SOIL STABILIZATION USING NANO CHEMICAL TERRASIL AND ZYCOBOND

MAJOR-II REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS

FOR THE AWARD OF DEGREE OF

MASTERS OF TECHNOLOGY

IN

GEOTECHNICAL ENGINEERING

SUBMITTED BY

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JUNE 2020

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CANDIDATE'S DECLARATION

I, **MOHIT PARASHAR, 2K18/GTE/08** student of M-tech (GEOTECHNICAL ENGINEERING CIVIL DEPART.), hereby declare that the dissertation entitled "**SOIL STABILIZATION USING NANO CHEMICAL TERRASIL AND ZYCOBOND**" which is submitted by me to department of Civil Engineering, Delhi Technological University, Delhi In Partial fulfillment of the requirement of the award of the degree of Master Of Technology , is original and not copied from any source without proper citation .This work has not formerly formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other alike title or recognition.

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Date: 29th Aug 2020

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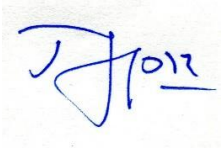
CERTIFICATE

I hereby certify that the dissertation entitled "**SOIL STABILIZATION USING NANO CHEMICAL TERRASIL AND ZYCOBOND**" which is submitted by **MOHIT PARASHAR, 2K18/GTE/08** to department of Civil Engineering Delhi Technological University, Delhi In Partial fulfillment of the requirement of the award of the degree of Master Of Technology, is record of the project work carried by the Student under my supervision. To the best of my knowledge this work has not been put forward in part or full for any Degree to this University or elsewhere.



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ACKNOWLEDGEMENT

I thank my parents and God almighty for bestowing their blessings and grace in completion of this major project II.

I express my sincere thanks to the respective V.C. of DTU and respective HOD of Civil Engineering Department and to the University Management . As I write this acknowledgement , I must shed light that this is not just a conventional acknowledgement but also a sincere note of thanks and regards from my side . I feel a deep sense of gratitude and affection for those who associacted with the project and without whose co-operation and guidance this project could not have been conducted properly.

Words fail me to express my regards towards my project guide , **Prof. A.K. Gupta** , Department of Civil Engineering ,Delhi Technological University , Delhi for giving me an opportunity to work under his guidance , which really instilled in me the requisite confidence. I also express my deep gratitude to all the Faculty members of Department of Civil Engineering . Last but not the least , I would like to thank my family and friends who stimulated me to bring this work to a successful close.

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LIST OF ABBREVIATION

C_u = Coefficient of uniformity

C_c = Coefficient of curvature

D_{10} = Effective particle size (m)

D_{30} = Diameter through which 30 % of the total soil particles is passing

D_{60} = Diameter through which 60 % of the total soil particles is passing

SM = Silty sand

OMC =Optimum moisture content

G = Specific gravity of soil

MDD = Maximum dry density

ABSTRACT

Many civil engineering structures fail due to failure of soil underlying the structure for construction of buildings, dam, bridges, etc. There are different improvement methods for treating and improving in situ soils, such as reinforcement, chemical stabilization, compaction, and lowering the groundwater level. Nowadays, in addition to traditional stabilization materials, nano chemicals also are used in soil stabilization. Nano Chemicals, because of their high particular surface area and surface charges, have the capability to significantly affect the engineering properties and behavior of soils, even if there is a small amount of them in the soil. The progress in materials science is based on the principle that properties of materials are due to their internal structure. In other words, material properties can be modified by proper changes in their structures.

In this project we are dealing with two major problems one is rainfall and other is to control the sand dunes (in desert) or soil erosion in several areas on underlying weak soil and soil is not that much strong to bear the load coming from daily traffic conditions as per IRC SP 72 so our aim to increase the strength of the underlying soil to overcome the failure of soil . As this being the most important factor for the destruction of the various civil engineering structures like road pavement, bridges, dams and many big structures. As per current research and history in this study our aim is to waterproofing of underlying soil and controls the soil erosion or sand dunes in deserts along with providing sufficient strength by using certain amount of cement. And we are doing it with two nano product terrasil and zycobond along with cement.

Basically, for stabilizing underlying base with terrasil and zycobond there are two ways of injecting it into the base, First we can spray the solution of terrasil and zycobond of different dosage on the dry compacted bed of soil to when our prime objective is water proofing and dust controlling of the base. Second we can mix terrasil and zycobond along with cement with underlying soil to increase the CBR values along with waterproofing and dust controlling.

1. INTRODUCTION

As the population is increasing day by day there is reduction of availability of a good land for construction, thus now a day's more construction of buildings and other civil engineering structures have to be carried out on weak or soft soil in urban areas and as in hilly areas we left with no other option for civil engineering construction due to less availability of land mainly for the road pavements. These soil of poor shear strength, has to be treated by some suitable means mostly soil stabilization and reinforcement are employed to improve mechanical behavior of soil, thus improving the reliability of construction. weak soil has the property of high swelling and contraction when exposed to changes in moisture content and hence have been found to be most infuriating from engineering considerations .which we are going to show how we can control it in our current study ,Along our aim to increase the strength of this weak soil using terrasil and zycobond along with cement as per IRC SP 72.

As the failure of underlying soil which is expansive or weak in nature shows high swelling and shrinkage in rainfall prone areas mainly in hilly areas rainfall is major component for the failure of underlying soil and heavy rainfall also arises the problem of soil erosion. In India, there is a huge problem of demolition of roads during monsoon season due to heavy raining. The roads investigated experienced severe failure like cracking, potholes, etc. there are effects on road transport system, accident is the major problem due to damp surface and widening of potholes. In India, soil erosion is also a big problem in desert which transport the soil due to heavy movement of traffic which also effects the health of the community and causes visibility problems in area. This project deals with waterproofing of underlying soil and controlling soil erosion upto maximum extent using two nano compounds mainly named as terrasil and zycobond and presenting soil stabilization using terrasil and zycobond along with cement.

2. LITREAURE REVIEW

A number of researchers have worked in improving the properties of soil for various engineering application which are practical and economical. The following literature review describes important research results regarding use of terrasil and zycobond in soil improvement.

Nandan A. Patel, Mishra C. B., D. K. Parmar, Saurabh B. Gautam -(2015) in "Subgrade Soil Stabilization using Chemical Additives" stressed that it is the obligation of the road powers to utilize the nearby material and right the soil properties utilizing added substances upgrading the grade of soil and make the road hefty. Test result shows that engineering properties got altered and CBR on balanced out clayey examples expanded remarkably, which glasses the lower thickness in linking with regular trademark soil properties. Also the cost is diminishing which points of interest the Road developer's engineers, strategy producers and asphalt originators too also found that the addition of Terrasil (0.041%) + zycobond (0.020%) to the soil the CBR value increased from 6.64% to 12.15%. This signifies that the quality of subgrade soil is boosted consequently mounting the load carrying limit of pavement .

Johnson R, Rangaswamy K – (2015) in his work on " Improvement of soil properties as a road base material using nano chemical solution" The soil was collected from Kunnamangalam area of Calicut district in Kerala and the Terrasil nano chemical was collected from Zydex Industries Ltd. for the stabilization studies. Experimental programs were carried out on both clay and cement treated clay treated with different dosages of Terrasil. Samples were prepared with 0.05%, 0.07% and 0.09% Terrasil and 1% cement by weight of soil. Results obtained were paralleled and studied. It is found out that increment in dosage of Terrasil the CBR quality of soil blended with ideal dose of 0.07% terrasil chemical is enhanced around 6 times the CBR quality of clay soil. The treated soil was observed to be impermeable. The optimum dosage of terrasil was obtained as 0.07% by weight of soil and the strength was maximum for 4% cement content.

Chaudhary R, Tabiyar S, Bholanda H, Chaudhari S (2016): The focus is to assess engineering properties of adjacent soil material with and without using Nano chemical terrasil

stabilizer of 0.041% percent dose and to discover the changes in CBR values for the thickness of adaptable elastic pavement design. Soil stabilization with terrasil offers the bitumen build a different. The procedure not just offers the capacity to improve the designing attributes of an unsatisfactory soil, additionally offers the specialist a more supportable way to deal with bituminous road development. Construction cost analysis for soil with and without additive is calculated. The results shows that soil mixed with 0.041% Terrasil, (as per Zydex Laboratory test protocol) is economical and is beneficial. Also load carrying capacity is increased. Thus it justifies from economy point of view, benefit associated with the utilization of chemical stabilizer such as Terrasil for enhancing the sustainable development in road construction needs to be worked evaluated.

Lekha B.M , Goutham S, Shankar A U – (2013) in his work on "Laboratory investigation of soil stabilized with Nano chemical" communicates the performance of Black Cotton (BC) soil with and without modification with compound named Terrasil demonstrated specific assessments and cured for 7-28 days. The vital geotechnical properties of soil were CBR qualities acceleration with the accumulation in rate of stabilizer. Vulnerability is seen to be nil for treated soil. The recognition record communicates those UCS quality augmentations with growth in measurements of stabilizer and curing period.

Nandan A. Patel, Mishra C.B, Vasu V. Pancholi (2015) In their paper titled "Scientifically Surveying the Usage of Terrasil Chemical for Soil Stabilization" highlighted that it is the accountability of the road authorities to use the native material and correct the soil properties using additives improving the strength of soil and make the road sturdy. The examination was completed to center first soil engineering properties (with and without stabilizer), standard compaction; four days soaked California Bearing Ratio (CBR), permeability test and cyclic loading test according to codal procurement. A nano chemical named Terrasil was employed as stabilizer and it was utilized for altered measurement i.e. 0.041% by dry aggregate weight of soil test according to the convention of Zydex Industries, Vadodara. Test outcome validates that designing properties got improved and CBR on stabilized clayey samples increased considerably, which reflects the lower thickness in correlation with natural distinctive soil properties.

Additionally the expenditure is diminishing which advantages the road builders, engineers, policy makers and pavement designers as well.

Nandan A. Patel and Mishra C.B. (2014) - "Improvement the Strength of Inorganic Clayey Soil using Cement Additive" states that the disappointments of pavement in form of heave depression cracking and disproportion are caused by the seasonal moisture deviation in subgrade soil. The correct stabilization of foundation soils constitutes an progressively important issue in the present civil engineering world to amend the properties of soil to meet the desired engineering properties for improving strength and sturdiness. Initially the investigation of soil is carried out to evaluate the physical and engineering properties as per Indian Standard classified as CL (Clay soil having low plasticity) as per Indian Standard (1498 – 1970) by conducting laboratory tests and to assess the enhancement in properties by the addition of 2 % PPC as stabilizers to be used in pavement design for economy.

Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018)- "A Study On The Effect Of Stabilizers(Zycobond & Terrasil) On Strength Of Subgrade On Black Cotton Soil'' states that The level of improvement is very significant. In view of this, the practicing Engineers may consider stabilization of soft clayey in-situ ground by Terrasil and Zycobond stabilization, to economise the pavement layers. Interestingly, the commercial stabilizers viz, Zycobond and Terrasil, found to be more fruitful .This study is likely to provide valuable inputs to the practising Engineers. For the clay used in this study there was a increase of 57.21% in the CBR value for unsoaked condition when it is stabilized with Terrasil and Zycobond. At the end it is notified that 0.6kg Terrasil and Zycobond is giving significant improvement in both CBR values(Soaked and Unsoaked).

Olumuyiwa S. Aderinola, Emeka S. Nnochiri (2017)"Sabilizing Lateritic Soil Using Terrasil Solution'' This study considers stabilizing lateritic soil using Terrasil solution. Initial tests were carried out on six natural soil samples from three borrow pit locations-two soil samples from a specific borrow pit location, for the purpose of identification and sorting. Soil samples 1 and 2 from borrow pit 3 were found to be poor, hence, needed stabilization. While the

other four samples from borrow pits 1 and 2 were found to be good enough. Engineering property tests such as California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and Compaction tests were executed on both the natural soil samples and the stabilized lateritic soil samples which were stabilized by adding terrasil solution in percentages ranging from 0% to 16% at 2% interval. The results showed that the addition of terrasil solution improved the strength of the two soil samples from borrow pit 3. For soil sample 1, the unsoaked CBR values increased from 8.4% at 0% to optimum value of 30.3% at 12% terrasil solution, while for soil sample 2, the unsoaked CBR values increased from 6.2% to optimum value of 32.0% at 12% terrasil solution. It was therefore established that the terrasil solution serves as a cheap and effective stabilizing agent for poor soil.

Raghavedra T., Rohini B., Divya G , Sharooq S.A, Kalyanbabu B(2015) "Stabilization Of Black Cotton Soil Using Terrasil And Zycobond'' states that the rate of montmorillonite is more in black cotton soil which causes expansiveness and crack occurs in soil without any warning which is dangerous for construction. Such expansive soils are very prone to detrimental volume variations with changes in moisture content. Expensive soils because of their precise physical & chemical make are exposed to volume changes. In this study nano chemicals terrasil and zycobond used for soil stabilization. In this investigation Cement is used in the constant proportion of 3% of amount of soil and the nano chemicals terrasil and zycobond are used are 0.6kg/m3, 0.8kg/m3, 1kg/m3, 1.2kg/m3 of each. And this paper concluded that Free Swell index is decreases from 30% to 27.5% with the addition of 0.6kg/m3 of Terrasil and Zycobond and decreased to 26.3%, 25%, 21.05% with the addition of 0.8kg/m3,1.0kg/m3,1.2kg/m3 when compared to 0% of Terrasil and Zycobond.

2.1 CONCLUSION FROM LITERATURE REVIEWS

Various type of possible and cost effective stabilization technique of the soil properties enhancement were presented in this literature review. It is clear that by use of terrasil and zycobond along with cement almost all the engineering properties of weak soil get modified. And the basic facts behind that by using terrasil and zycobond it create water repellent layer which makes soil hydrophobic results in waterproofing of soil base which reduces the swelling

and shrinkage of weak soil occurs due to seepage of water and cement provide sufficient strength to the soil base against the load coming on it.

3. MATERIAL AND METHODOLOGY

As, there are two ways of injecting these nano products into underlying soil according to our result objectives as follows,

3.1 WATERPROOFING AND DUST CONTROL OF SOIL USING TERRASIL AND ZYCOBOND (Mainly in hilly areas and desert areas)

3.1.1 MATERIAL USED

Following are the Materials and equipments have been used in this experiment.

- Silty sand (SM)
- Terrasil
- Zycobond

3.1.1 A) PROPERTIES OF SOIL(Silty sand)

- **Procurement**

The silt which we use in our experiment is collected from DTU college only. It underwent through cleaning to remove the debris from it like organic particles, gravel ,stones etc. The soil was then sieved through a 2.6 mm sieve to remove gravel and lumps of clay.

- **Classification of soil**

Dry Sieve analysis: After procurement of soil dry sieve analysis perform over the respective soil.

Fig 1: Sieve analysis arrangement

Table 1: Sieve Analysis

Seive size(mm)	WEIGHT RETAIND gm	Retained percentage %	cumulative Retained %	pass percenatge %
4.75	58.9	5.89	5.89	94.11
2.36	53.7	5.37	11.26	88.74
1.18	138.48	13.84	25.1	74.9
0.6	84.74	8.47	33.57	66.43
0.3	260.18	26.018	59.58	40.92
0.15	218.36	21.83	81.418	15.582
0.075	145.3	14.53	95.941	4.052
PAN	38.7	3.87	99.818	0.19

The % soil weight retained on the each sieve was noted on the refrence with the total weight of soil taken during the test . Then cumulative % of soil retained (which gives th % finer when subtracted from 100) on successive sieve is calculated.

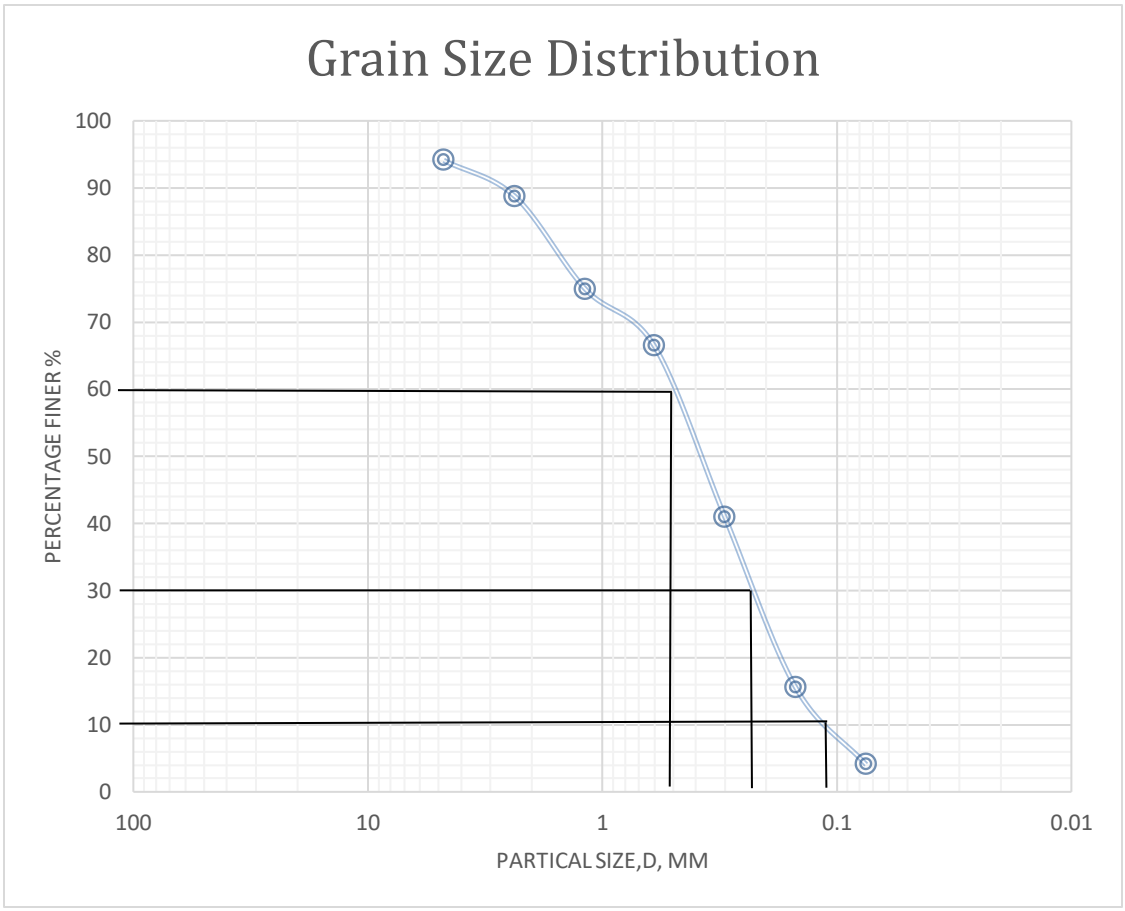

Fig 2: Particle Size Distribution of soil

D60 = 0.6 mm , D30 = 0.15mm , D10 = 0.075mm

Uniformity coefficient Cu =8

Coefficient of curvature Cc = 1

Cu is more than 5 and Cc is lie in the 1 to 3, so this is well graded soil .

- **Specific gravity**

As per IS:2386-1963 ,pycnometer test is generally used in determination of the definite gravity of soil . with the help of following equation Specific gravity can be determined **.**

$$\mathbf{G} = \frac{(W2-W1)}{(W2-W1)-(W3-W4)}$$

Where ,

W1 is weight of empty pycnometer

W2 is weight of pycnometer with soil

W3 is weight of pycnometer with water and soil.

W4 is weight of pycnometer filled completely with water.

Table 2: Specific Gravity

Weight (gm)	**Sample 1**	**Sample 2**	**Sample 3**
W1	**687**	**688**	**689**
W2	**1115**	**1088**	**1107**
W3	**1840**	**1806**	**1823**
W4	**1575**	**1580**	**1596**
G	**2.62**	**2.29**	**2.18**

Sample calculation

For sample 1: $\mathbf{G} = \frac{(1115-687)}{(1115-687)-(1840-1575)} = 2.62$

Average value of specific gravity is **2.36** which is in normal range as per IS:2386 1963 for silty sand.

- **Liquid limit (W_L)**

It is well-defined as the liquid state at which soil having minimum water content and poses a very less strength against its flowing behavior , which can be estimated by standard evaluated means.Casegrande apparatus is used for finding out the liquid limit

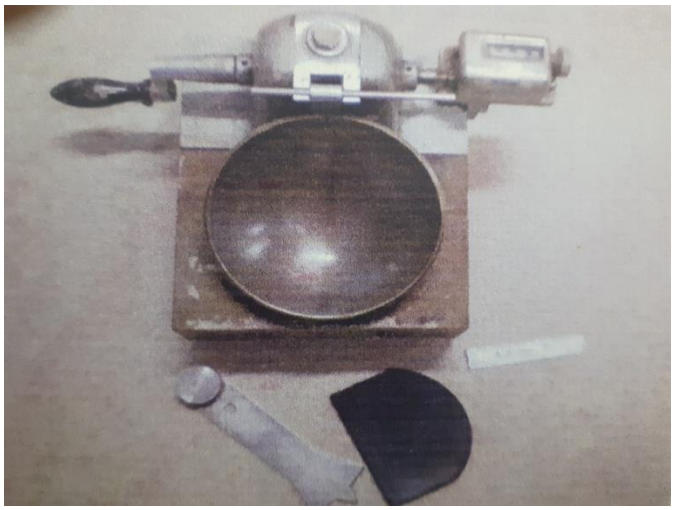

Fig 3: Casegrande Apparatus

Table 3: Liquid limit

No of blows	W1 (grams)	W2(grams)	Water content %
28	15.73	12.45	26.34
24	17.71	14.80	19.66
21	13.26	11.21	18.28
20	18.31	15.75	16.25

Where,

W1 = Weight of wet soil sample

W2 = Weight of Dry sample

Sample 1 calculation for water content

Water content (w) = $\frac{(W2-W1)}{W2}\ X\ 100\ = \frac{(15.73-12.45)}{12.45}$ X 100 = 26.34 %

Average water content in the soil mass = 20.13 %

Calculation for Liquid limit Determination following graph will give the worth of liquid limit respectively whatever will be the value of water content at 25 blows will give the liquid limit of the soil mass.

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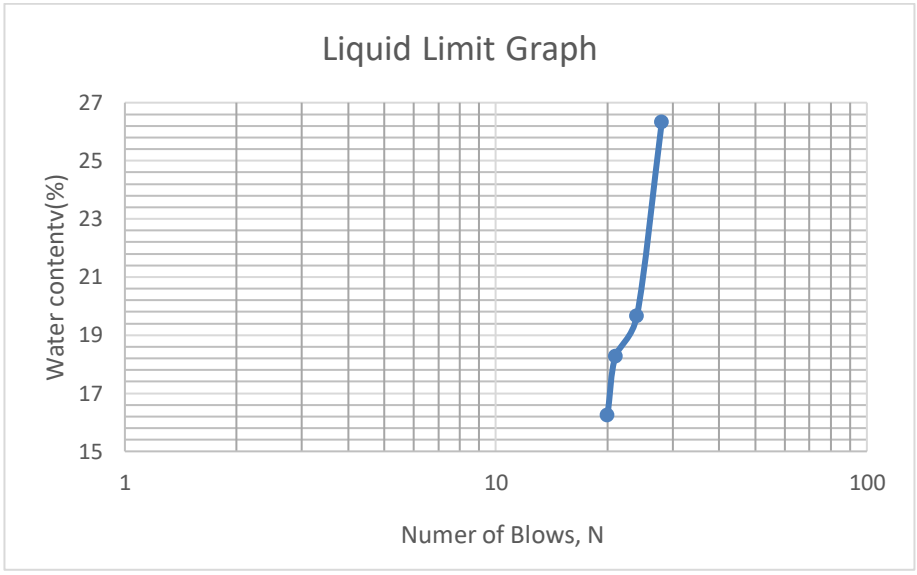

Fig 4: liquid limit graph

With the help of graph the liquid limit value will be = 20.6

- **Plastic limit (W_P%)**

It is the property of the soil which is defined as the lowermost water content and can be determined as a weight percentage of dried soil at which it can easily rolled into 3.2 mm diameter without breaking into pieces.

Table 4: Plastic limit

W1(grams)	W2(grams)	Water content %
3.04	2.66	14.28
2.45	2.07	18.35
4.18	3.66	14.21

Where,

W1 is the weight of wet soil sample

W2 is the dry weight of the soil sample

After calculating it the average plastic limit will be = 15.61

- **Standard Proctor Test**

To determine the optimum moisture content (OMC) and maximum dry density of soil in laboratory , standard proctor compaction was performed . It is defined as the minimum moisture content at which the soil specimen will become highly dense and obtains its maximum value of dry density . in this soil was filled in three layers in proctor compacted mould and each layer was given 25 blows by proctor compaction hammer weighting 2.6 kg.

Table 5: Standard proctor test

Weight of mould +soil	**Weight of soil (grams)**	**ρ_d (gm/cc)**	**Υ_d (kN/m^3)**	**W_1 (grams)**	**W_d (grams)**	**Water content**
3660	1500	1.47	14.42	21.21	20.36	4.17
3760	1600	1.57	15.4	16.73	16.73	9.34
3935	1775	1.74	17.07	12.11	12.11	9.9
3885	1725	1.69	16.58	16.1	16.1	11.3
3690	1530	1.5	14.715	14.16	14.16	15.4

Sample 1 calculation for Dry density and moisture content

$$\rho_d = \frac{weight\ of\ soil}{volume\ of\ mould} = \frac{1500}{1020} = 1.47\ gm/cc$$

$$\Upsilon_d = 1.47 \times 9.81 = 14.42\ kN/m^3$$

So from the above table we obtain the supreme dry density = 14.42 kN/m^3 and optimum water content will be 9.9 %.

Properties Of silty sand

Table 6: Properties of silty sand

SL. NO	PROPERTY	CODE REFERRED	VALUE
1.	Specific gravity	IS 2386(Part-3) 1963	**2.36**
2.	Maximum dry density	IS 2720 (Part-7), 1980	**14.42 kN/m^3**
3.	OMC	IS 2720 (Part-7), 1980	**9.9%**
4	Liquid limit (W_L)	IS 2720 (Part-5), 1985	**20.6%**
5.	Plastic Limit (W_P)	IS 2720(Part-5) 1985	**15.6%**

3.1.1 B) TERRASIL:

Terrasil is nanotechnology based product produced by Zydex Industries Ltd., Gujarat. Terrasil is water soluble, ultra violet and heat stable, responsive soil modifier. It improves the frictional value, reduces water penetrability and maintains breathability of the soil layer.

Table 7: Chemical composition of terrasil

Chemical compound	**Value in range, %**
Hydroxyalkyl-alkoxy-alkylsil	65 – 70%
Benzyl alcohol	25 – 27%
Ethylene glycol	3 – 5%

Table 8: Physical properties of terrasil

Property	**Description**
Appearance	Pale yellow liquid
Density	1.01g/cc
Viscosity at 25ºC	20-100 cP
Solubility	Forms water clear solution
Flash Point	$>80^0$C
Freezing point	5^0C

Fig 5: Terassil

3.1.1 C) ZYCOBOND

Zycobond is a sub-micron acrylic copolymer emulsion with long life of above 10 years for bonding soil particles. It imparts water proofing and resists water ingress through the unpaved areas like shoulders and slopes. Characteristics of the chemical stabilizer used in this work are shown in Table 3. It is manufactured by ZYDEX INDUSTRIES.

Table 9: Physical properties of zycobond

Parameter	**Value**
Colour	Milky White
Odour	No
Flash point	Above 100º C
Explosion hazard	No
Ignition temperature	Above 200º C
Solubility in water	Dispersible
PH value	5-6

Fig 6: Zycobond

3.1.2 METHODOLOGY

EXPERIMENTAL PROCEDURE

- Take three rectangular tray of size .267 X .305 m^2.

Fig 7: Tray

- Sieve the soil sample through 4.75mm sieve

Fig 8: Sieving of soil sample

- Oven dry the sieved soil sample for 24hrs at 105ºC and than mix OMC water content in dried sample.

Fig 9: Mixing OMC in dried soil sample

- Prepare three bed sample in tray of prepared soil sample of OMC using light compaction to stimulate the field condition.

Fig 10: Moist compacted bed sample.

- After that moist compacted bed put into oven for 24hr at 105ºC to get dry compacted bed.

Fig 11: Dry compacted bed

- Prepare solution of terrasil and zycobond wih water in three ratios by weight and spray it on the top of the bed as it is discussed in previous research work.

Fig 12: Solution of terrasil and zycobond with water

Fig 13: compacted bed after spraying solution

- Dry the sprayed compacted bed for 4 days at room temperature.

Fig 14: dry sprayed bed sample

- After placing water droplet on the dried bed on it is found that there will be no seepage through soil and no soil erosion as shown.

Fig 15: Condition after placing water droplets

3.1.3 CALCULATION AND RESULT

CALCULATION

As per previous research done by various researchers it is suggested that for one meter square bed we have to apply 3 liters of solution on dry compacted bed.

Dry compacted bed area taken in study is .267 X .305 m^2 = .0813 m^2

So, for .0813m^2 area .0813 X 3000 = 245ml of solution is required.

For better accuracy we make 300ml solution than we take 245ml from that and spray it.

- First solution sample 1/800 of terrasil and zycobond.

Quantity of terrasil and zycobond required in 300ml solution = 300/800 = .375 gm

- Second solution sample 1/400 of terrasil and zycobond.

Quantity of terrasil and zycobond required in 300ml solution = 300/400 = .75 gm

- Third solution sample 1/200 of terrasil and zycobond.

Quantity of terrasil and zycobond required in 300ml solution = 300/200 = 1.5 gm

Table 10: Dosage of Terrasil and Zycobond in solution

S.NO	SOLUTION	TERASSIL REQ.	ZYCOBOND REQ.
1	1/800	.375gm	.375gm
2	1/400	.75gm	.75gm
3	1/200	1.5 gm	1.5gm

RESULT

Optimum dosage as per experimental results for waterproofing and dust control of soil is coming out to be 1/400 i.e for .0813 m^2 the optimum quantity of terrasil and zyconond required is .75gm.

3.2 INCREASING LOAD CARRYING CAPACITY ALONG WITH MAKING SOIL BASE IMPERMEABLE BY USING TERRASIL AND ZYCOBOND.

Mainly in construction of pavement on weak soil leads to various challenges in daily practice for road constructions. So, as of now new nano technology comes under practice as it offers various benefits for weak soil along with increasing the load carrying capacity of soil by making soil subgrade impermeable which is one of the main problem with the weak soil because they show high swelling and shrinkage which is very challenging in today's world.
And this can achieve by adding terrasil and zycobond along with cement. California bearing ratio (CBR) of such soil comes very low which leads to increase the depth of pavement in turns it becomes uneconomical so, are prime objective is to increase this CBR value to counter these problems as suggested under IRC SP-72 for different categories of traffic.

For understanding these facts some previous research and history are going to present in these study on different clayey soil (weak soil).

3.2.1 EFFECT ON CBR

Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018) studied black cotton soil tested using stabilizing agent terrasil and zycobond. In these reaserch they compare the CBR(soaked and unsoaked) at different dosage of terrasil and zycobond.

- Properties of soil.

Subgrade soil, clayey soil which is used in the work was collected from Kothapallu village near bheemadevarapally mandal, Karinagar district , Telangana. The engineering and index properties of the soil used are as follows,

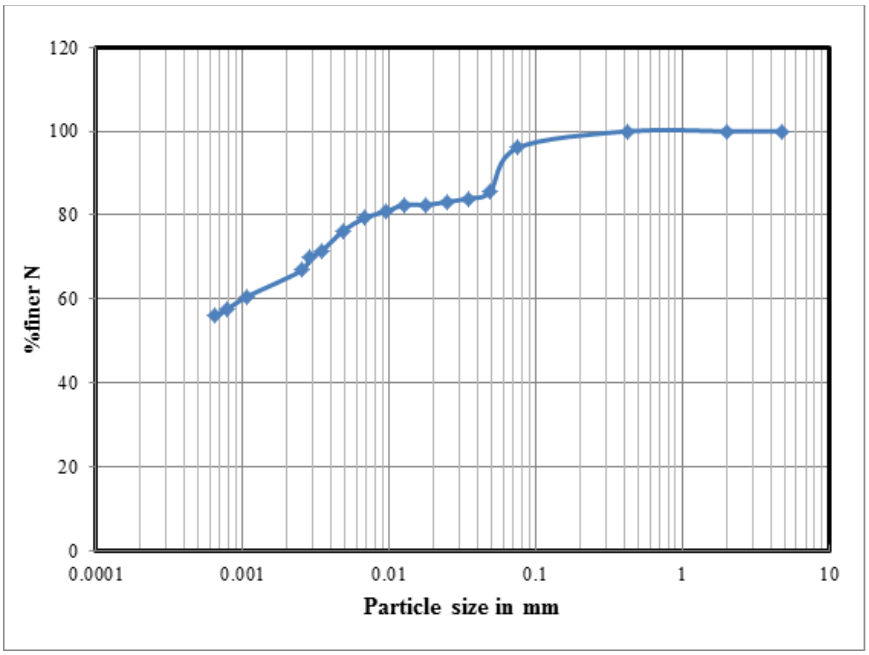

Fig 16: Particle Size Distribution of soil

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

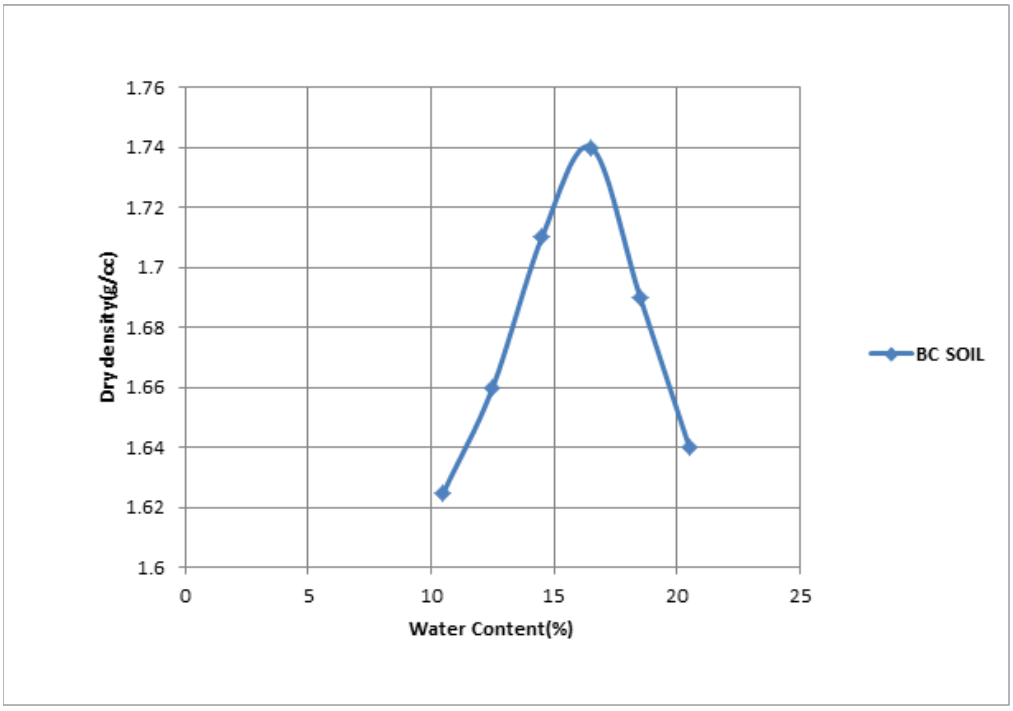

Fig 17: Compaction curve

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

Table 11: Properties of soil

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

SL. NO	Property	Value
1.	Specific gravity	2.58
2.	Differential Free Swell %	90
3.	Liquid Limit %	60
4.	Plastic Limit %	35.4
5.	Plasticity Index %	24.6
6.	Gravel Size Particles %	0%
7.	Sand Size Particles %	33%
8.	Silt Size Particles %	42%
9.	Clay Size Particles %	29%
10.	MDD (ISHCT)	1.74g/cc
11.	OMC (%)	16.5%
12.	Classification as per IS:1498-1970	CH
13.	UCC kg/cm2	1.82
14.	CBR Unsoaked %	2.7
15.	CBR Soaked 4days %	2.18

EXPERIMENTAL PROCEDURE OF CBR TEST(STABILIZED SOIL)

- Take 5 to 6 Kg air dried and pulverized soil sample passing through 4.75 mm sieve.
- Taken soil sample is thoroughly mixed with water at OMC with stabilizers i.e terrasil and zycobond.
- Take standard mould, after fixing the extention collar and placing te base plate at bottom, the soil is compacted in five layers of 56 blows to each layer by using standard hammeer.
- After compaction, the soil layer is levelled uniformly.

- The same procedure is continued up to the top level depending upon number of layers. The collar is removed and excess soil is trimmed off. The mouldis reversed and displacer disc is detached.
- The surcharge weight is placed on the top of the specimen. The mould is placed on the loading machine and the load and penetratin dial gauges are set to zero.
- The load is applied on the specimen at the rate of 1.25mm/min.
- The load reading are recorded at penetration 0, 0.5,1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5.
- The load penetration curve is drawn and CBR value is calculated at 2.5 mm and 5.0 mm penetration and higher of these two values is taken.

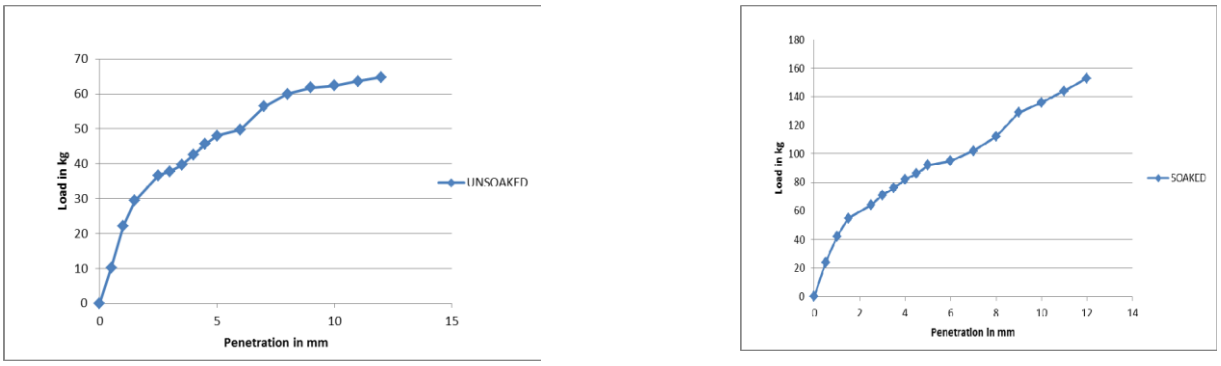

Fig 18: load vs penetration curve of unstabilized soil (unsoaked and soaked)
(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

Table 12: CBR result of unstabilized soil
(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

Test Condition	CBR Test Results	
	Unsoaked	Soaked 4 days
Unstabilized soil	2.7	2.18

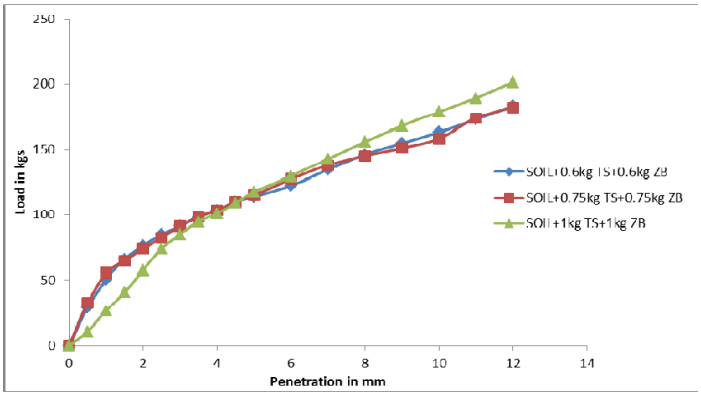

Fig 19: Load vs Penetration of soil stabilised with Terrasil and Zycobond in Unsoaked condition at different dosage.

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

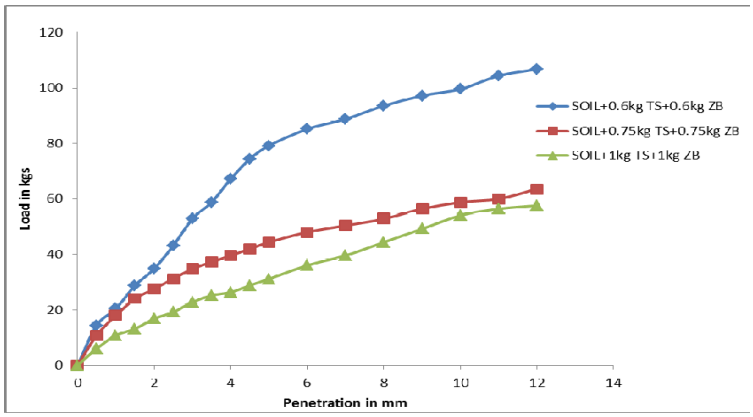

Fig 20: Load vs Penetration of soil stabilized with Terrasil and Zycobond in 7 days soaked condition

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

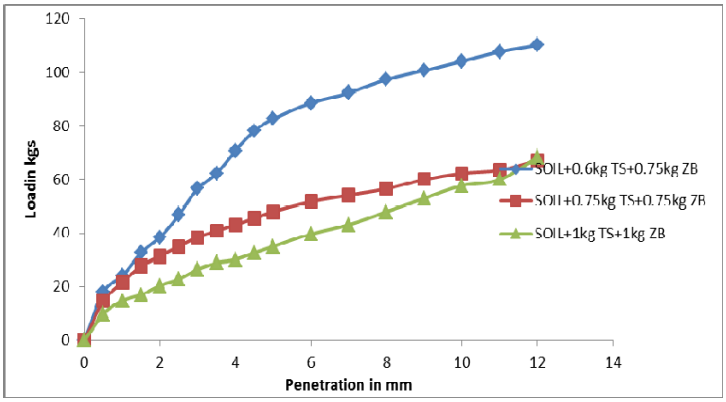

Fig 21: Load vs Penetration soil stabilised with Terrasil and Zycobond in 14 days soaked condition.

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

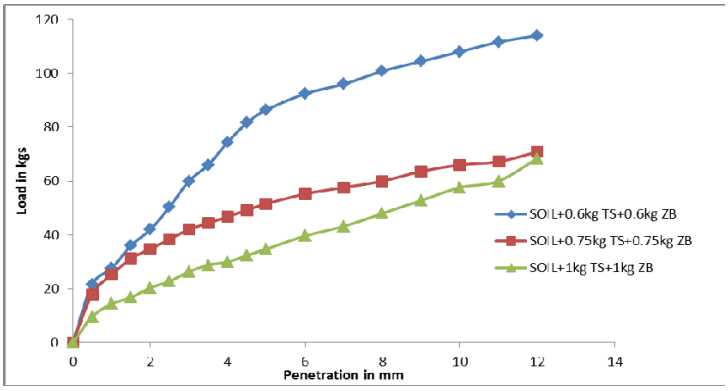

Fig 22: Load vs Penetration soil stabilised with Terrasil and Zycobond in 28 days soaked condition.

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

Table 13: Variation in CBR values

(Rohith S.R, Kumar S.R, Paul W, Kumraswamy N (2018))

Terasil& Zycobond	CBR Test Results			
	Unsoaked	Soaked 7 days	Soaked 14 days	Soaked 28 days
0.6 kg	6.31	3.2	3.4	3.72
0.75 kg	6.13	2.31	2.57	2.83
1 kg	5.51	1.42	1.68	1.94

As it is clearly seen in above figures, the addition of terrasil and zycobond to the soil, indicated improvement in unsoaked CBR value as 2.7% to 6.31%.The zycobond is the chemical binder injected in liquid form, its effect may have commenced during the preparation of the CBR test mould and may have resulted an increase. Addition of terrasil and zycobond to a soil, indicated improvement in the soaked (7 days) CBR value as 2.18% to 3.2% for a dosage of 0.6 Kg terrasil and zycobond and it is also seen that as the dosage increases the CBR value decreases from 2.18% to 1.42%.

As on increasing the soaking period taken in study like 14 days and 28 days it is clearly seen higher the soaking period more will be the improvement in CBR value using terrasil and zycobond upto optimum dosage. Addition of terrasil and zycobond to a soil, indicated improvement in the soaked (14 days) CBR value as 2.18% to 3.4% and soaked (28 days) value as 2.18% to 3.72% for a 0.6 Kg terrasil and zycobond. As the curing period increases the ability to react the chemical with soil increases and it is more for 0.6 Kg chemical and it is decreasing as the chemical dosage increases.

3.2.2 EFFECT ON FREE SWELL INDEX

Raghavedra T., Rohini B., Divya G , Sharooq S.A, Kalyanbabu B(2015) studied black cotton soil with a stabilizing agent terrasil and zycobond along with cement. In this reaserch they compare the value of Free swell index at a different dosage with of terrasil and zycobond with fixed proportion of cement.

- Properties of soil

The soil used in this research is black cotton soil collected nearby from RGM College, Nandyal. The soil and index properties are as follows,

Table 14: Properties of soil

(Raghavedra T., Rohini B., Divya G , Sharooq S.A, Kalyanbabu B(2015))

SL. NO	Property	Value
1.	Specific gravity	2.57
2.	Free Swell Index %	30%

3.	Liquid Limit %	52%
4.	Plastic Limit %	26.78%
5.	Plasticity Index %	25.22%
6.	Gravel Size Particles %	1%
7.	Sand Size Particles %	26%
8.	Silt Size Particles %	38%
9.	Clay Size Particles %	35%
10.	MDD (ISHCT)	1.63g/cc
11.	OMC (%)	20.3%
12.	UCS kg/cm2	4.79kg/cm^2
13.	CBR Unsoaked %	3.85

EXPERIMENTAL PROCEDURE OF FREE SWELL INDEX (STABILIZED SOIL)

- Take dried and pulverized soil sample.
- Add water equals to the OMC of the soil which is calculated from compaction test along with terrasil and zycobond and mixed thoroughly.
- After that placed the soil specimen under sun for one hour and sieved again through 425 microns to avoid the development of lumps.
- 20 gm soil specimen is placed in two 100 ml measuring jars one jar filled with water and another filled with kerosene upto 100 ml and measured the volume of soil.
- The volume is further noted after 24 hrs than the free swell index is calculated.
- Free swell index = $[V_d - V_k] / V_k$ X 100%

  Where,

  V_d = volume of soil specimen read from the graduated cylinder holding water.

  V_k = volume of soil specimen read from the graduated cylinder holding kerosene.

Table 15: Variation in Free swell index

(Raghavedra T., Rohini B., Divya G., Sharooq S.A, Kalyanbabu B (2015))

FREE SWELL INDEX %	TERRASIL	ZYCOBOND
30	0	0

27.5	0.6kg/m^3	0.6kg/m^3
26.3	0.8kg/m^3	0.8kg/m^3
25	1kg/m^3	1kg/m^3
21.05	1.2kg/m^3	1.2kg/m^3

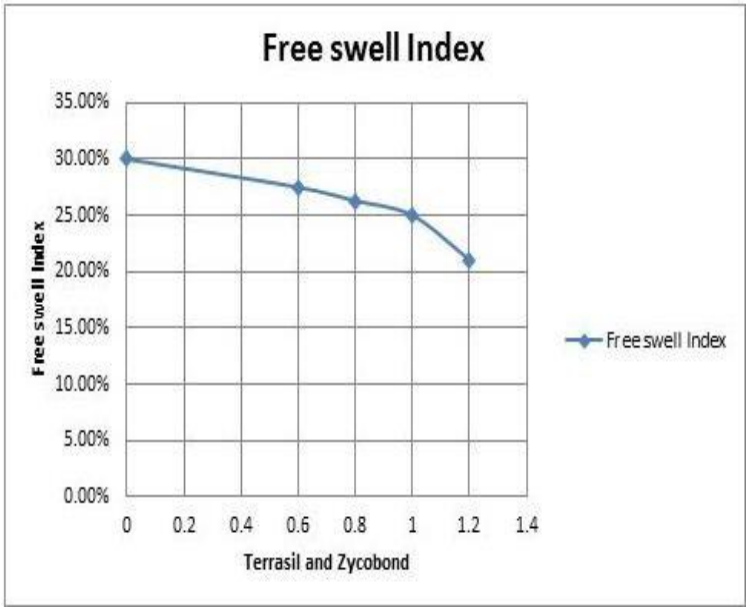

Fig 23: Variation of free swell index on addition of terrasil and zycobond

(Raghavedra T., Rohini B., Divya G., Sharooq S.A, Kalyanbabu B (2015))

Free Swell index diminishes from 30% to 27.5% with the mixing of 0.6 kg/m^3 of Terrasil and zycobond and further decrease was noticed to 26.3%, 25%, 21.05% with the addition of 0.8kg/m^3,1.0kg/m^3,1.2kg/m^3 when compared to 0% of Terrasil and Zycobond.

4. CONCLUSION

Various type of possible and cost effective stabilization technique of the soil properties enhancement were presented in this research. It is clear that by use of terrasil and zycobond various engineering index properties of weak soil get modified and roughly load bearing capacity is increased to fulfill the construction criteria for pavement construction as per IRC SP 72 in terms of CBR, Free Swell index, plasticity index etc.

Based the results and observations presented in the previous section, the following conclusion are drawn.

- For the soil used it is showing waterproofing and dust control at 1/400 solution as we discussed above in result.
- Other two bed sample 1/800 and 1/200 shows insufficient results as shows in figure.
- In 1/800 solution sample some seepage is observed so it is not considered as optimum dosage. Whereas in 1/200 solution the water droplet shows some inaccurate dispersion.
- For the clay used in this study there was a increase of 57.21% in the CBR value for unsoaked condition when it is stabilized with Terrasil and Zycobond.
- For the clay used in the present study, there was a drop of 19.62 % in the CBR value when it was soaked for four days.
- All other parameters remaining same, higher the soaking period (up to 28 days observed in this study), higher was the improvement in CBR value.
- All other parameters remaining same with the increase of chemical dosage the value of CBR decreases.
- At the end it is notified that 0.6kg Terrasil and Zycobond is giving significant improvement in both CBR values.
- Free Swell index diminishes from 30% to 27.5% with the mixing of 0.6 kg/m^3 of Terrasil and zycobond and further decrease was noticed to 26.3%, 25%, 21.05% with the addition of 0.8kg/m^3,1.0kg/m^3,1.2kg/m^3 when compared to 0% of Terrasil and Zycobond.

The level of improvement is very significant. In view of this, the practicing Engineers may consider stabilization of soft clayey in-situ ground by Terrasil and Zycobond stabilisation, to economies the pavement layers. Interestingly, the commercial stabilisers viz., Zycobond and Terrasil, found to be more fruitful .This study is likely to provide valuable inputs to the practicing Engineers. The conclusions based on the analysis of experimental results performed in the present study are presented in this study. At the end, the scope for future study is stated in brief.

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