Soil Stabilization by Using Citrus Bio- Enzyme

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Abstract: In India, urbanization in recent decade's demands to take up construction of civil engineering projects even in weak soil due to the land constraints has taken a boost. This requires huge amount of natural soil excavated or deposited which has economical issue and environmental issues. Due to these issues there is a development of alternative methods such as use of natural products or reuse of the industrial by products.

Soil stabilization is one of the techniques which can be used for improving the properties of soil by using different types of waste products or industrial by products. Soil stabilization also improves the engineering properties e.g. bearing capacity, compressibility, strength, and various other properties of soil.

This paper presents investigation of series of laboratory experiments has been performed to study the engineering properties, Optimum Moisture Content (OMC), Maximum Dry Density (MDD), California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) of the virgin soil and the soil mixed with the citrus bio-enzyme. In this first we have conducted the above experiments on virgin soil and later we have done for citrus bio-enzyme mixed with the locally available soil.

The experimental results had shown a significant change in the properties of soil with the addition of citrus bio-enzyme. From this investigation we want to conclude that the addition of citrus bio- enzyme can improve the strength characteristics of the soil.

KEYWORDS: Citrus bio-enzyme, stabilization, engineering properties, optimum moisture content (OMC), maximum dry density (MDD), California bearing ratio (CBR), unconfined compressive strength (UCS).

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I. INTRODUCTION

Black cotton soils in Indian name given to the expansive soil deposits soil in the central part of the country. Expansive soils are highly problematic soils and cause damage to the structure commonly known as Black cotton soils. Black cotton soils accounts about 20% of land area in India. These soils expand and become sticky during rainy season and contract during the dry season causing deep cracks into the soil. They exhibit high rate of swelling and shrinkage when exposed to change in moisture content and hence have been found to be most troublesome from engineering considerations. The rate of montmorillonite s more in black cotton soils which causes expansiveness and crack occurs in soil without any warning which is dangerous for construction

Problem of expansive soil:

Expansive soil problematic for civil engineers because of their unconventional behavior. Expansive soil is inorganic clay of medium to high compressibility and form a major group in India. Expansive soil can cause foundation problems, and hydrostatic pressure. Expansive soil is distinguished by the presence of swelling clay minerals that can absorb a significant amount of water molecules. When expansive soils obtain moisture, they expand or swell up.

Expansive soil areas, unpaved berms pose the maximum problem as they become slushy during rains. Water penetrates into road pavement from three sides' viz.top surface, sides berms Therefore, road specification in expansive soil areas must be take factors into consideration.

Hence, these soils are to be stabilized before constructing the roads in order to have efficient and long-lasting roads. The stabilization process can be done with using different types and materials. As compared to the other soil, Expansive soils possess more settlement due to which spacing between clay particles is more. Then it can lead to decreasing the strength of the soil.

Soil stabilization:

Soil stabilization is a process of treating a soil in such a manner as to maintain, alter or improve the performance of soil as a road construction material. It refers to the process of changing of soil properties to improve strength &durability. There are many techniques for soil stabilization, including compaction, dewatering &by adding material to the soil.

Soil stabilization can be utilized on roadways, railways, parking areas, site development projects, airport and many situations where sub-soil are not suitable for construction. Stabilizing can be used to treat a wide range of sub- grade materials, varying from expansive clays to granular materials.

Benefits of soil stabilization:

- Soil stabilization can improve stiffness and tensile strength of material.
- To improve the strength of sub-bases, bases and sometimes surface courses, in case of low-cost roads.
- To improve certain undesirable properties of soils, such as excessive swelling or shrinkage, high plasticity, difficulty in compacting etc...,
- To reduce compressibility and there by settlements.
- To improve permeability characteristics and increase load bearing capacity.
- Reduction in plasticity and pavement thickness.
- Elimination of excavation, exporting unsuitable material and importing new materials.
- Usage of large waste as stabilizing material, which cleans the environment.

Types of stabilization:

- Mechanical stabilization
- Chemical stabilization
- Thermal stabilization

Mechanical stabilization:

The oldest types of soil stabilization are mechanical in nature. It is the process of improving the properties of the soil by changing its gradation. This process includes soil compaction and densification by application of mechanical energy using various sorts of rollers, rammers, vibration techniques and some blasting. Preferably for construction of embankment for roads, railways etc... Stability depends upon degree of compaction.

Chemical stabilization:

Soils are stabilized by adding different chemicals. The main advantage of chemical stabilization is to control the curing and setting time.it lowers the optimum water content the benefits of stabilization requires the presence of the chemical in the fore fluid. Calcium chloride, sodium chloride, polymer etc. Have been used successfully.

Thermal stabilization:

Thermal stabilization of soil is ground improvement technique. The Concept method and application of thermal stabilization is discussed. It has been observed that heating or cooling shows certain marked changes in the soil properties .Heating and cooling have been extensively used soil improvement techniques. Whatever be the mode of thermal stabilization we opt for it has the following needs:

- Thermal evaluation of heat flow
- Heating or refrigeration system has to be designed
- Strength and stress –strain – time properties of the soil have to undergo performance analysis

Aims and Objectives

The present study is aimed at stabilization of black cotton soil with Bio-Enzymes, to achieve the aim work has been planned to achieve the following objectives.

- To prepare and establish engineering properties of black cotton soil by laboratory investigation.
- To study the strength parameters of expansive soils with Bio-Enzyme.
- To study the compaction characteristics of expansive soils at different percentage of Bio- Enzyme with the soil.
- To study the index properties of black cotton soils and how there varied at different percentage of Bio-Enzymes with the soil.

Specific Scope of Study:

- The scope of the project to increase the strength of the expansive soil.
- It is to investigate on different percentage of bio enzymes with soil sample.
- To increase the strength of soil by increasing the percentage of bio enzymes with soil.

LITERATURE REVIEW

Lacuoture and Gonzalez (1995) [1] conducted study on the effects of Terrazyme on sub-base and subgrade. The reaction of the soil treated with Bio Enzyme was observed and compared with soil without Bio Enzyme. It was concluded that soil showed improvement in short duration of time but the cohesive soils showed improvement successively.

Bergmann (2000) [2] concluded from his study on bio enzyme that for imparting strength to the soil, bio enzyme requires some clay content. He stated that for successful stabilization of soil minimum 2% clay content is required and 10 to 15 % of clay content gives good results. Compared to 28 % of untreated soil CBR after 1, 2, 3, 14 weeks was found as 37, 62, 66 and 100 respectively.

Manoj Shukla et al. (2003) [3] carried out test on five different type of soil. The clay content in soil varies from low to high. Tests were conducted on soil samples with and without Bio Enzymes to determine different engineering properties, Atterberg's limit, CBR and UCS at different curing period in laboratory. Little to high improvement is seen in the physical properties of soil with Bio Enzyme. The reason behind this little improvement is the chemical composition of soil which is less reactive with the Bio Enzyme. Sandy to silty type soil showed improvement in the CBR and UCS. It was observed that pavement thickness is reduced by 24 to 48 %. In places where the availability of granular material is less, Bio Enzyme treated soil with thin bituminous coating can satisfactorily fulfill the pavement requirement.

Shankar et al. (2009) [4] conducted tests on lateritic soil of Dakshin a Kannad (district of India). The initial liquid limit and plastic limit of soil were 25 % and 6% respectively. The lateritic soil of the district was not satisfying the sub base requirement. For satisfying the sub base course requirements sand is mixed with soil in different proportions until specified values were attained. Study was done on the effect of enzyme, on soil properties like CBR, UCS and permeability for a period of 4 weeks. CBR value increased by 300% with about 10 % sand and 200ml/m3 of enzyme mixed with soil after 4 weeks of curing. An increase of 300% is seen the CBR value, increase of 450% in unconfined compressive strength value and decrease of 42 % in permeability of soil was seen with high dosage of enzyme of 200ml/2m3 after 4 weeks of curing. It was concluded from the CBR results of treated and untreated soil that addition of enzyme in no cohesive soil has no effect on the cohesion less soil. It was also stated that the bio enzyme used shall be checked for its effect on type of soil in laboratory prior to the field application. In order to check the efficiency of Bio Enzyme in field, test was performed on National Highway which affirms that soil blended with enzyme shows high CBR value than ordinary soil.

Venkata Subramanian & Dina Karan (2011) [5] performed test on 3 different soils with different properties. These soils were tested with different dosage of enzyme. The liquid limit and plasticity index of soil were reported as 28, 30, 46 % and 6, 5 and 6 % respectively. An increase of 157 to 673 % is seen in CBR after 4 weeks of curing and 152 to 200 % in UCS.

Vijay Rajorial, Sumeet Kaur (2014) [6] carried out a theoretical evaluation of enzyme. Reduction of about 18 to 26 % is seen in cost of construction of roads by using Terrazyme as a soil stabilizer, constructed by public work department in Maharashtra. Structures made of bio enzyme are economical and have greater strength. Sandeep Panchal, Md. Mohsin Khan and Anurag Sharma, Stabilization of Soil Using Bio-enzyme, (2017) this paper presents the result that after addition of varying amount of terrazyme, the effect on the characteristics of soil is analyzed & the results are shown in graphical form. Variation of load w.r.t. penetration in CBR test is shown for normal soil.

Ishwarya S Dhanesh, Twinkle Vinum Mohandas (2016) [7] Effect of Bio-enzyme Stabilization on Geotechnical Properties of Thonnakal Clay, this study suggested that the variation of maximum dry density & optimum moisture content at varying dosages of enzyme treated soil for different curing periods is obtained.

Saurabh B. Gautam, C.B. Mishra, N. F. Umrigar (2016) [8] Subgrade Soil Stabilization using Terrazyme, this study suggested that the CBR value of soil have significant rise and swelling property FSI comes down to 24% of treated soil from 50% of untreated soil.

Deficiencies Identified from Literature:

For all the literature studies, we observed that the soil lack of high compressive strength and bearing capacity. It leads to formation of large cracks, deterioration and depression in the highways, expressways and foundation of buildings.

MATERIALS AND METHODOLOGY

Materials:

In this chapter, we discuss about the material used in the present study. The main materials characterized in the present study are expansive soil and other material is bio enzymes. We compare the results of the soil and the bio enzyme along with the soil. From the results we will conclude the characteristics of the soil.

Citrus Bio enzyme:

- Bio enzymes are chemicals, organic and liquid concentrated substances which are used to improve stability of soil, sub base of pavement structures.
- Citrus Bio enzymes is made up of fermentation of plants, vegetables extract and fruit extract. It improves the CBR value in road construction.
- It replaces adsorbed water with organic cations, thus neutralizing the negative charge on a clay particle.

Figure 1 : Citrus Bio-enzyme

Expansive clay soil:

The expansive soil proved to be very problematic for the construction of various infrastructures like embankment, foundation, pavement, hydraulic barriers etc... The expansive clay soil contains montmorillonite and bentonite clay minerals which have most shrink-swell capacity, due to the water bond between the particles of the soil. About 20-25% of the land area is expansive soil in India, which includes Major Madhya Pradesh, Andhra Pradesh. Due to wet and dry conditions, the soil causes shrink-swell properties which leads to cracking, raveling and rutting in pavements and settlement in foundation.

The soil for a research was collected from Rajanagaram, west Godavari distict in several trail pits as indicated in plate. The sample was picked along the soil profile at depth of 1.5m to avoid the inclusion of organic matter. Preliminary checks indicated that the soil was grayish black in color and high plastic in nature. The soil sample collected was a disturbed sample.

Figure 2 : Black cotton soil

Experimental Work

First to know the properties of expansive soil by using laboratory investigations.

Ex: Index and Engineering properties. Adding citrus bio-enzymes to the soil for strengthening purpose. Comparing the those values the soil strength will be improved or not.

In this present study we have to conduct laboratory investigation of soil like index and engineering properties. Expansive soils possess high swelling and shrinkage because of absorbing of water. Citrus bio-enzyme are associated with soil the bearing capacity and compressive strength can be increased. The whole testing was done in two phases. In the first phase we conduct the laboratory tests simple local soil to investigate the geotechnical properties. In the second phase, the local sample was mixed with citrus bio-enzymes with different proportion are 2%, 4%, 6% in 5kg of soil for various test should be conducted. After addition of variation amount of citrus bio-enzyme the effect on characteristics of soil is analyzed and the results are shown in the graphical form. Variation of load w.r.t penetration in CBR test is shown for normal soil and add citrus bio-enzyme soil

Index properties

Specific Gravity:

The ratio of the weight of the given volume of solid to the weight of an equivalent volume of water.

Standard Reference: IS: 2720-(Part3) sect-2-1981.

Formula Used:

Specific gravity = (W2-W1)/ ((W2-W1) - (W3-W4))

Where, W_1= weight of empty bottle

W_2= weight of bottle + dry soil

W_3= weight of bottle + soil + water

W_4= weight of bottle + water

Sieve Analysis:

The grain size analysis is widely used to in classification of soils. The data obtained from grain size distribution curves is used to determine suitability of soil for road construction, air field etc.

Standard Reference: IS 2720-(Part4)-1975.

Formula: Percentage retained on any sieve= (Weight of soil retained/total weight) *100

Liquid Limit:

The boundary between the liquid and plastic states. The water content at which the water has such a small shear strength then it flows to close a groove of standard width when jarred in a specified manner.

Standard Reference : IS: 2720-Part 5-1970.

Plastic Limit:

The boundary between the plastic and semi-solid states. The water content at which the soil begins to crumble when rolled into threads of 3mm size.

Standard Reference: IS: 2720-Part 5-1970

Formula: plasticity index = liquid limit-plastic limit

Standard Reference: *IS: 2720-Part 5-1970*

Shrinkage limit:

The shrinkage limit is the water content where further loss of moisture will not result in any

Standard Reference: IS: 2720-Part 6-1972

Formula:

Shrinkage limit (wS) = ((Mo-Ms)-(Vo-Vd) *pw/Ms)

Hydrometer Analysis:

It is used to determine the particle size distribution passing through 75 microns.

Standard reference: IS: 2720-(Part 4)-1975.

Engineering properties

Free Swell:

It is the increase in volume of soil without any external constraints on submergence in water.

Standard reference: IS: 2720-(Part40)-1977

Formula:

Free swell index= (vd-vk)/vk) *100.

Compaction:

Compaction generally leads to reducing the void ratio of soil under short term loading and tests were performed to determine the maximum dry density and optimum moisture content.

Standard Reference: IS: 2720-Part 8-1983

Formula:

Bulk density (pt) = (M2-M1)/V Dry density (pd) =pt/(1+w)

CBR Test:

It is a penetration test to evaluate sub grade strength of roads and pavement .The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers.

Standard Reference: IS: 2720-Part 16-1979

Formula:

CBR = (Test load/Standard load) *100

Unconfined compression test:

The unconfined compression test is by far the most popular method of soil shear testing because it is one of the fastest and cheapest method of measuring shear strength. This test is in appropriate for dry sands or crumbly clays because the materials would fall apart without some land of lateral confinement.

Standard Reference: IS: 2720-Part10-1973

RESULTS AND ANALYSIS

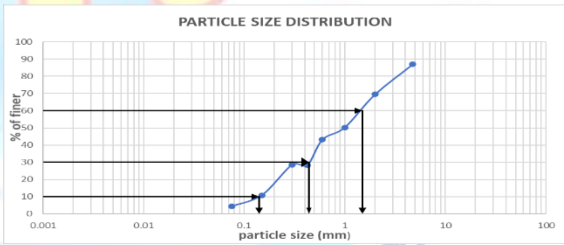
INDEX PROPERTIES

Sieve Analysis of soil

S. No	IS Sieve (mm)	Mass retained (gm.)	% Mass retained	Cumulative Mass retained (gm)	% of finer
1	4.75	65.4	13.08	13.08	86.92
2	2.00	87.4	17.48	30.56	69.44
3	1.00	96.1	19.22	49.78	50.22
4	0.6	35.4	7.08	56.86	43.14
5	0.425	74.3	14.86	71.72	28.28
6	0.3	28.6	5.76	77.48	28.52
7	0.15	58.4	11.68	89.16	10.84
8	0.075	31.9	6.38	95.54	4.46
9	PAN	17.6	3.52	99.06	0.94

Tabel : 1

- % of finer=94.6
- % of sand =3.08
- % of gravel =1.30
- D10=0.14
- D30=0.44
- D60=1.50
- CU = D60/D10 =10.7
- CC =D30²/(D60*D10) =0.92



Graph-1

S.no	Description	Test1	Test2	Test3	Test4
1	Weight of container (W1)	15.6	9.5	16.0	14.9
2	Weight of container+ wet soil(W2)	16.4	10.6	16.9	16.0
3	Weight of container + dry soil(W3)	16.3	10.4	16.8	15.8
4	Water content = W2-W1/W3-W1	14.286	22.22	12.50	22.21
	Average water content	17.79			

Plastic limit

Table: 2

Liquid limit

S.NO	Description	88	65	45	30	18	17	12
1	Weight of container (W1)	23.8	27.1	27.1	10.9	22.1	29.5	28.7
2	Weight of container+ wet soil (W2)	30.6	29.6	31.5	17	27.2	37.7	37.3
3	Weight of container + dry soil (W3)	28.4	27.5	29.9	15.0	25.5	34.7	34
4	Weight of water	2.2	2.1	1.6	2	1.7	3	3.1
5	Water content =W2-W3/W3-W1	0.47	0.46	0.57	0.48	0.5	0.57	0.58
6	%Of Water content	47	46	57	48	50	57	58

Table: 3

Shrinkage Limit

S.no	Descripition	Sample
1	Mass of shrinkage dish (M1) ,g	63.2
2	Mass of shrinkage dish with wet soil(M2),g	103.3
3	Mass of shrinkage dish with dry soil(M3),g	90.1
4	Mass of dry soil Mo=(M3-M1),g	26.9
5	Mass of wet soil Mo=(M2-M1),g	40.1
6	Water content(%)	32.9
7	Mass of shrinkage cup with mercury,g	484.4
8	Mass of mercury ,g	397.9
9	Volume of shrinkage dish=volume of wet soil(v)ml	29.25
10	Mass of displaced mercury,g	162.8
11	Volume of dry soil(Vo),ml	11.92
12	Shrinkage limit (Ws)=[w-[(V-Vo)/Mo]*100](%)	12.22
	Shrinkage limit=12.22%	

Table: 4

Specific gravity

S.no	Description	Sample1 (gm)	Sample2 (gm)
1	Weight of container (W1)	34.8	35.5
2	Weight of container + soil (W2)	55.1	55.7
3	Weight of container + soil + water(W3)	87.3	87.9
4	Weight of container + water (W4)	71.9	74.1
5	Specific gravity (G)=(W2-W1)/ (W4-W1)-(W3-W2)	4.14	3.15
6	Avg specific gravity	2.66	

Table: 5

ENGINEERING PROPERTIES

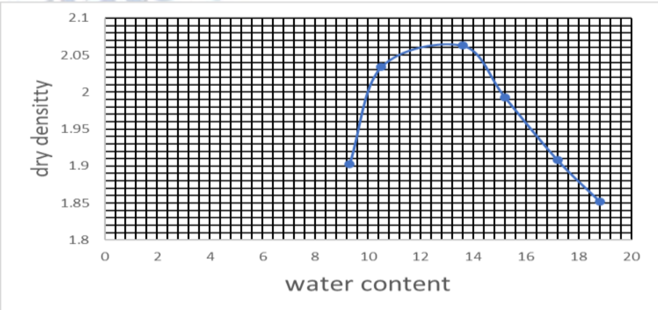
Modified proctor compaction

S. no	Description	Test1	Test2	Test3	Test4	Test5	Test6
1	Weight of container(kg)	2.84	2.84	2.84	2.84	2.84	2.84
2	Height of empty mould (cm)	12.5	12.5	12.5	12.5	12.5	12.5
3	Diameter of mould	15	15	15	15	15	15
4	Volume of mould (cm3)	2209	2209	2209	2209	2209	2209
5	Mass of mould (kg)	7.44	7.88	7.94	7.85	7.78	7.7
6	Mass of wet soil (kg)	4.6	5.04	5.10	5.01	4.94	4.86
7	Water content %	9.3	10.57	13.69	13.13	17.21	18.80
8	Bulk Density (g/cc)	2.08	2.28	2.30	2.26	2.23	2.20
9	Dry Density (g/cc)	1.90	2.03	2.06	1.99	1.90	1.85

Table: 6

Optimum moisture content: 14%

Maximum dry density: 2.06 g/cc



Graph: 2

Free swell index

S.no	Description	Sample 1
1	Vd	36
2	Vk	20
3	Vd- Vk	16
4	%Free swell index = $(V_d - V_k) / V_k$	80%

Table: 7

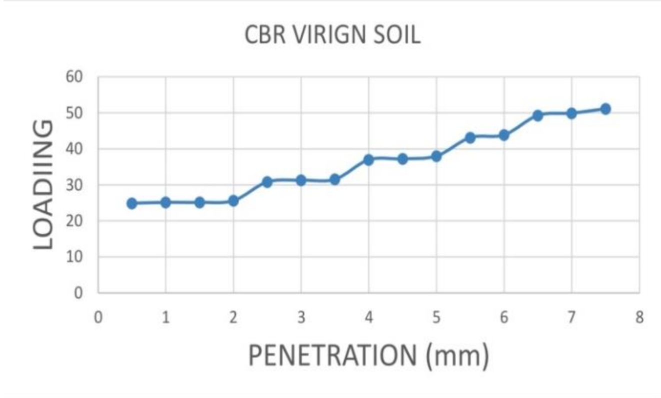
CBR Test for Virgin soil

S.no	Dial Gauge reading	Penetration	Provision reading	Loading
1	50	0.5	20.2	24.889
2	100	1.0	20.4	25.13
3	150	1.5	20.4	25.13
4	200	2.0	20.8	25.62
5	250	2.5	25	30.8
6	300	3.0	25.4	31.29
7	350	3.5	25.6	31.54
8	400	4.0	30	36.96
9	450	4.5	30.2	37.21
10	500	5.0	30.9	38
11	550	5.5	35	43.12
12	600	6.0	35.6	43.86
13	650	6.5	40	49.28
14	700	7.0	40.5	49.90

Table: 8

CBR at 2.5mm = 0.2%

CBR at 5.0mm = 0.18%



Graph: 3

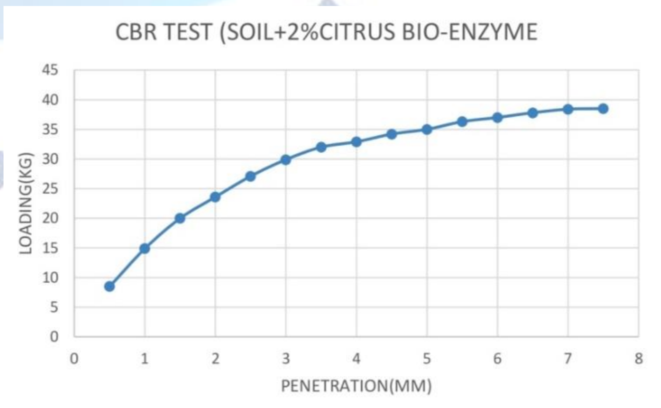
CBR TEST (SOIL+2% CITRUS BI0-ENZYME)

S.no	Dial Gauge reading	Penetration	Proving ring division	Loading
1	50	0.5	12.2	8.5
2	100	1.0	21	14.9
3	150	1.5	28.8	20
4	200	2.0	33.8	23.6
5	250	2.5	38.6	27.1
6	300	3.0	42	29.9
7	350	3.5	45	32
8	400	4.0	46.8	32.9
9	450	4.5	48.4	34.2
10	500	5.0	49.8	35
11	550	5.5	51.0	36.3

Table: 9

CBR at 2.5mm = 1.98%

CBR at 5.0mm = 1.7%



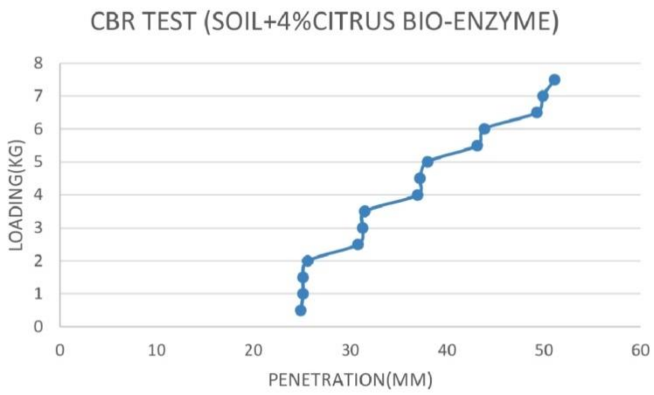
Graph: 4

CBR TEST (SOIL+4% CITRUS BI0-ENZYME)

Table: 10

CBR at 2.5mm = 5.2%

CBR at 5.0mm = 7.3%



Graph: 5

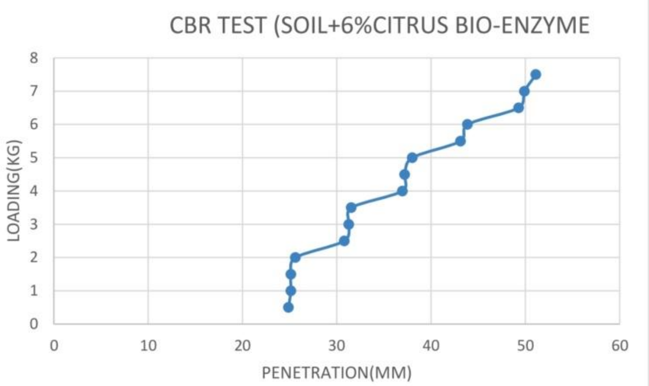
S.no	Dial Gauge reading	Penetration	Proving ring division	Loading
1	50	0.5	12.2	24.97
2	100	1.0	21	30.67
3	150	1.5	28.8	49.18
4	200	2.0	33.8	68.51
5	250	2.5	38.6	71.3
6	300	3.0	42	100.5
7	350	3.5	45	111.24
8	400	4.0	46.8	121.16
9	450	4.5	48.4	129.12
10	500	5.0	49.38	151.16

CBR TEST (SOIL+6% CITRUS BI0-ENZYME)

Table: 11

CBR at 2.5mm = 5.2%

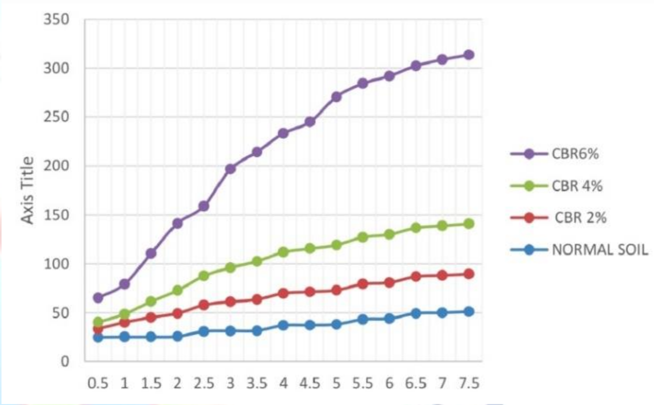
CBR at 5.0mm = 7.3%



Graph: 6

S.no	Dial Gauge reading	Penetration	Proving ring division	Loading
1	50	0.5	9.8	6.8
2	100	1.0	12.8	8.6
3	150	1.5	23	16.3
4	200	2.0	33	23.52
5	250	2.5	42	29.9
6	300	3.0	49.2	34.95
7	350	3.5	55.2	39.2
8	400	4.0	59.8	42.16
9	450	4.5	62.8	44.30
10	500	5.0	65.4	46.30

COMPARASION OF CBR VIRGIN SOIL AND MIXED CITRUS BIO-ENZYME GRAPH



Graph: 7

UNCONFINED COMPRESSIVE STRENGTH TEST (UCS) TEST

Initial Length = 7.6cm

Initial Diameter = 3.8 cm

Initial Area = 11.34cm^2

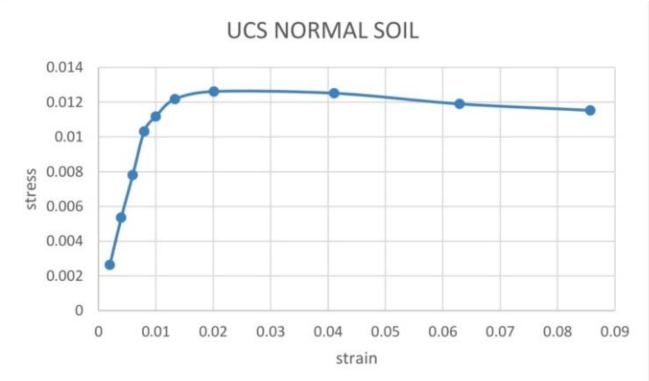
Initial Mass of Specimen = 120

Initial Water Content = 14%

By conducting the test, the tabular values obtained,

Unconfined compressive strength q_u=0.125N/mm^2

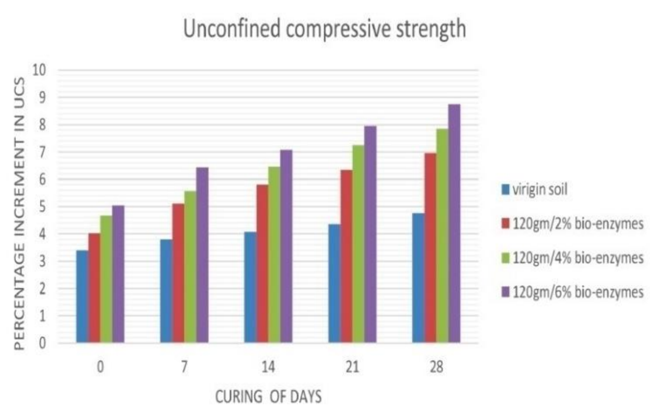
Undrained shear strength Cu=0.062N/mm



Graph: 8

UNCONFINED COMPRESSIVE STRENGTH TEST (UCS) TEST FOR (VIRIGIN SOIL+2%,4%6%)

Table: 12



Graph: 9

V.CONCLUSIONS & RECOMMENDATONS

Conclusions:

The following conclusions are drawn from the results of investigation carried out with the scope of the study.

- The soil sample contains major part of clay (C) and it is classified as highly compressibility clay.
- The unconfined compressive strength of the soil is 12.5*10^-3 KN/cm^2.
- The California bearing ratio of the soil when it is soaked is 0.2 % & 0.18 % with 2.5mm & 5mm penetration.
- The CBR for Bio enzymes with soil at 2% is 1.98 % & 1.7 % with 2.5mm &5mm penetration.
- The CBR for Bio enzymes with soil at 4% is 2.18 % & 2.15 % with 2.5mm & 5mm penetration.
- The CBR for Bio enzymes with soil at 6% is 5.2 % &7.3 % with 2.5mm &5mm penetration.
- The best results given at 6 % Bio- enzymes mixed with soil when compared to the 2 % & 4 %
- So, 6% is considering as effective percentage of Bio-enzymes to get the best CBR improvement.

Recommendations

Based on the findings of the research, the following recommendations are forwarded.

- As the expansive soil has low bearing capacity, we recommended Bio enzymes used to stabilize the soil.
- It makes the environmentally friendly, organic, nontoxic and also biodegradable in nature.
- It improve stability of soil, sub base of pavement structure.

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