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Stabilizing Lateritic Soil Using Terrasil Solution

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Abstract

This study assesses stabilizing lateritic soil using Terrasil solution. Preliminary tests were carried out on six natural soil samples from three borrow pit locations-two soil samples from a particular borrow pit location, for the purpose of identification and classification. 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 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. The results showed that the addition of terrasil solution enhanced 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 concluded that the terrasil solution serves as a cheap and effective stabilizing agent for poor soil.

Key words: Atterberg limits, geotechnical tests, Lateritic soil, Stabilization, terrasil solution

1 Introduction

The origin of expansive soil is related to a complex combination of condition and processes that result in the formation of clay mineral having a particular chemical makeup which, when in contact with water, will expand [1]. All clay soils are not expansive and the degree of expansion varies with the type of clay mineral predominantly present in the soil mass. The presence of montmorillonite in the soils imparts their high swell-shrink potentials [2]. These soils are very hard when dry, but lose strength completely when wet. Pavement structures on poor soil subgrades show early distresses causing the premature failure of the pavement. Stabilization of these types of soils using different additives is a usual practice as it becomes uneconomical to replace the foundation material with good quality soils. Many additives such as lime, cement, fly ash, bitumen and different chemicals are being used for stabilization [3].

In most geo- technical projects, it is not possible to obtain a construction site that will meet the design requirements without soil modification. The current practice is to modify the engineering properties of the native problematic soils to meet the design specifications. Nowadays, soils such as, soft clays and organic soils can be improved to meet the civil engineering requirements [4].

Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two [5]. Usually, the technology provides an alternative structural solution to a practical problem. The simplest stabilization processes are compaction and drainage (if evaporation takes place in wet soil, then the soil becomes stronger). The other process is by improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils [6].

1. 1 Chemical Stabilization

Under this category, soil stabilization depends mainly on chemical reactions between stabilizer and soil minerals to achieve the desired effect [7]. According to Raymond [8] explained that through soil stabilization, unbound materials can be stabilized with cementitious materials (cement, lime, fly ash, bitumen or combination of these). Chemical stabilization is achieved by mixing appropriate percentages of chemical such as lime, fly ash, bitumen or terrasil. The process of selecting the appropriate chemicals involves the study of the soil type and properties, the design intent for stabilizing the material, the required strength and durability of the product, initial cost/cost savings and environmental consideration [9].

1.2 Terrasil

Terrasil are water soluble compound which forms form water clear solution. Terrasil nanotechnology offers a permanent water repellent Nano layer on all types of soils, aggregates and other inorganic road construction materials [10]. The reaction leads to permanent nanosiliconization of the surfaces by converting the water loving silanol groups to water repellent siloxane bonds. The Si-O-Si Siloxane bond is Mother Nature's strongest bond which survives for centuries. The substantial reduction in soil water infiltration and erosion has ultraviolent and thermal stability for over 20 years. The siloxane is non-leachable as it chemically binds to surfaces permanently. Terrasil unique chemical structure makes it water soluble. However, when it applied on the surface and is bonded to the surface, the water repellent characteristic of the molecule dominates on the surface and provide water repellency [11].

Terrasil is defined according to Prakash and Sridharan[12] as an organosilane compound which reacts with soil particles and form hydrophobic (oily) layers on the surface of the soil and clay particles. This make soil particles water insensitive and can be compacted to a better particle interlock state by equipment and traffic forces. Terrasil can treat material ranging from clays to silty sand and gravel. It is a nanotechnology that offers a permanent water repellent nano layer on all types of soils, aggregates and other inorganic road construction materials. The reaction of Terrasil and soil leads to permanent nanosiliconization of the surfaces by converting the water loving silanol groups to water repellent siloxane bonds. The siloxane is non-leachable as it chemically binds to surfaces permanently. Terrasil unique chemical structure makes it water soluble. However, when it applied on the surface and is bonded to the substrate, the water repellent characteristic of the molecule dominates on the surface and provide water repellency [13].

Terrasil is an organo-silane technology and forms one of nature's strongest naturally occurring molecular bonds. Furthermore, terrasil covalent bond structure continues to allow treated materials to breathe. The free flow of air through brick and concrete preserves a structure's thermal insulation properties. This unique feature also allows trapped moisture to escape building materials. Water droplets remain too large to penetrate terrasil's hydrophobic barrier, but much smaller water vapor droplets can easily escape. Terrasil prevents mold and mildew; rusting of rebar (reinforcement bar); water damage due to capillary rise; blistering of plaster walls; paint peel-off; efflorescence in cement and brick and fungus growth. It prevents the damaging effects of freezing water's expansion and subsequent cracking; water damage and deterioration of concrete infrastructure; pocking and general damage. By creating a water resistant surface, costly maintenance repairs are minimized and a structures life is prolonged. Terrasil is a nanotechnology soil and infrastructure chemical/agent for road construction, especially in the aspect of soil stabilization, it makes the roads or soil impermeable to water, abrasion and many other benefits. Terrasil mixed with zycobond gives you excellent bonding of road construction materials, erosion control permanently and suppressed dust on the road and your environment. Terrasil is a new concentrate created to make soils, sand, and aggregates repel water. This breakthrough technology makes treated soils 98% water resistant and delivers proven results in road construction while sharply reducing soil erosion.

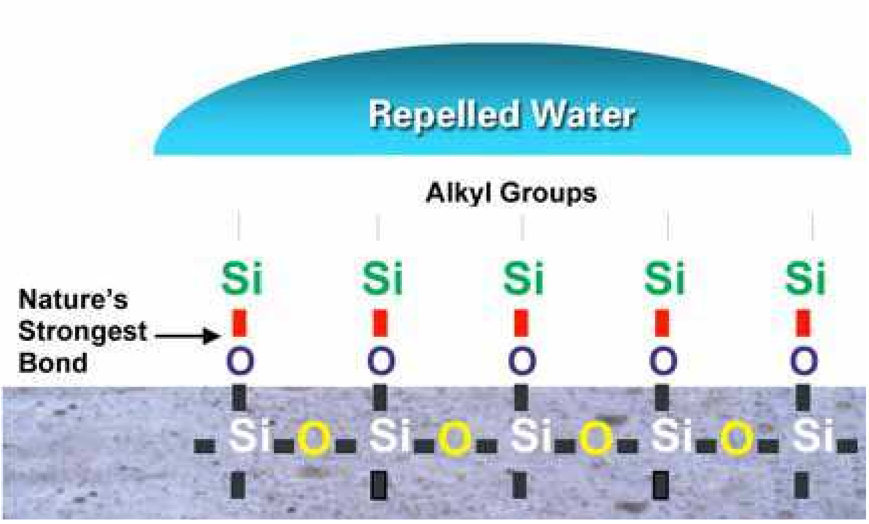

Figure 1: chemical compositions of terrasil [14].

Terrasil mixes easily with water and can be applied using a low-pressure sprayer. Terrasil, zycosoil, and Zycobond are the only water repellents in the world which are applied using water. They require no special equipment and minimal clean-up time. Once applied, Terrasil bonds to become a permanent part of the treated soil or aggregate and provides long-lasting water repellency. While existing polymer technologies are surface coatings that deteriorate from UV exposure, Terrasil resists UV degradation and remains stable for years, substantially reducing the expense of continuing repairs. The advantages of the use of terrasil among others include; reduces road surface cracking caused by soils' expansion and contraction, greatly enhances road solidity and longevity where poor quality aggregates are used, increases soils' durability through improved compaction, the patented molecule in Terrasil forms a permanent bond with soils, sands and aggregates to create a barrier against water, saving money on road upkeep and repairs. It is equally useful in the areas of constructing levees and dams, erosion control, hillside stabilization, unpaved paths, excavation stabilization.

2 Materials and Methods

The following materials were required for this research: Soil samples, Terrasil and Distill water.

2.1 Soil Samples

Six different lateritic samples were sourced from three borrow pits located within Akure and subjected to preliminary tests with at least two samples taken from each borrow pit locations, Assessments of the index properties of the samples-taken from each borrow pit locations- favors borrow pit 3 samples for stabilization.

2.2 Terrasil

Terrasil is a commercially available chemical stabilizer which is used in the present investigation. The Terrasil that was used for this research was bought from VLX group of companies in Lagos and properly kept safe in the Geotechnical Laboratory of Department of Civil Engineering, Federal University of Technology Akure, before use. It is available in concentrated liquid form and is to be mixed with water in specified proportion before mixing with the soil. Technical specifications are shown in Table 1 below:

Property	**Description**
Appearance	Pale Yellow Liquid
Solid Content	68±2%
Viscosity at 25^{0}C	20-100cps
Specific gravity	1.01
Solubility	Forms water clear solution
Flash Point	Flammable 12ºC
Terrasil : Water	1: 200ml
Dosage	2% to 16% at 2% interval by weight of dry soil

2.1.3. Distil water

The water used throughout the experiment was gotten from a borehole and distilled in the geotechnical engineering laboratory of the Department of Civil and Environmental Engineering, Federal University of Technology Akure, Nigeria.

2.2 Methods

Preliminary tests such as Natural Moisture Content Test, specific gravity Test, Grading test, Consistency Limits Test, and compaction Test were performed on the lateritic sample for the determination of index properties of the samples. Constant terrasil - water ratio of 1: 200 was added to the poor lateritic soil (which were samples 1 and 2 from borrow pit number 3) with variations of terrasil solution contents – ranging from 0% to 16% at 2% interval. All proportions of terrasil solution were measured in percentages by weight of the dry soil samples.

Geotechnical tests such as compaction Test and California Bearing Ratio Test – which involve the treatment of poor lateritic soil with terrasil – water solution at a constant ratio of 1:200 were carried out on each of the lateritic soil samples at varying proportions of 2, 4, 6, 8, 10, 12, 14 and 16% of Terrasil solution.

3 Results and Discussion

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.

Table 2: Summary of preliminary results of lateritic soil sample from borrow pit 1

Property	Sample 1	Sample 2
Specific gravity	2.67	2.62
Natural Moisture Content (%)	23.9	14.4
% passing through Sieve No 200	21	31
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
Optimum Moisture Content (OMC) (%)	15.61	11.20
AASHTO Classification	A-1-b	A-2-4

Table 3: Summary of preliminary results of lateritic soil sample from borrow pit 2

Property	Sample 1	Sample 2
Specific gravity	2.67	2.53
Natural Moisture Content (%)	18.8	18.2
% passing through Sieve No 200	8.5	7.9
% passing through Sieve No 40	55	59
Liquid Limit (%)	31.0	35.3
Plastic Limit (%)	21.8	26.5
Plastic Index (%)	9.2	8.8
Maximum Dry Density (MDD) (Kg/m^3)	1952	2139
Optimum Moisture Content (OMC) (%)	10.4	13.8
AASHTO Classification	A-3	A-3

Table 4: Summary of preliminary results of lateritic soil sample from borrow pit 3

Property	Sample 1	Sample 2
Specific gravity	2.69	2.64
Natural Moisture Content (%)	20.8	21.4
% passing through Sieve No 200	47.0	53.4
Liquid Limit (%)	46.0	49.0
Plastic Limit (%)	16.3	20.3
Plasticity Index (%)	29.7	28.7
Maximum Dry Density (MDD) (Kg/m^3)	1267	1420
Optimum Moisture Content (OMC) (%)	19.92	22.70
AASHTO Classification	A-7-6	A-7-6
Unsoaked CBR (%)	8.4	6.2

Table 5: Compaction tests results for borrow pit 3, Sample 1

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	MDD (Kg/m^3)	OMC (%)
100	0	1267	19.92
98	2	1590	19.05
96	4	1668	17.50
94	6	1697	17.20
92	8	1707	17.00
90	10	1769	16.43
88	12	1785	15.97
86	14	1717	18.95
84	16	1608	19.24

Table 6: Compaction tests results for borrow pit 3, Sample 2

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	MDD (Kg/m^3)	OMC (%)
100	0	1420	22.70
98	2	1559	20.22
96	4	1608	19.84
94	6	1678	19.06
92	8	1760	18.41
90	10	1793	18.10
88	12	1942	17.92
86	14	1766	19.35
84	16	1633	20.90

Table 7: CBR tests results for borrow pit 3, Sample 1

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	Unsoaked CBR (%)
100	0	8.4
98	2	11.1
96	4	14.4
94	6	16.3
92	8	20.3
90	10	25.4
88	12	30.3
86	14	26.1
84	16	24.8

Table 8: CBR tests results for borrow pit 3, Sample 2

Percentage of Laterite (%)	Percentage of Terrasil Solution (%)	Unsoaked CBR (%)
100	0	6.2
98	2	13.5
96	4	17.3
94	6	18.7
92	8	21.7
90	10	26.3
88	12	32.0
86	14	27.9
84	16	25.5

Tables 2 and 3 show that the soil samples from borrow pits 1 and 2 were good enough and therefore needed no stabilization, while soil samples 1 and 2 from borrow pit 3 are poor in strength, thus, necessitating the need for stabilization. Tables 5 and 6 show the relationship between the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) with variations of water – terrasil ratio contents. The result indicated that between 0% and 12%

terrasil solution, the MDD values for both samples generally increased and the OMC generally reduced. For soil sample 1, the MDD increased from 1267 Kg/m^3 at 0% to 1785 Kg/m^3 at 12%, for sample 2, MDD increased from 1420 Kg/m^3 at 0% to 1942 Kg/m^3 at 12%. With the addition of more terrasil solution, that is, at 14% and 16%, values of MDD in both samples reduced and OMC values increased. Increased MDD may be due to a decrease in the surface area of lateritic soil sample arising from the reaction of terrasil as an organo – silicon compound which react with soil particles on a molecular level and makes each and every particles waterproofed [16]. According to [17], an increase in MDD is a good indication of improvement in soil property, whereas a reduction in OMC enhances the workability of a good soil. Also the result shows that the OMC values decreased with increase in the terrasil - water ratio before the optimum point- which implies the reaction of terrasil molecules with water generates silinol groups. These silinol groups condense with silinol groups of the soil particles and forms Si-O-Si bonds. This chemical reaction between terrasil and soil particles imparts hydrophobic groups on the surface. This hydrophobic group will not allow soil particles to wet with water. At the optimum moisture, there was a structural adjustment which induced the peak strength with corresponding optimum moisture content for the sample which was usually the lowest optimum moisture content for the stabilized soil. While the reduction in MDD values as a result of further addition of terrasil solution - may be due to excess organo-silanes that could not be mobilized for the reaction which consequently make the solution to be less reactive and therefore forming weak bonds. Increase in OMC may be due to the addition of terrasil solution which decreases the the quantity of free silt and clay fraction and coarser materials with larger surface areas are formed [18]. Tables 7 and 8 show that for the increasing addition of terrasil solution, CBR value rose from 8.4% at 0% to optimum value of 30.3% at 12% terrasil solution, for sample 1. For sample 2, the CBR rose from 6.2% at 0% terrasil solution to 32.0% at 12% terrasil solution before reducing in values to 27.9% and 25.5% at 14% and 16% terrasil solution respectively.

4 Conclusions

The procedures for the various tests were carried out in accordance with that stipulated in BS 1377-1990: 1-8 [19] and British Standards (BS) 1924 [20].Using terrasil reduced the plasticity indices of the soil therefore improving the strength property of the soil. CBR values increased with the increase in percentage of terrasil solution. Terrasil serve as a cheap stabilizing agent for poor soil.

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