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Soil Stabilization Using Terrasil, Zycobond and Lime: A Review

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ABSTRACT: From the last two decades, India has seen a significant increase in infrastructure development, which has resulted in a rapid increase in pavement construction and structural foundation. During construction work soil stability is one of the major problems. Clayey soil is termed as difficult soil to work with because it is cohesive, highly unstable, and prone to volumetric shrinkage, has low shear strength, and is susceptible to moisture. A cost-effective solution would be to convert locally available and difficult soil into suitable construction material. Soil stabilization techniques can be adopted in the field to enhance the properties of clayey soils. However, the conventional methods of soil stabilization such as use of cement, flyash can be replaced with innovative approach. Now a days, use of few chemical stabilizers such as Terrasil, Zycobond along with pozzolanic material was proven to be most effective and economical over conventional methods.

KEYWORDS: Terrasil, Zycobond, Lime, Soil Stabilization, Clayey Soil

I. SOIL STABILIZATION

Soil stabilization is the biological, chemical, or mechanical modification of soil engineering properties. In civil engineering, soil stabilization is a technique to refine and improve the engineering properties of soils. These properties include mechanical strength, permeability, compressibility, durability, and plasticity. Some schools of thought prefer to use the term stabilization in reference to chemical improvements in the soil properties by adding chemical admixtures as shown in Figure 1.

Fig. 1: Mixing Stabilizer to Soil

For any construction project, whether it's a building, a road or an airfield, the base soil acts as the foundation. Additionally, soil is one of the crucial construction raw materials. As such, the soil should possess properties that create a strong foundation.

1.1 Methods for Soil Stabilization

There are three methods of soil stabilization as follows:

1.1.1 Mechanical Stabilization

The objective is to achieve dense, well graded material by mixing and compacting two or more soils and or aggregates.

1.1.2 Chemical Stabilization

It refers to the alteration of soil properties by changing its chemical make-up with different additives like Terrasil, Zycobond, lime, cement, fly ash or by the addition of chemicals such as polymers, resins, and enzymes.

1.1.3. Biological Stabilization

It refers to the planting of vegetative cover to prevent wind, water, and soil erosion. The roots hold and aggregate soil particles together although in the beginning, other methods of stabilization should be used to support the growth of seeds and

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seedlings. The method of stabilizing soils is a commonly undertaken procedure in the construction of airfields, parking lots, landfills, embankments, roads and foundations, waterway management, agriculture, and mining sites. The type of stabilization that might be used depends on the site, it may use a single method or a combination of the two.

1.2 Advantages of Soil Stabilization

The advantages of soil stabilization are as follows:

1. Converting poor soil into strong soil.
2. Cost effective.
3. Decreases OMC.
4. Reduces permeability.
5. Reduces soil compressibility, deformation, and settlement.
6. Long lasting results of soil stabilization in road construction have positive influence on the environment, saving energy, materials, and equipment.

1.3 Purpose of Soil Stabilization

The purposes of soil stabilization are as follows:

1. Enhancement of the strength and therefore bearing capacity of the soil.
2. Substituting poor grade soils with aggregates possessing more favourable engineering properties.
3. To increase the load-bearing capacity
4. Enhancing the properties of soil on site.

1.4 Objectives of Soil Stabilization

The effect of chemically treated bio-enzymatic soil will be studied for following objectives:

1. To study the effect of various dosages of Zycobond and Terrasil on characteristics of treated soil.
2. To study the effect of curing period on strength characteristics of treated soil.
3. To specify the most economical and practical combination of materials for chemically treated soil.

II. LITERATURE REVIEW

Nandan A. P. et al. (2015) performed test on the stabilization of soil using Terrasil and Zycobond involves a process that enhances the engineering properties of soil to make it more stable and suitable for construction purposes. Terrasil was a soil stabilizer, and Zycobond was a bonding agent. The Terrasil- Zycobond combination creates a stable foundation, making it an effective solution for various civil engineering applications. In this study, an effort has been made to enhance the strength properties of soil from black cotton that has been treated with Nano-chemicals. In the first stage various tests were performed on Black Cotton soil such as: Wet sieve analysis, Atterberg's limit test (LL and PL), Standard Proctor Compaction test, California Bearing Ratio test (CBR), and Unconfined Compression test. Black cotton soil treated with Waste Foundry Sand of 10%, 20%, and 30% by dry weight of soil, free swell Index Test, Modified Proctor Compaction Test, California Bearing Ratio Test (CBR), and Unconfined Compression Test were conducted in the Second Stage. In third stage Black cotton soil treated with Terrasil and Zycobond of 0.06%, 0.08%, 0.1%, and 0.12% by dry weight of soil with the ideal dose of Waste foundry sand, the Frees well index test, Modified Proctor Compaction test, California Bearing Ratio test (CBR) and Unconfined Compression test were performed. Based on strength characteristics, the stabilized samples were evaluated to determine the impact of varied Terrasil and Zycobond dosages. They concluded that there was an increase in the maximum dry density of the soil in each of the compaction test carried out. The California Bearing Ratio of the subgrade showed improvement.It was found that the liquid limit of untreated soil was around 30.23% whereas the liquid limit for soil treated with T+Z was 29% as shown in Figure 2.

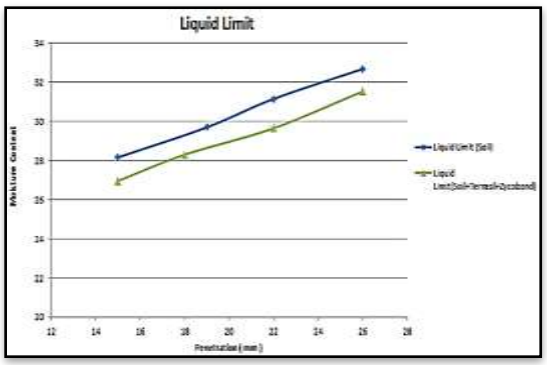

Fig. 2: Moisture Content vs. No. of Blows (Nandan A. P. et al. 2015)

Italiya K. et al. (2020) investigated the effect of GGBS on the engineering property (optimum moisture content and maximum dry density, plastic limit, liquid limit, compaction, and California bearing ratio test) of the soil and determined the engineering properties of the stabilized soil. Granulated shaped blast furnace slag is most suitable for increasing the strength of the soil. GGBS, Zycobond, Terrasil were added from 0% to 15% by dry weight of soil, first of all check all soil property at 0 % (no GGBS, ZB, TS) and then compared after addition of GGBS, ZB, and TS from 5% to 15%. From this they concluded that

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soil used in study there was an increase the percentage in the CBR value for unsoaked condition in both samples, when it is stabilized with GGBS, Zycobond and Terrasil. At the end is notified that 10% (GGBS, ZB, TS) giving significant improvement in CBR value in study. Table 1 shows physical properties of material used, Table 2 shows physical properties of zycobond and Table 3 shows physical properties of terrasil.

Table1:Physical Properties of Material Used (Italiya K.et al. 2020)

Property	**BCSoil**	**GGBS**
SpecificGravity	2.60	2.84
Liquidlimit(%)	78	40
Plasticlimit(%)	45	NP
PlasticityIndex	33	NP
Shrinkagelimit(%)	16	-
Sand(%)(4.75-0.075mm)	1	1
Silt(%)(0.075-0.002mm)	29	99
Clay(%)(0.002mm)	70	0

Table2: Physical Properties of Zycobond (ItaliyaK.et al.2020)

Parameter	**Value**
Colour	MilkyWhite
Odor	No
Flashpointabove	100^0C
ExplosionHazard	No
IgnitionTemperature	Above200^0C
Solubility	Dispersible
PHvalue	5-6

Table 3. Physical Properties of Terrasil (Italiya K. et al. 2020)

Property	**Description**
Appearance	Pale yellow liquid
Density	1.01 g/ml
viscosity at 25^0C	20-100 Cp
Solubility	Forms water clear solution
Freezing point	5^0C

Rakshitha G. S. et al. (2022), conducted a study for the enhancement of soil subgrade properties using Terrasil and Zycobond with waste foundry sand. Their objective was to determine the properties of black cotton soil, to access the effect of varying dosage of Terrasil and Zycobond (0.06%, 0.08%, 0.1% and 0.12% by dry weight of soil) on the strength properties and to find out the optimum dosage of Terrasil and Zycobond with addition of waste foundry sand to achieve

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maximum strength of soil. Black cotton soil was tested with nano chemicals for stabilization. From that study they concluded that Free swell index decreases from 40% to 20% with an increase in dosage of Terrasil and Zycobond along with optimum content of waste foundry sand. Maximum dry density is achieved at 0.1% of Terrasil and Zycobond is 1.84g/cc and optimum moisture content of 16.2%.Results of Free Swell Index Test is shown in Table 4.

Table 4: Results of Free Swell Index Test (Rakshitha G. S. et al. 2022)

Description	FSI	FSR
BCsoil+4%cement+ 10% WFS	61.90	1.619
BCsoil+4%cement+ 20% WFS	45.45	1.455
BCsoil+4%cement+ 30% WFS	36.36	1.364

VariationinCompactionCurvesofBlackCottonSoil Treated with Percentage ofWaste Foundry Sand is shown in Figure 3.

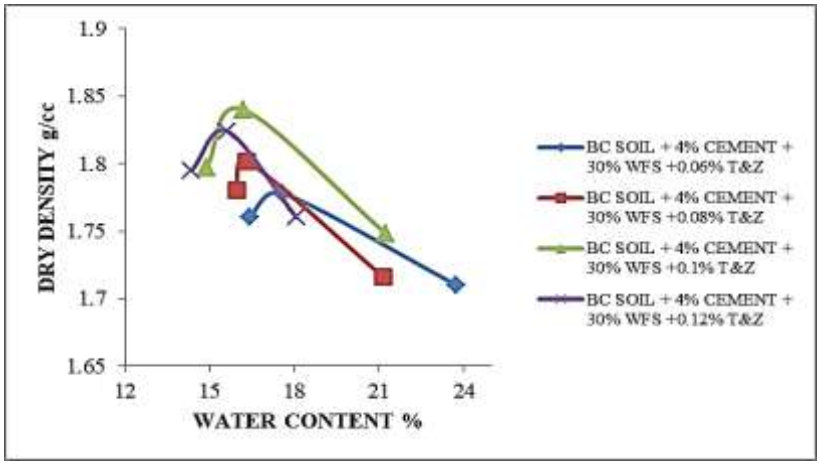

Fig. 3:CompactionCurvesfor Soil Treated with Varying Percentage ofWaste Foundry Sand (Rakshitha G. S. et al. 2022)

Gande S. et al. (2023) investigated the strength characteristics of block cotton soil when mixed with a range of proportions of additives such as Terrasil, fly ash and cement using CBR and UCS tests. The natural soil was tested according to Indian standards. The soil is classified as CH. Addition of cement and Terrasil were based on the guidelines given by the ZYDEX Company. The test results show that the CBR and UCS values are similar for the proportions Cement (OPC) (3%) + Terrasil (0.1%) and cement (OPC) (2%) + fly ash (5%) + Terrasil (0.1%). The liquid limit of CH soil decreases, and Plastic limit of CH soil increases with addition of stabilizers to the soil. UCS strength of soil increased with the addition of stabilizers to soil. Table 5 shows additive mix proportion. The following three sets of additives were used in the experiment.

Table5:AdditiveMix.(GandeS.et al.2023)

AdditiveMix	Cement(OPC) %	Terrasil(%)	FlyAsh
A	3	0.01	0
B	2	0.01	5
C	1	0.01	5

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CBR tests were conducted to determine CBR values of soil treated with Cement, Terrasil and Flyash. CBR tests were conducted as per guidelines of IS 2720 Part 16. Loadv/s Penetration Curve is as shown in Figure 4.

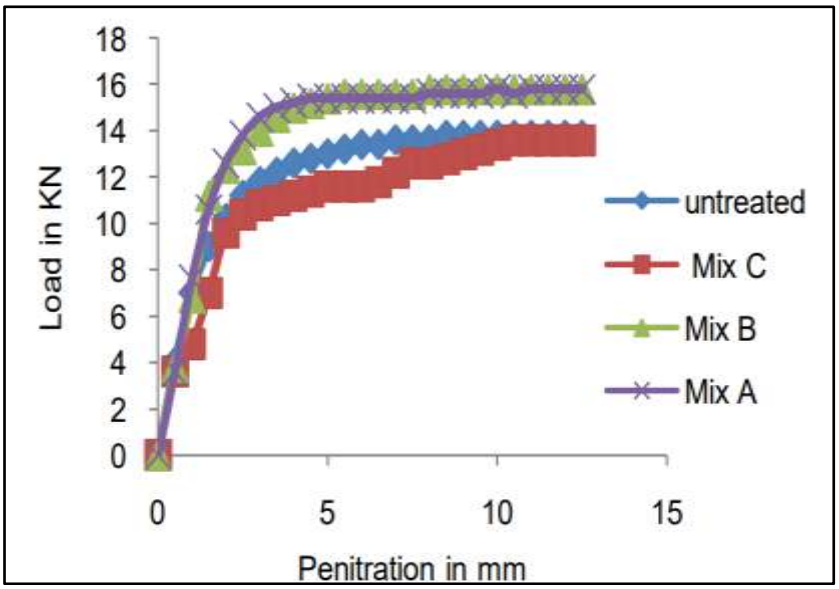

Fig. 4: Load v/s Penetration Curve (Gande S. et al. 2023)

Emeka S. et al. (2017) carried out experimental investigation on laterite soil by adding Terrasil solution. Engineering property tests such as California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and Compaction tests were performed 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.Terrasil can treat material ranging from clays to silts sand and gravel.Table 6 shows the technical specifications.

Table6:TechnicalSpecifications(Emeka S. et al.2017)

Property	**Description**
Appearance	PaleYellow Liquid
Specificgravity	1.01
Solubility	SolubilityFormswaterclearsolution
FlashPoint	12ºC
Terrasil:Water	1 :200 ml
Dosage	2%to16% at2%intervalby weightofdry soil

Preliminary tests were carried out for purposes of identification and classification. These tests include Grain size analysis, Moisture content determination, Specific gravity tests and Atterberg's limit tests are given in Table 7.

Table 7: Results of Lateritic Soil Sample from Borrow Pit 1 (EmekaS.et.al. 2017)

Property	**Sample 1**	**Sample 2**
Specific Gravity	2.67	2.62
Liquid Limit (%)	31.6	39.0
Plastic Limit (%)	25.8	29.4
Plastic Index (%)	5.8	9.6
Maximum Dry Density (MDD) (Kg/m^3)	2198	1864
(OMC) (%)	15.61	11.20

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Lekha B. M. et al. (2013) studied the behavior of Black Cotton (BC) soil Terrasil was used as stabilizer and it was used for different dosages and cured for 7, 14 and 28 days. Due to the chemical reaction, the soil mass densifies by minimizing the voids between particles and it makes the soil surface impervious. The chemical compositions and microstructures of soils were analyzed using X Ray Diffraction (XRD) and Scanning Electron Microscope (SEM) respectively. The materials used in that work are clayey soil, Zycobond and Terrasil. The study investigating the effects of stabilizers, specifically Zycobond and Terrasil, on the strength of subgrade in BC (Black Cotton) soil has provided valuable insights into the potential improvements in soil properties. Zycobond and Terrasil have demonstrated their effectiveness in enhancing the engineering properties of BC soil, including increased shear strength, reduced compressibility, and improved stability.Load vs Penetration Curve (Soaked) is shown in Figure 5. Load vs Penetration Plots Pertaining to Clay Stabilised with TS and ZB in 14 Days-Soaked Condition is shown in Figure 6.

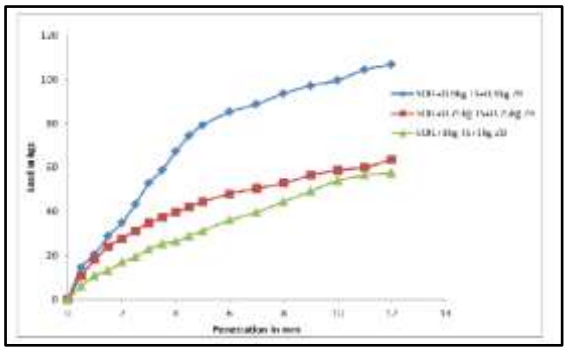
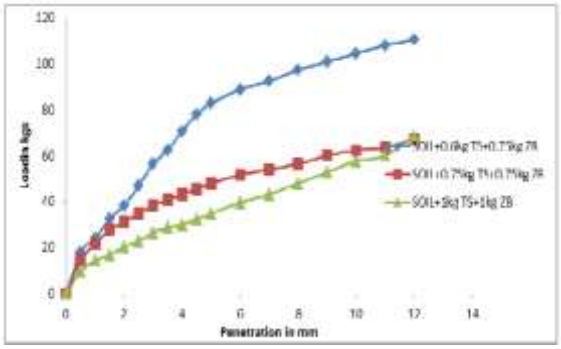


Fig. 5: Load vs Penetration Curve (Soaked) (Lekha B.M et al. 2013)



Fig, 6: Load vs Penetration Plots Pertaining to Clay Stabilised with TS and ZB in 14 Days-Soaked Condition (Lekha B.M et al. 2013)

T. Raghavendra et al. (2018) studied the behavior of black cotton soil using Terrasil and Zycobond. The rate of montmorillonite was more in black cotton soil which causes expansiveness and crack occurs in soil without any warning which was dangerous for construction. In that study nano chemicals Terrasil and Zycobond were used for soil stabilization. The unconfined compressive strength test was performed after the curing period of 7 days, 21 days, and 28 days. A free swell index test was performed for the proportions of 0.6 kg/m^3, 0.8 kg/m^3, 1 kg/m^3, 1.2 kg/m^3 of Terrasil and Zycobond. Nano chemicals Terrasil and Zycobond were nanotechnology-based products which can provide solutions to moisture and bonding issues. Addition of nano particles as an external factor to soil will result in soil manipulation at atomic or molecular level and it influences the strength, permeability indices and resistance properties of soil. In that study soil with variable dosages of chemicals were tested for stabilization process and strength of the stabilized soil had been evaluated after curing period. The experiments such as specific gravity, liquid limit, plastic limit, sieve analysis, hydrometer analysis, IS light compaction, unconfined compression test, direct shear test, CBR test and free swell index test were conducted on the soil. They concluded that Free swell index decreases from 40% to 20% with an increase in dosage of Terrasil and Zycobond along with optimum content of waste foundry sand. Maximum dry density is achieved at 0.1% of Terrasil and Zycobond is 1.84g/cc and optimum moisture content of 16.2%. Higher soaked CBR and UCS

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can be achieved with a combination of 0.1% Terrasil and Zycobond with 30% waste foundry sand and 4% cement.

V. Padmavathi et al. (2019) studied the properties of poor-quality soils available at the site, to make them meet the desired requirements of design/construction. Terrasil solution is prepared in the proportion 1:200. The required quantity of soil (approximately 5 to 6 kg) for conducting direct shear tests and permeability test is taken in a tray and completely inundated with the prepared Terrasil solution. The soil is left to air dry for a few days and then oven dried. The OMC obtained for the local base soil is used for the preparation of direct shear and permeability test samples. Direct shear tests were conducted on samples compacted at OMC and at SMC. For stabilizing the soil with Zycobond, the required quantity of soil is taken. Zycobond is added to the optimum moisture content in proportion 1:99 to prepare the Zycobond solution. This water is then added to the soil, and direct shear and permeability tests samples were prepared. When Terrasil is used as an admixture to the local soil, there is considerable increase in the friction property of the modified material, imparts resistance to UV rays, and makes the material imperviousness. The combination of Terrasil and cement yielded the best of results and hence can be beneficially used for treating the local soils. Variation in C and Φ For Different Admixture are shown in Figure 7 and Figure 8 respectively.

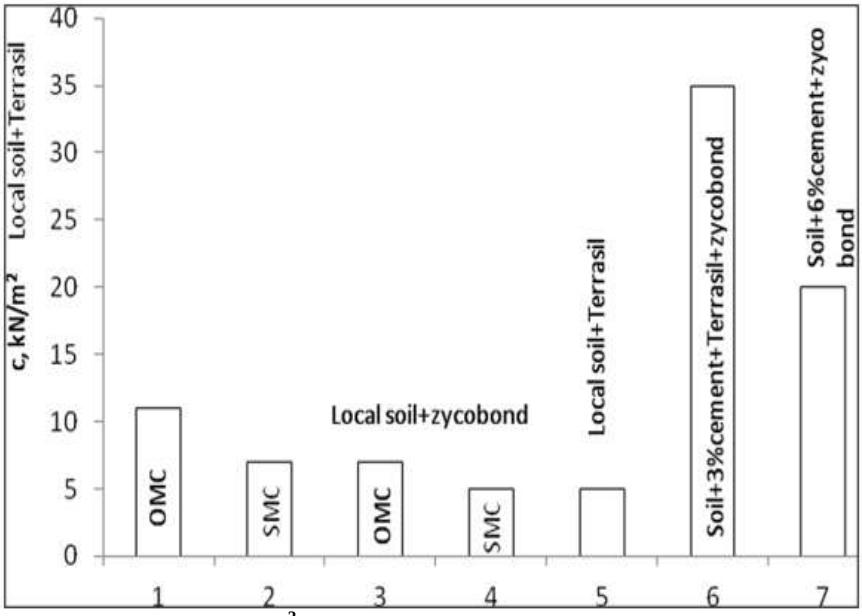

Fig. 7: Variation of C (kN/m^2) for Different Admixture (V.Padmavathi, et.al 2019)

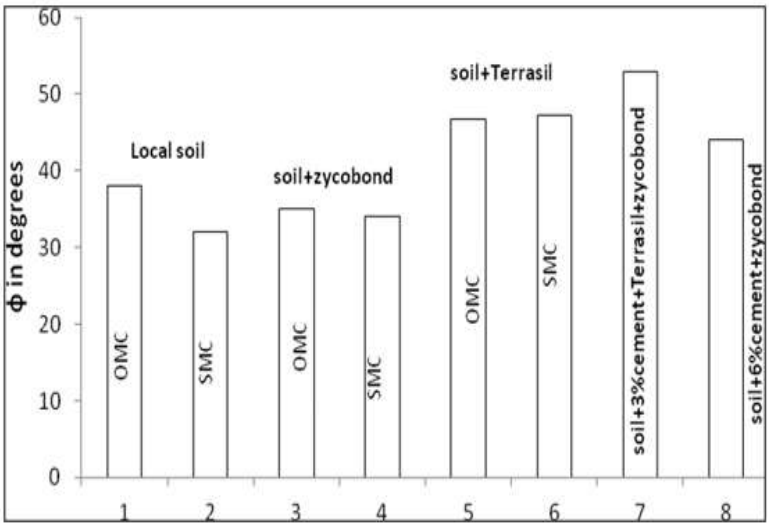

Fig. 8: Variation of Φ For Different Admixture (V.Padmavathi, et.al 2019)

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Table8 shows properties of locally available soil,

Table 8: Properties of locally available soil (V. Padmavathi, et.al 2019)

Test conducted	**Results**	
Grain size distribution		
Gravel (%)	5	
Coarse sand (%)	22	
Medium sand (%)	29	
Fine sand (%)	13	
Liquid limit (%)	33	
Plastic limit (%)	18	
Plasticity index (%)	15	
IS Classification of soil	SC	
Compaction test	Standard Proctor Test	Modified Proctor Test
OMC (%)	11.0	8.0
Maximum dry density (kN/m^3)	18.9	20.6
Direct Shear Test	OMC	SMC
Cohesion, C	11kN/m^2	07kN/m^2

III. CONCLUSIONS

The conclusions were found out be as follows:

1. The findings indicate that the application of these stabilizers contributes positively to the strength characteristics of the subgrade.
2. Zycobond and Terrasil have demonstrated their effectiveness in enhancing the engineering properties of BC soil, including increased shear strength, reduced compressibility, and improved stability.
3. When Terrasil is used as an admixture to the local soil, there is considerable increase in the friction property of the modified material, imparts resistance to UV rays.
4. Blocks prepared from Terrasil, and cement yielded good compressive strength. Hence, they can be used in the preparation of paving blocks.
5. Zycobond stabilized local soil can also be used as a replacement material for clay as core or hearting material in zoned earthen embankments and further the thickness of the zoned section can also be reduced.
6. Black Cotton soil stabilized with Terrasil and Zycobond (0.1%) with waste foundry sand of 30% and 4% of cement yield substantial strength
7. Higher soaked CBR and UCS can be achieved with a combination of 0.1% Terrasil and Zycobond with 30% waste foundry sand and 4% cement.
8. The crust thickness of stabilized black cotton soil with optimum content of Terrasil and Zycobond decreases when compared to crust thickness of silty soil.
9. All the other parameters remained the same, higher the stabilizer percentage rate, higher was the improvement in soil properties.
10. There was an increase in the maximum dry density of the soil in each of the compaction test carried out. The California Bearing Ratio of the subgrade showed improvement.

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