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Black Cotton Soil Stabilization Using Terrasil for Its Expansive Nature

Krupa R. Kalariya¹, Parth N. Lakhani²

PG. Scholar, Faculty of Technology, Marwadi University, Rajkot, Gujarat, India
E-mail: krupakalariya12345@gmail.com

Assistant Professor, Civil Engineering Department, Marwadi University, Rajkot, Gujarat,
India E-mail: parth.lakhani@marwadieducation.edu.in

Abstract. The swelling and shrinkage phenomenon in expansive soil is one of the major issues that damages the civil engineering structures. Expansive soil has montmorillonite as primary mineral composition, which exhibits high volume change when subjected to moisture variations. Numerous methods and techniques have been proposed and developed based on several types of research for the stabilization of expansive soil.

In this study, experimental tests were conducted on different expansive soil to investigate the effect of nanotechnology-based material, Terrasil (Developed and manufactured by Zydex industries). Soil samples were collected from three different places of Gujarat and are classified as CH type soil. Liquid limit, plasticity index and swelling potential of treated soil were found to be reduced significantly by adding Terrasil.

The addition of Terrasil increases dry density while decreasing the optimum moisture content. The optimum dosage of Terrasil is found to be approximately 2-3% by weight of dry. Test results are compared to study the changes occurred after the mixing of Terrasil in soil. Terrasil altered the properties of expansive soil significantly and can give the solution for swelling and shrinkage behavior of soil.

The test findings indicate that, due to the inclusion of Terrasil, the swelling characteristics decreased along with its cohesive behavior. Apparently the UCS value of the treated soil declines with an increase in Terrasil dosage.

Keywords: Nanotechnology, Soil stabilization, Expansive soil, Nano chemical – Terrasil, Free Swell Index

1 Introduction

At the end of the 1930s, issues relating to expansive soil were identified for the first time in civil engineering structures. Expansive soil when exposed to moisture deviations due to seasonal climatic conditions or artificial causes reveals a high volume change [17]. Whether the soil mass has active clay minerals or not, can govern the degree of expansiveness. Montmorillonite is the typical active clay-mineral. Variation causes deformation of the soil mass due to alternate expansion and contraction by moisture, causes damage to the infrastructure structures built on that soil mass [23,4].

Stabilization is the foremost technique of soil reinforcement. The stabilizer significantly improves soil performance by modifying its physical or chemical properties; soil can therefore be used for various construction purposes. Research has shown that soil improvement techniques have classified soil-based stabilization techniques: mechanical stabilization, thermal stabilization, chemical stabilization, and electrical stabilization. Mechanical and chemical stabilization are among these widely used techniques, due to the provision of rapid, efficient, repeatable and reliable improvements to raw soil properties. In mechanical stabilization, soil physical characteristics are modified while chemical characteristics have been modified in chemical stabilization. Chemical stabilization is a time-saving method that allows the soil to achieve higher density and strength by avoiding the need for costly excavation and non-expansive material replacement [1,3].

Current trend in geotechnical engineering research works has evolved innovative technology, such as nanotechnology. Nanotechnology is the science that deals with nano-scale particles and plays a key role in soil behavior that has different properties. On a micro-scale, for bulk content, most features remain almost identical. Researchers have tested many types of nanomaterials for its improvement, among them few materials are silica [18], nano silica [2], nano clay, nano-copper and nano-alumina [24]. The lack of one or more geometric nano-scale measurements completely alters the material's behavior. Therefore, on the nano scale, there is a high surface volume ratio and a high cation exchange capacity, resulting in improvement of the shear strength, maximum dry density, CBR value, permeability and soil bearing capacity. Nanoparticles interact very effectively with other particles and solutions, and can greatly affect the physical and chemical properties of a substance. The gravitational force can be ignored at Nano scale. Electromagnetic forces are however prevailing. An experimental study conducted by researchers on different soil types, Terrasil[5,20, 22] Terrasil with fly ash[6], Terrasil with zycobond[21] and Terrasil with cement[10]. The study shows that very small quantities of Terrasil could alter soil particle behavior. The liquid limit and plasticity index decreased, OMC decreased and MDD increased, Terrasil alone could decrease UCS but when mixed with Fly Ash or cement, the strength parameter such as CBR, UCS increased with increased Terrasil dosage.

In this investigation, an attempt was made to examine the influence of nano chemicals-Terrasil on improving black cotton soils with different expansive features. The main objective of this experimental work is to reduce the soils expansive potential after stabilization and to optimize the dosage in order to use the treated soil as a sub-base material.

2 Materials

The following materials are used in the experimental program

2.1 Black cotton soil. Experimental studies were carried out using problematic local expansive soil collected from Bhavnagar, Jamjodhpur and Rajkot regions of Gujarat, India. The soil was obtained from a depth of 1.5 m below ground level, organic and other wastes removed if any and dried in an oven for 24 hours at $110 \pm 5^\circ \text{C}$,

crushed, pulverized, and finally homogenized. The basic geotechnical tests have been carried out on the soils and the results have been tabled in Table 1. These three soils were classified as CH-clayey soil with high compressibility and high swelling characteristics as per IS specifications.

2.2 Terrasil. Terrasil is a stable solution based on nanotechnology: organosilane, water-solvent, UV, and heat. Terrasil manufactured by Zydex Industries, Gujarat has ingredients Hydroxyalkyl-alkoxy-alkylsilyl compounds (65-70%), Benzyl alcohol (25-27%), Ethylene glycol (3-5%). It attempts to bond with the oxygen & silica atoms of the soil which, at normal temperature, chemically converts water absorbing silicon groups to water resistance alkyl siloxane surfaces. Figure 1 shows a chemical reaction between the Terrasil solution and the particles in the soil.

Table 1. Basic soil properties

Sr. no.	Properties	Bhavnagar Soil	Jamjodhpur Soil	Rajkot Soil
1	Particle size distribution			
	% Gravel	0	0	0
	% Sand	8	11	3
	% Silt	52	40	54
	% Clay	40	49	43
2	Atterberg's limits			
	Liquid limit (%)	65.11	75.06	73.50
	Plastic limit (%)	31.11	30.39	34.40
	Plasticity Index (%)	34.00	32.83	41.90
	Shrinkage limit (%)			8.11
	IS classification	CH	CH	CH
3	Compaction characteristics			
	Maximum Dry Density, (g/cm ³)	1.49	1.44	1.41
	Optimum Moisture Content, (%)	26.88	24.33	23.80
4	Unconfined Compressive Strength (kN/m ²)	53.94	105.33	60.93
5	Free Swell Index (%)	56.66	62.27	77.77

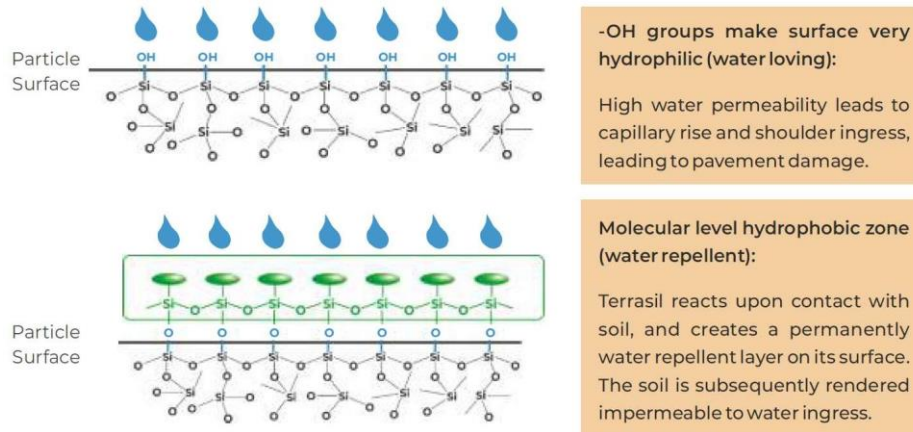


Fig. 1. Chemical action of Terrasil on soil particles

3 Methodology

3.1 Sample preparation

Soil was oven-dried for 24 hours and then crushed with the help of wooden hammer so that lumps of clay particles can be crushed to smaller sizes. The Terrasil solution was prepared with various concentrations such as 1%, 2% and so on. To prepare 1% concentrate soil – Terrasil mixture, Take 1gm of Terrasil and mix it with 100gm of water after the Terrasil mixed thoroughly with water add this Terrasil mixed water to 100 gm of oven dry soil.

The quantity of Terrasil was calculated using dry weight of virgin soil. The oven dried soil was mixed with this Terrasil solution and thoroughly mixed and put into humid environment for 48 hours to mature. This soil-terrassil sample was oven-dried again and crushed according to various test criteria.

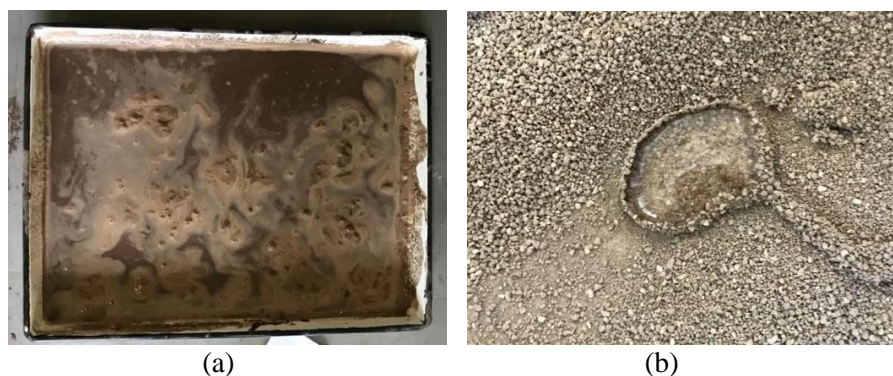


Fig. 2. (a) Maturing process of Soil-Terrasil mixture, (b) Behavior of water droplet with Terrasil modified soil particles

4 Results and Discussions

All three soils, mixed with different Terrasil dosages, were investigated for consistency limits, free swell index, compaction parameters and UCS tests to evaluate the effect of Terrasil on different expansive black cotton soil.

4.1 Effect of Terrasil on Atterbergs limits

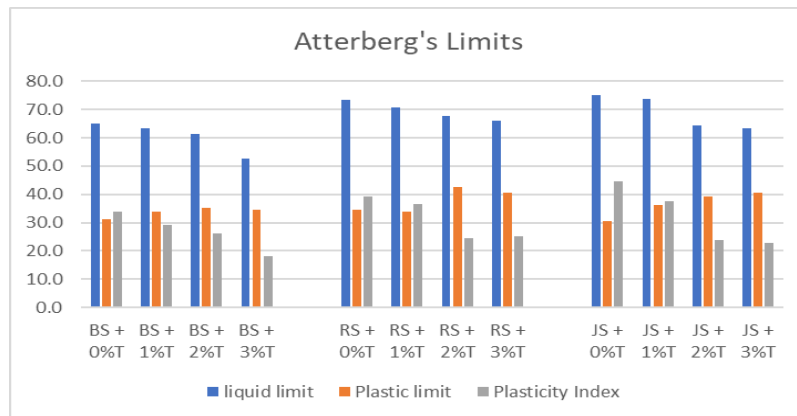


Fig. 3. Atterberg Limit test results of BS(Bhavnagar Soil) , RS(Rajkot Soil) , and JS (Jamjodhpur Soil) modified with Terrasil

The figure initially shows a slight decrease in liquid limit and plasticity index with the addition of 1% terrasil, whereas there is a significant decrease in liquid limit and plasticity index with the addition of 2% and 3% terrasil. This reduction in Atterberg's Indices shows improvement in its index properties.

4.2 Effect of Terrasil on Free Swell index

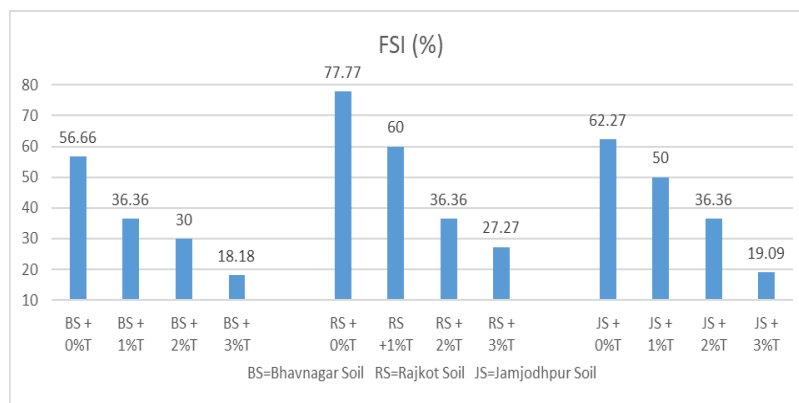
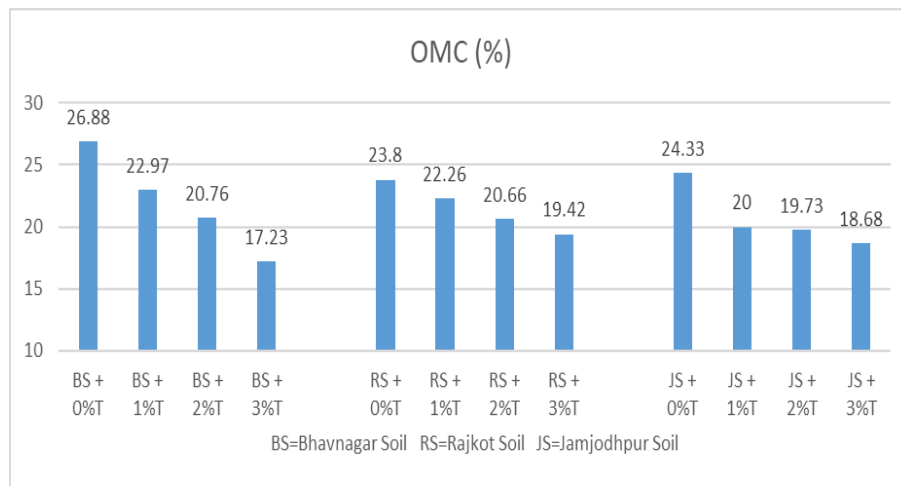


Fig. 4. Free Swell Index results of BS, RS, and JS soil modified with Terrasil

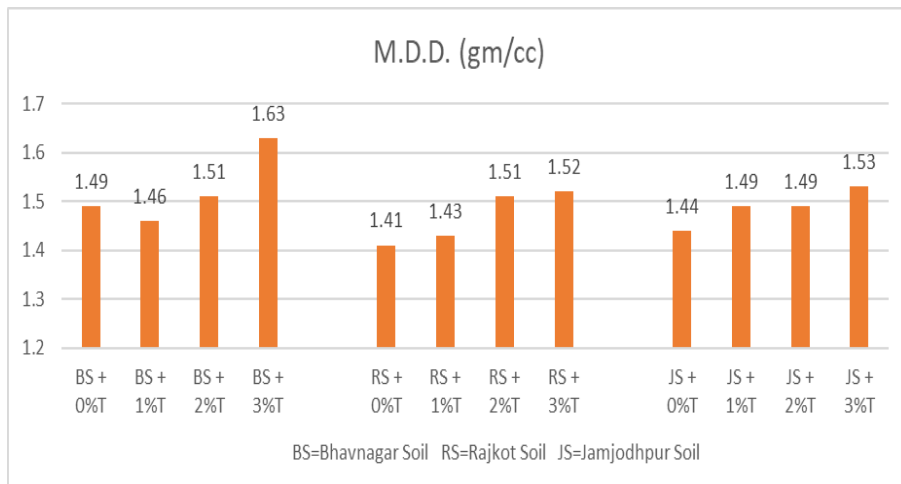
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From the above graph, it can be detected that there is approximately 70% reduction in free swell index with addition of 3% terrasil compare to virgin soil. This shows that with an increase in terrasil percentage the expansiveness of soil is reduced from very high to low.

4.3 Effect of Terrasil on Optimum Moisture Content (OMC) and Maximum Dry Density (MDD)



(a)



(b)

Fig. 5. Compaction Test results of BS, RS, and JS soil modified with Terrasil

For the soil sample of Bhavnagar, the optimum value of OMC and MDD is 17.23 percent and 1.63gm/cc was obtained at 3 percent terrasil dosage as well as the optimum value of OMC and MDD was obtained at 3 percent terrasil dosage for other two soil samples. Because of the reaction between the Terrasil and silicates present in soil, the formation of siloxane bonding may be responsible for improving MDD. An increase in the maximum dry density generally indicates improvement in soil.

4.4 Effect of Nano-chemical on Unconfined compressive strength test (UCS)

UCS tests were carried out with the OMC and MDD for the investigation of the effect of Terrasil on the strength parameter. The UCS values for terrasil modified soil samples were shown in Table 2. Here, with only 1% of Terrasil, the strength began to decrease. After increasing the dosage, the UCS sample was unable to prepare and the samples failed to extract from the UCS mould.

Table 2. UCS values of Terrasil modified soil samples

S. no.	Soil type	UCS (kN/m ²)			
		0% Terrasil	1% Terrasil	2% Terrasil	3% Terrasil
1	BS	53.94	47.72	NA	NA
2	RS	60.93	53.48	NA	NA
3	JS	105.33	47.66	NA	NA

BS=Bhavnagar Soil RS=Rajkot Soil JS=Jamjodhpur Soil

5 Conclusions

The impact of Terrasil on soil samples from three different regions was investigated in this study. The present study presents the following conclusions:

1. Liquid limit and plastic limit decrease as addition of Terrasil to the soil. As a result, the plasticity index decreases and the workability of clay increases.
2. Terrasil forms a water-resistant layer of soil particles, decreasing the attraction between clay soil particles and water molecules. This is reflected in the results of the free swell index testing.
3. The compaction parameter of the modified soil sample shows a higher MDD with a lower OMC, which could be the combined effect of the water proofing layer and increased workability.
4. As a result, Terrasil-a nanochemical by Zydex Industries has been shown to be an effective soil stabilizer and can be used in waterproofing roads, slopes and canals to make them moisture-resistant, maintenance-free and more sustainable.

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