the top of the cub was used as the soil LL. The plasticity index is the difference of the liquid limit and the plastic limit: Plasticity Index (PI) = LL − PL (6) 3.4. Assessment of Soil Compaction Characteristics A proctor test was conducted to determine the maximum dry density (MDD) and optimum moisture content

(OMC) as per AASHTO T180:2011 [25]. Black cotton soil (BCS) and BCS specimens with various additives were thoroughly mixed and stored for 24 h. A compaction test was performed for all 15 specimens to determine the MDD and OMC. 3.5. Assessment of Soil Bearing Strength The California bearing ratio (CBR) was measured per the American Standard ASSHTO: T193:2003 [26]. Specimens were prepared at the OMC and MDD and stored for 24 h. Samples were compacted into three layers of CBR molds. A 2.5 kg rammer was used to apply 30 blows in every layer. After soaking for 7 days, a penetration test was conducted with a 1935 mm2 area plunger at a 1.27 mm/min penetration rate. Values corresponding to 2.5 mm penetration were computed and recorded as the sample's CBR values. 3.6. Assessment of Swelling Soil Characteristics Swell percent was determined using the same CBR apparatus as per ASSHTO: T193:2003 the soaked specimen fitted with a CBR swell tripod. The initial gauge reading was recorded as (R1) mm; the final gauge reading was recorded as (R2) mm after 7 days of soaking. The swell percent was calculated as follows: Swell = (R1 − R2) 116.4 × 100% (7) where 116.4 mm is the height of the specimen,further drops in density with the addition of lime can be attributed to the replacement of soil particles with lime particles of comparatively low specific value.

In the MDD increased while the OMC decreased with the addition of volcanic Ash (VA) from 0% to 25%. Hossain et al. [22] similarly observed the same behavior. According to their explanation, an increase in MDD with the gradual addition of VA is attributed to VA's lower affinity for water. Increased MDD is an indication of improved soil strength characteristics. BCS 1L15VA 1L20VA 3L15VA 3L20VA 4L15VA 4L20VA20 24 28 32

36 Moisture content (%) Mix designation(%) Plasticity IndexFigure 5. Effects of (a) lime and VA and (b) Lime–VA combined stabilizer on the plasticity of BCS. Figure 5b presents the effect of lime, VA and their mixtures on the plasticity index of natural BCS. BCS mixed with 4% lime, 25% VA, and a mixture of 4% lime + 20% VA decreased the plasticity index from 35% to 21%, 26% and 21%, respectively. According to the Ministry of Public Works Kenya: Road material design manual [5], the plasticity index of subgrade layer material should not exceed 50%. The sampled BCS used in this study satisfies the code plasticity index requirement but does not meet the swell and CBR requirements. BCS stabilized with 3% lime + 20% VA reduced the PI by 1.2 times, to 24.9%. 4.2. Effects of Stabilizers on Compaction Characteristics Figure 6 presents the influence of lime and volcanic ash (VA) on the optimum moisture content (OMC) and maximum dry density (MDD) of black cotton soil (BCS). As observed in Figure 6a, the addition of lime caused a gradual decrease in the MDD and a nearly linear increase in the OMC. Similar behavior was observed by other researchers [3,21]. The immediate decrease in MDD due to the addition of lime can result from particles' aggregation caused by lime. These particles occupy larger spaces and affect soil grading; further drops in density with the addition of lime can be attributed to the replacement of soil particles with lime particles of comparatively low specific value. In Figure 6b, the MDD increased while the OMC decreased with the addition of volcanic Ash (VA) from 0% to 25%. Hossain et al. [22] similarly observed the same behavior. According to their explanation, an increase in MDD with the gradual addition of VA is attributed to VA's lower affinity for water. Increased MDD is an indication of improved soil strength characteristics.

4.3. Effects of Volcanic Ash and Hydrated Lime on the California Bearing Ratio and Expansion Ratio The CBR and expansion ratio of treated black cotton soil after 7 days of soaking are presented in Figure 7. The lime-stabilized BCS CBR values increased with the increasing of the lime content from 1% to 4%. The CBR values increased from 1.7% to 19%. The expansion ratio of lime-stabilized BCS decreased from 4% to 0.4%, with 4% lime. This behavior is attributed to cation and pozzolanic reactions between BCS and lime. The CBR values of the Volcanic Ash (VA)-stabilized soils increased from 1.7% to 7% with 25% VA. According to the Ministry of Public Works Kenya: Road material design manual, a minimum of 8% CBR is required for the class 2 (S2) subgrade. Subgrade class S2 has a CBR range of (5–10) with a medium of 7.5. The code recommends that subgrade soils with this range of CBR be further treated with cement. Table 5 presents the subgrade soil classification in Kenya. Thus, BCS stabilized with VA alone is not sufficient to lay a subgrade. The expansion ratio decreased 2.7-fold from 4% to 1.5% with the Addition of 25% .

K. Suresh, V. Padmavathi, Apsar Sultana(2018): associate degree experimental investigation is administrated to review the impact of stone mud and plastic fibers on engineering and strength properties of the Black Cotton Soils. The properties of stable soil like compaction characteristics, unconfined compressive strength and Calif. bearing magnitude relation were evaluated and their variations with content of stone mud and fibers square measure evaluated. Addition of either Optimum share of stone mud (3%) and Optimum share of fibers (0.6%) or Optimum share of its combination to the Black Cotton Soil has improved the strength characteristics of sub grade. ways in which of stabilization may even be sorted beneath two main types: (a) modification or improvement of a soil property of the prevailing soil whereas not exploitation any admixture and (b) modification of the properties with the help of admixture. The samples of the first kind square measure compaction and removal, that improve the inherent shear strength of soil. The samples of the second kind square measure stabilization with admixtures like cement, lime, bitumen, ash and chemicals. Deep soil deposits square measure stable by electrical ways in which, grouting, freeze etc. the use of lime, cement and organic compound has become common as helpful agents. The soil chosen for the aim of this study may well be a Black Cotton soil and conjointly the stabilizers used square measure Stone mud. Effect of Granite mud on Engineering Properties of Lime stabilised Black Cotton Soil - This paper presents the results of granite mud on the engineering characteristics of BC soil stable with ball lime. A laboratory study was undertaken to measure the results of granite mud as a soil stabilizer. Soil sample containing ball lime and 1/3, 10%, 2 hundredth and 30 minutes of granite mud were prepared and compaction characteristic and California bearing relation take a glance at were conducted as per relevant IS code of practise. The take a glance at results disclosed that the compaction parameters and radiation values of the soil square measure improved well with the addition of the granite mud. it's together found that the swelling of the BC soil is sort of controlled. The result showed the radiation price increased from one.7% to 7.15%, the optimum wet content square measure reduced from twenty second to 14.3% and so the foremost dry density square measure increased from one.58 g/cc to at least one.88 g/cc. The conclusion drawn from this experimental work is that the expansive clay like black cotton soil are going to be stable by the mixture of lime and stone mud to manage its swelling nature and increase the soundness. Black cotton soil is Associate in Nursing expansive soil found in many components of state. It contains montmonrollite minerals because of this these soils incorporates an inclination swell and shrink to a fault with the modification in wet content. to achieve the economy and proper performance supported such soils it is necessary to check the expansive behaviour and improve the strength characteristic of such weak soils.

On the experimental study following conclusions are the addition of stone dust in Black Cotton Soil improves the Engineering properties of soil. Present study shows that optimum combination of stone dust within the black cotton soil. Reduces swelling pressure and shrinking pressure. The adding the certain amount of stone dust in the black cotton soil the value of plastic limit percentage changes from 0% to 8% it will decrease and in the liquid limit it will increase. The tremendously raise in California Bearing ratio the penetration of plunger at 12.5mm the value of 3% will increase compare to the 0% and 8%. And in the standard proctor compaction test Will increase soil porousness that is sweet for voidance purpose. when Analysing price, the value the price profit quantitative relation cost has reduced. The value of delta H (1600) the percentage of the 0% to 8% it will decrease this set it will show that individual they're weak to provide smart result however use in proportion will increase the soil properties quite there individual performance. Hence, from the on top of take a look at results, it may be complete that the Black Cotton Soil may be used as a sub grade soil for construction when Stabilization victimization stone dust.

Vishal Dilip Khatate, Dinesh Subhash Gavande (2015): The recent development inside the utilization of advanced composites inside the advance of soil is increasing on the premise of specific desires and national wishes. the requirement of economical and strengthening techniques of existing soil has resulted in analysis and development of newer materials for improvement. Here as an extra step toward the innovative material to be used for stabilization, this study endeavour to use industrial material like measuring instrument mud (EAFD)iron mud and dolime fine for the soil improvement. The term 'soil' has varied meanings, relying upon general skillful field throughout that it's being thought-about. To associate farmer, soil is that the substance existing on the surface, that grows and develops flora. To the person of science to boot, soil is that the fabric inside the relatively skinny surface zone at intervals that roots occur, and each one the rest of the crust is sorted below the term rock notwithstanding its hardness. To associate engineer, soil is that the unaggregated or uncemented deposits of minerals and organic particles or fragments covering huge portion of the crust. It includes wide all totally different materials like boulders, sands, gravels, clays and silts, and so the direct the particle sizes throughout a soil may extend from grains alone a fraction of micrometre (10 cm) in diameter up to huge size boulders. Betterment and prediction of CMB of stone dirt mixed poor soils by -Pradeep Muley, K. Jain: The paper discusses the results of tests that unit performed on three soils notably the expansive black cotton soil, the yellow clay, and {thus|and so} the red murrum mixed with stone mud (crusher dust) in varied proportions thus on study the event inside the cosmic microwave background price of these soils. the information generated from the tests is then accustomed evolve Associate in Nursing empirical correlation between the cosmic microwave background price and so the essential soil parameters of the mix soil notably the fine content (less than 75 μ particles), D60 (particle size resembling hour finer), the liquid limit and so the plasticity index. the one correlation that is obtained from the take a glance at info predicts pretty much as good because the soaked cosmic microwave background of the mix soils with ample accuracy and so square measure usually used by practitioners to possess an idea of the cosmic microwave background of the soil mixed with stone mud by the essential soil parameters, that unit invariably administrated for the classification purpose.

RESEARCH OUTCOME

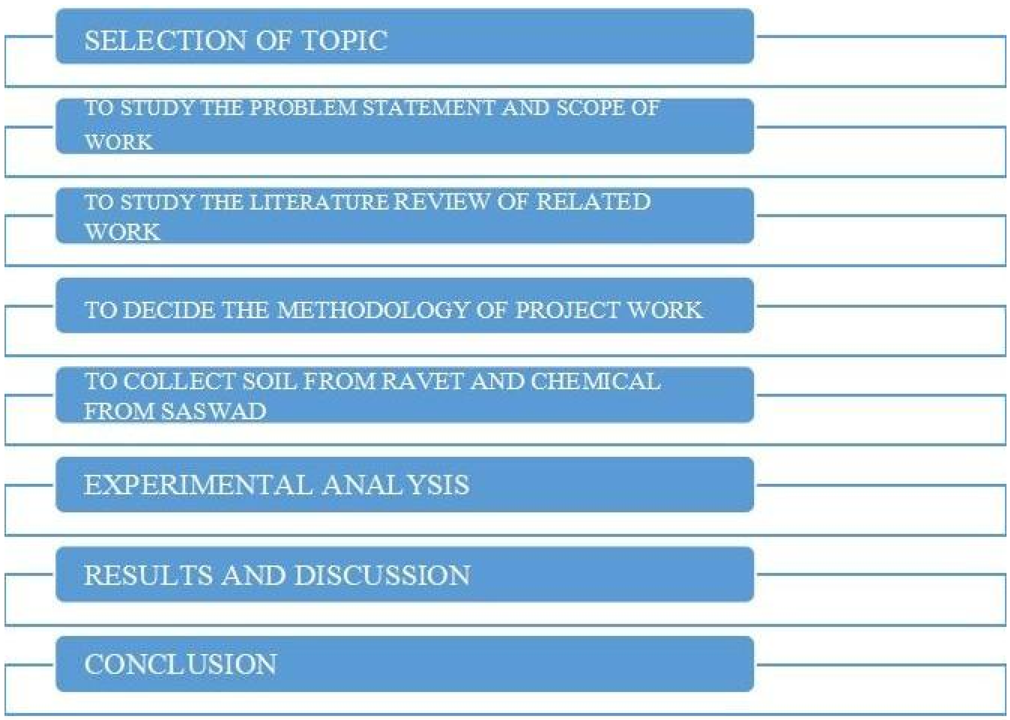
As we have seen the literature review portion we have come to an outcome that the main problem of Black Cotton Soil is with the strength of soil, its shrinking and swelling property. We have also seen that lime RGB18 and many other chemicals can't increase its strength to required level.

Few chemicals have increased the strength of soil at a good level eg . RGB18, isoaldehydes , etc but it has negative impact on soil like its OMC & MDD by 16% to 12% which is not good for soil uses .

So we have also used a chemical named Terrasil compound which is successfully fulfil all the requirements and needs of soil and its properties.

METHODOLOGY

The table shows the details of actual procedure which will be followed to achieve the above set objectives



FLOW CHART OF METHODOLOGY

3.1 MATERIALS

3.1.1 BLACK COTTON SOIL

Soil used in this experimental work is Black Cotton soil and is collected from site near Sagda Railway station, Sagda, Jabalpur, (M.P.). Coordinates of this site are: 23˚8'30"N and 79˚51'53" E. Geotechnical properties of black cotton soil are given in

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TABLE 3.1 PHYSICAL PROPERTIES OF PARENT SOIL

Physical properties	**Value**
Gravel	0
Sand	0
Silt	5
Clay	95
Specific Gravity	1.69
Liquid Limit	77.65
Plastic Limit	58.59
Plastic Index	19.06
I.S classification	CH
M.D.D	1.438g/cc
O.M.C	23.7%

TABLE 3.2 LIQUID LIMIT

Determinationno.	1	2	3	4
Number of blows	46	39	22	15
Moisture container no.	LL1	LL2	LL3	LL4
Weight of Container	22	16	15	14
WT+Wet soil	30	24	26	23
WT+dry soil	28	21	21	21
WT of water	02	03	05	06
WT of dry soil	06	05	06	07
WT of wet soil	33	60	83.33	90

TABLE NO 3.3 PLASTIC LIMIT TABLE

Moisture Container no	PL1	PL2	PL3
Weight of container	10	11	12
Weight of soil +wet	16	16	17
Weight of soil +dry	14	13	15
Weight of water	2	3	2
Weight of dry soil	4	5	3
Moisture content%	50	60	66.67
Plastic limit		58.59	

LIQUID LIMIT TEST

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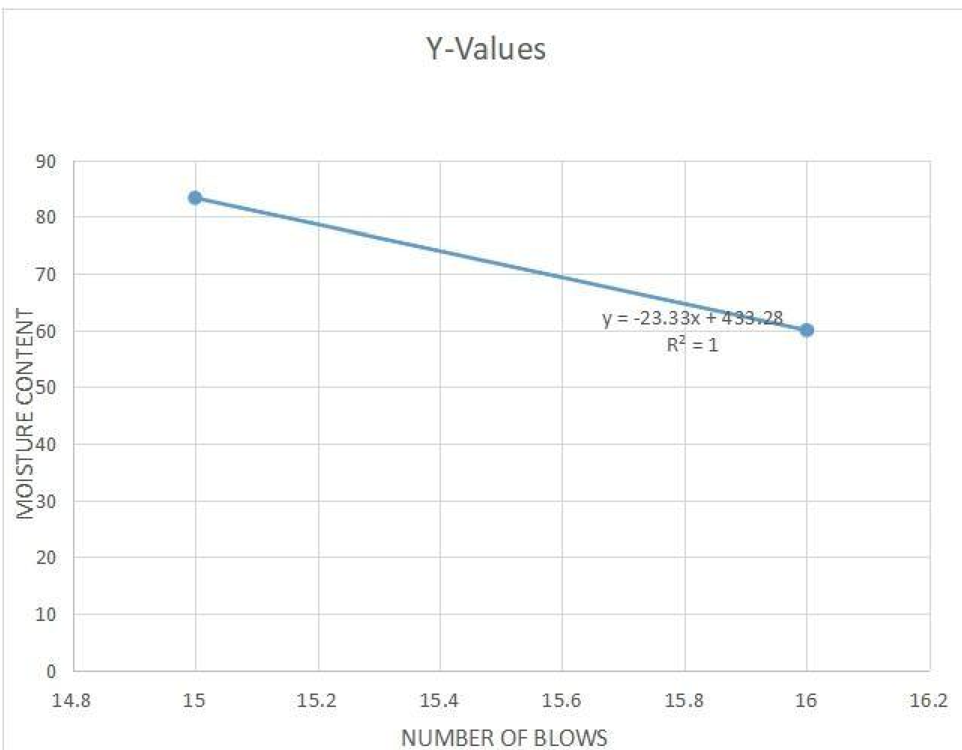
PLASTIC LIMIT TEST



GRAPH 3.1 WATER CONTENT VS NO OF BLOWS FOR DETERMINATION OF LIQUID LIMIT OF PARENT SOIL

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TABLE NO 3.4 SPECIFIC GRAVITY TABLE

Determination no.	1	2	3
Wt of pycnometerW1	674	674	674
Wt of pycnometer+dry2	874	872	874
Wt of dry Ws	200	198	200
Wt of pycnometer +soil+water3	1618	1614	1616
Wt of pycnometer +Water4	1537	1532	1535
Specific Gravity G	1.68	1.70	1.68
Specific Gravity		1.69	

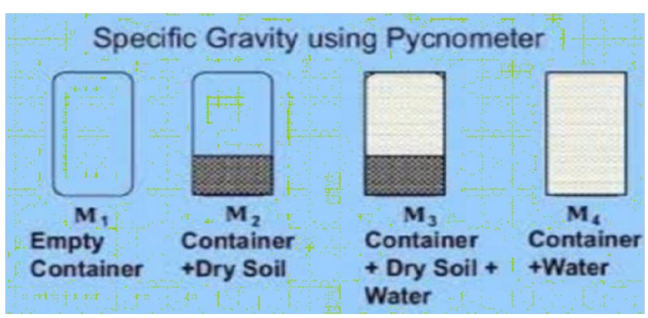

FIG 3.5 PYCNOMETER

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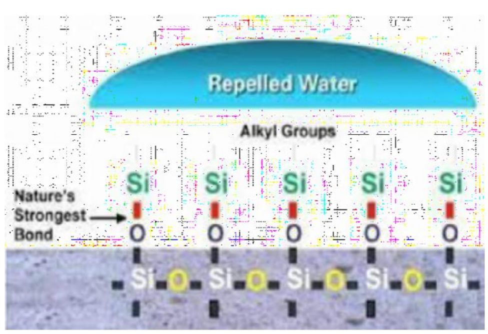
Terrasil

Terrasil is a nanotechnology based material. It is made of 100% organo-silane molecules. Terrasil forms Si-O-Si bonded nano-siliconize surfaces and converting water loving Silanol groups to water repellent Alkyl Siloxane groups in soil. Terrasil is highly water- soluble, UV stable, heat stable and active soil stabilizer which is used for subgrade stabilization till yet. Terrasil is a user friendly product and easy to use that renders treated soils highly water repellant. It improves the cohesion as well as adhesion value and maintains breathability of the soil layer. Terrasil is environmental friendly as it uses the in situ soil and conserves restricted resources like aggregates and bitumen which minimizes use of fuel for transporting good soils over long. Terrasil delivers proven results with all types of soils and doesn't change their appearance. Once applied, it works to bond with the soil's silica and oxygen molecules. This chemical reaction makes the soil about 98% water resistant. The bonding process starts within 3 hours of the initial application and completed about 72 hrs. After application of Terrasil, it becomes a permanent part of each soil molecule and will not separate or leach into groundwater. It is available in concentrated liquid form and is to be mixed with water in specified proportion before mixing with the soil. Terrasil was purchased from Zydex Industries Pvt. Ltd.

TERRASIL

CHEMICAL COMPOUND	VALUE IN RANGE %
Hyrdoxyalkyl-alkoxy-alkylsilyl	65-70%
Benzyl alcohol	25-27%
Ethylene glycol	3-5%

CHEMICAL COMPOSITION OF TERRASIL



REPELLED WATER BOND WITH TERRASIL AND SOIL

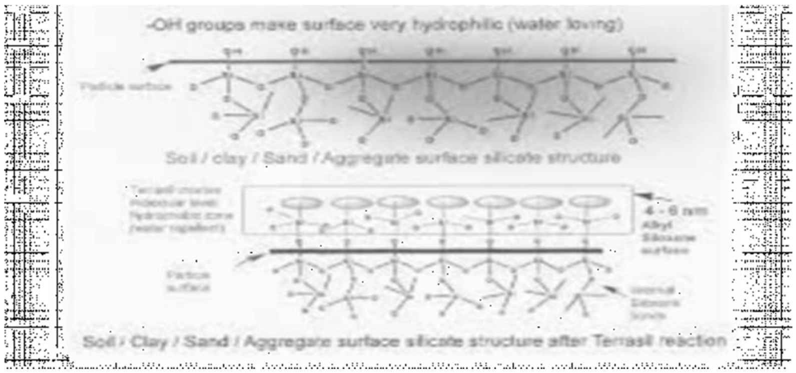
TECHINCAL SPECIFICATION OF TERRASIL PROPERTY	DESCRIPTION
Appearance	Pale Yellow Liquid
Solid content	68+_2%
Viscosity at 25%	20-100cps
Specific gravity	1.01
Solubility	Forms water clear solution
Flash Point	Flammable 12oc

MECHANICAL PROPERTIES OF TERRASIL

TERRASIL AND COLOUR OF COMPOUND

Reaction mechanism

A simplified diagram of the reaction mechanism of Terrasil with soil is shown in figure below. Soil when treated with Terrasil with forms Si-O-Si bonded nano-siliconize surfaces and converting water loving Silanol groups to water repellent Alkyl Siloxane groups in soil



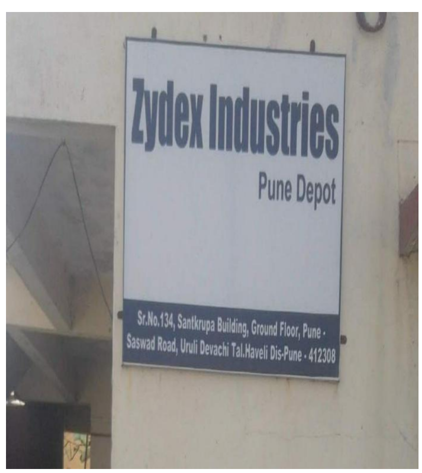
REACTION MECHANISM

Dosages of Terrasil

Dosage of Terrasil is basically about 1litre per 1000kg of Terrasil weight of soil. In this study the dosage was varied from a minimum of 900ml to a maximum of 1300ml of chemical for 1000kg of soil. Trials were carried out by treating the soil at 0.9% (dosage- 1), 1.1% (dosage 2) and 1.3% (dosage-3) by weight of dry soil and variations in geotechnical properties were observed. Application of stabilizer to soil was done in two levels as per specifications of Zydex industries. First Terrasil was diluted in water at 150% of the OMC and added to soil, mixed properly and the mixture was kept for air drying for 3 days, which made the mixture surface 90-95% water resistant. In the second stage, one percent cement by weight of soil was added before compaction to achieve desired proctor density. The dosage of chemical per liter of water is shown in table

DOSAGE DILUTION %	**AMOUNT OF CHEMICAL /LITRE**
DOSAGE 1[0.9%]	26ml
DOSAGE 2 [1.1%]	32ml
DOSAGE 3[1.3%]	37ml

DOSAGE OF CHEMICAL



ZYDEX INDUSTRY (CHEMICAL)

3.3 Experimental investigation

3.3.1 Standard Proctor Test

Standard proctor test has been conducted to determine maximum dry density and optimum moisture content of parent soil and soil treated with different dosages of Terrasil. These tests were conducted so as to prepare specimens at maximum dry density by adding desired optimum moisture content as per specification of IS: 2720 (Part 7).

Sample preparation

About 3 kg of oven dried soil sample was taken in a tray. Terrasil was diluted in water at 150% of the OMC and added to soil, mixed properly and the mixture was kept for air drying for 3 days, which made the mixture surface 90-95% water resistant. In the second stage, one percent of cement by weight of soil was added before compaction to achieve desired proctor density.

Procedure:

The mixed sample was placed in previously weighted mould (m1 kg) of capacity 1000cc in three layers. Each layer was given 25 blows with a 2.6 kg rammer with free fall of height 310mm. After compacting three successive layers collars was removed and excess soil was trimmed off. The weight of mould with soil was taken (m2 kg). This process was repeated for other water content also until there was a decrease in m2 value. For each trial a portion of soil was taken for moisture content determination.

Calculation:

Bulk density = (m2- m1)/1000

Dry density = (bulk density) / (1+w) Where w moisture content present in soil. The results of Standard Proctor Test

STANDARD PROCTOR TEST

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3.3.2 Free Swell Test

Sample preparation

About 100-150 gm of soil was dried in oven. Terrasil was diluted in water at 150% of the OMC for different dosages and added to soil, mixed properly and the mixture was kept for air drying for 3 days, which made the mixture surface 90-95% water resistant. Total eight samples were tested, out of which two were tested on parent soil and six samples two each for different three different dosages of Terrasil were tested as per IS 2720 (Part- 40) (1977)

Procedure

About 10 gm passing through 425 micron sieve oven dried samples of two specimens were taken each of parent soil and soil treated with different dosages of Terrasil. Two cylinders of about 50ml one filled with kerosene oil and other with distilled water was taken. Entrapped air was removed by stirring with clean glass rods. Samples in both cylinders were allowed to settle for 24 hrs. Final volume of both cylinders were noted down.

Calculation

Free swell index (%) = $(V2-V_1)/V_1 x\ 100$

Where, V_1= Volume of soil specimen in the graduated cylinder containing Kerosene oil. V_1= Volume of soil specimen in the graduated cylinder containing distilled water.

FREE SWELL TEST

IV. RESULTS AND DISCUSSION

The objective of the present study is to investigate the strength characteristics of Black cotton soil treated with different dosages of Terrasil. This has been done to make the black cotton soil suitable for the construction of structure and safeguard the structures form the hazards of expansive soil Shear strength of soil treated with different dosages of chemical is analysed by unconfined compression tests. The results of these tests have been analysed under following heading

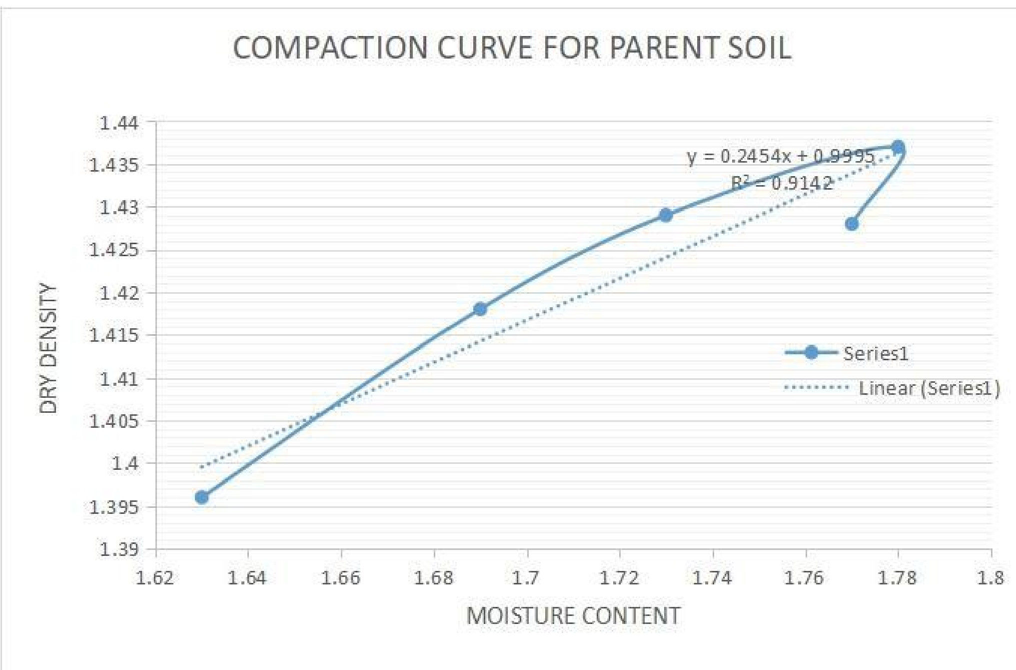
4.1 Moisture density relationship

Standard proctor test have been conducted to determine the optimum moisture content and maximum dry density of soil under investigation, stabilized with different dosages of Terrasil Graph 4.1 to 4.4 shows the values of MDD and OMC for soil under investigation stabilized with various dosages of stabilizer.

For parent soil, OMC and MDD was observed to be 23.7% and 1.437g/cc. The optimum moisture content (OMC) of soil treated with different dosages of Terrasil increases as we increase the dosage of Terrasil. It has been observed that OMC value increased from 23.7% to 28%

Maximum dry density of parent soil is 1.437g/cc. The MDD of soil decrease with increase in dosages of Terrasil. At dosage 1, MDD value was observed to be 1.370g/cc. As further increase the content of Terrasil, MDD value further decreases to 1.368g/cc. At dosage 3 it was observed to be 1.320g/cc. This decrease in value of maximum dry density is may be due to formation of new chemical product after reaction between soil mineral and chemical.

DETERMINATION	1	2	3	4	5
WT OF MOULD	4318	4318	4318	4318	4318
WT OF MOULD +COMPACTED SOIL	5943	6004	6051	6096	6088
MOISTURE CONTENT NO.	L1	L2	L3	L4	L5
WT OF MOISTURE CONTENT W1	10.18	10.21	10.53	10.15	10.41
WT OF CONTAINER + WET SOIL W2	29.24	26.15	28.41	24.14	24.14
WT OF CONTAINER + DRY SOIL W3	26.55	23.62	25.27	19.81	21.49
MOISTURE CONTENT	16.43	18.87	21.30	23.71	23.92
WET DENSITY	1.63	1.69	1.73	1.78	1.77
DRY DENSITY	1.396	1.418	1.429	1.437	1.428



PARENT SOIL TESTED

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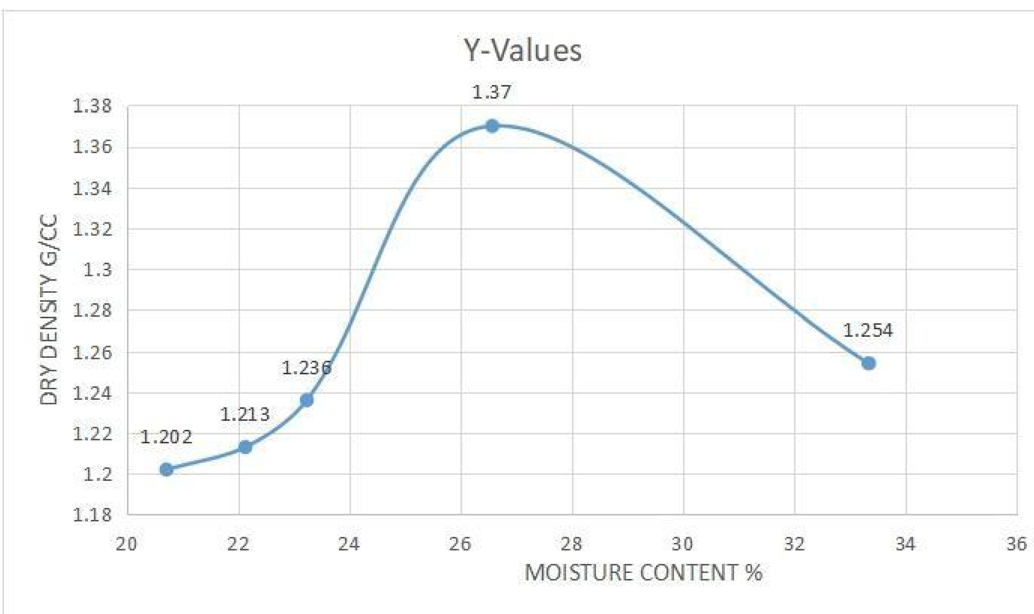
DETERMINATION	1	2	3	4	5
WT OF MOULD	4318	4318	4318	4318	4318
WT OF MOULD +COMPACTED SOIL	5770	5800	5840	6025	5990
MOISTURE CONTENT NO.	L1	L2	L3	L4	L5
WT OF MOISTURE CONTENT W1	10.18	10.21	10.53	10.15	10.41
WT OF CONTAINER + WET SOIL W2	41.30	40.79	34.45	31.82	21.93
WT OF CONTAINER + DRY SOIL W3	35.96	35.25	29.94	27.27	19.05
MOISTURE CONTENT	20.71	22.123	23.23	26.57	33.34
WET DENSITY	1.452	1.482	1.522	1.734	1.672
DRY DENSITY	1.202	1.213	1.236	1.370	1.254



COMPACTION CURVE FOR SOIL TREATED WITH 0.9% TERRASIL

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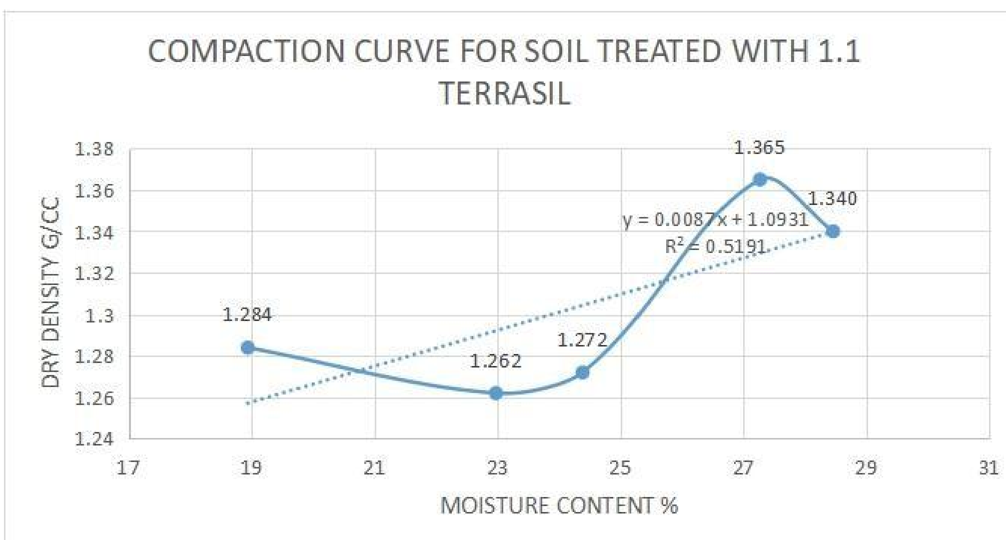
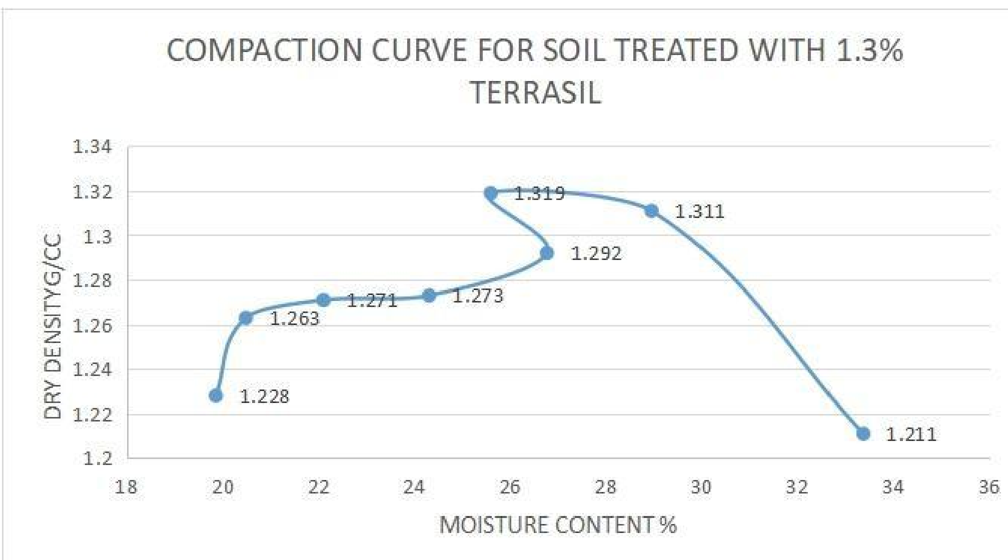
DETERMINATION	1	2	3	4	5
WT OF MOULD	4318	4318	4318	4318	4318
WT OF MOULD +COMPACTED SOIL	5845	5870	5900	6055	6040
MOISTURE CONTENT NO.	L1	L2	L3	L4	L5
WT OF MOISTURE CONTENT W1	9.74	10.52	19.04	8.25	10.08
WT OF CONTAINER + WET SOIL W2	34.37	53.46	31.80	23.79	46.37
WT OF CONTAINER +	30.45	45.44	26.22	20.46	38.33
DRY SOIL W3					
MOISTURE CONTENT	18.93	22.97	24.38	27.27	28.46
WET DENSITY	1.53	1.55	1.58	1.74	1.72
DRY DENSITY	1.284	1.262	1.272	1.365	1.340



COMPACTION TEST ON SOIL TREATED WITH 1.1% OF TERRASIL

DETERMINATION	1	2	3	4	5	6	7	8
WT OF MOULD	4318	4318	4318	4318	4318	4318	4318	4318
WT OF MOULD +COMPACTED SOIL	5790	5840	5870	5900	5940	5990	6010	5980
MOISTURE CONTENT NO.	L1	L2	L3	L4	L5	L6	L7	L8
WT OF MOISTURE CONTENT W1	10.66	10.38	10.43	9.40	9.09	10.54	10.59	16.83
WT OF CONTAINER + WET SOIL W2	51.72	34.56	44.57	41.72	52.48	42.07	31.70	58.48
WT OF CONTAINER + DRY SOIL W3	44.92	30.45	38.39	35.40	43.64	35.41	26.96	47.97
MOISTURE CONTENT	19.85	20.48	22.10	24.31	26.77	25.59	28.95	33.37
WET DENSITY	1.47	1.52	1.55	1.58	1.62	1.67	1.69	1.62
DRY DENSITY	1.228	1.263	1.271	1.273	1.292	1.319	1.311	1.211



COMPACTION CURVE FOR SIL TREATED WITH 1.3% TERRASIL

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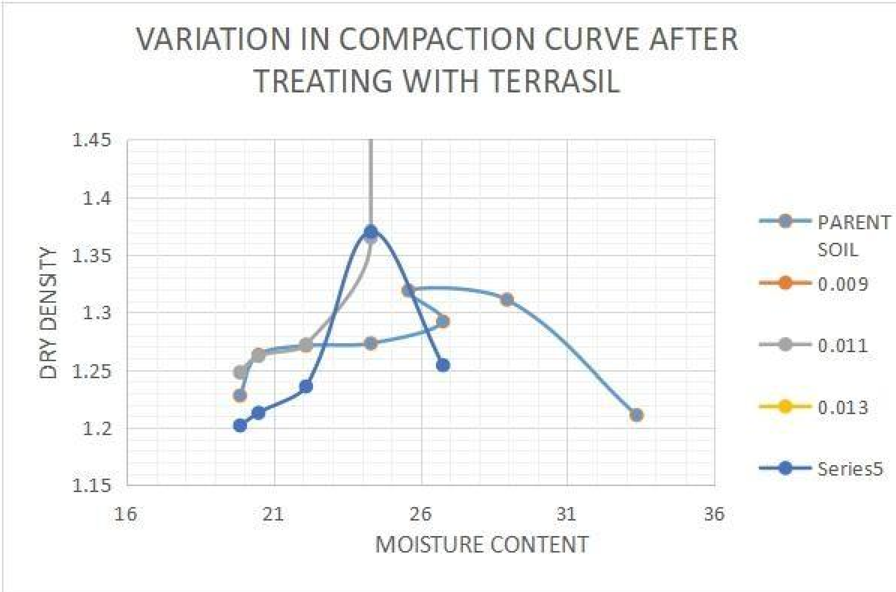

VARIATION IN COMPACTION CURVE AFTER TREATING SOIL WITH TERRASIL

4.2 Free swell test

Black cotton soil has a tendency to swell when submerged in water. The swelling behavior of Black Cotton soil and Terrasil treated soil has been determined by free swell test as per IS 1720 (Part-40) (1977). Free swell value of Black Cotton soil was found to be 60%. As we treat the soil with the dosage 1, free swell value was observed to be 55% Further on treating with dosage 2, it was 42%. Finally after dosage 3, the free swell value shows a very small

TEST RESULTS OF FREE SWELL INDEX

DOSAGE	VOLUME OF SOIL IN KEROSENE V1	VOLUME OF SOIL IN WATER V2	FREE SWELL INDEX
0%[PARENT SOIL]	10	16	60
0.9%	10	15.5	55
1.1%	9.5	13.5	42
1.3%	9	12.8	34

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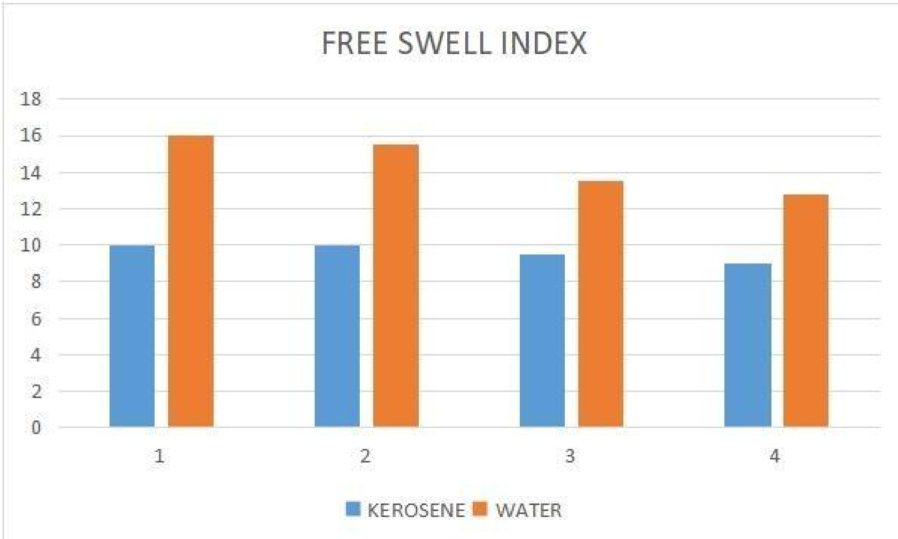

FREE SWELL INDEX

V CONCLUSION

This ready demonstrate the influence of Terrasil with various dosages (0.9%, 1. Land 1.3%) on geotechnical properties of Black Cotton soil of Ravet Pune Maharashtra. Based on exponential test results, major conclusions have been drawn with regards to the effect of Tensile on proctor density and free swell value of Black Cotton soil:

1. It has been observed that maximum dry density of Black Cotton soil decreases with increase in Terrasil content. The maximum dry density of parent Black Cotton soil was observed to be 1.437g/cc. With the addition of Terrasil, MDD value starts decreasing, It was found to be 1.320 g/cc at dosage 3. This decrease in value of maximum dry density is may be de to formation of new chemical product after reaction between coal mineral and chemical.

2. It has been observed that optimum moisture content of parent soil was 23.7%. With the addition of Terrasil, OMC value starts increasing. It was found that OMC value increased from 23.07% to 28% at dosage 3.

3 FSI value of treated soil reduced considerably in comparison to parent soil. This is because the film of adsorbed water around soil particles is greatly reduced for treated soil and the surface area reduces, resulting in decreased swelling capacity. This study shows that treatment of soil with Terrasil provides a substantial and durable benefits when used as stabilizing agent for Black cotton. There is significant change in the welling behaviour as well the compressive strength of Black Cotton soil which proves Terrasil a worthy stabilizer for Black Cotton soil.

Scope of Further Studies

1. This study identified related topics on which further study would be beneficial: Studies can be carried out to optimize the content of Terrasil for different types of soil found in India.

2. The X-Ray Diffraction (XRD) and Search Engine Marketing (SEM) analysis needs to be conducted for the soil samples to justify the improvement for stabilized soil.

3. Fatigue analysis and tri-axial tests for untreated and treated soil samples for better idea about the use of the soil in construction can be carried out.

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