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DETERMINATION STRENGTH OF LATERITE STABILISED WITH CEMENT AS A BINDER AGENT

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Abstract— This paper investigates the effect of a chemical stabiliser, which is cement, on the strength of laterite soil to act as a subgrade for the pavement layer. The analysis will focus on the improvement of laterite soil's strength withstanding the load applied during the Unconfined Compressive Strength (UCS) test. Cement was utilised as the stabiliser in this method. According to the UCS, cement content rises in strength. Sub-grade or Soil stabilisation is a technique to increase the pavement layer's strength by altering the soil's chemical and mineral composition using chemical additives or non-chemical additives as the stabilising agents.

I. Introduction

In 1993, according to Bell, mixing chemicals with soil to increase its volume stability, permeability, durability, and strength, thereby improving the pavement structure's quality is known as soil stabilisation [1]. Then, in 1996, any procedure that improves and makes a soil material more stable is defined as stabilisation [2]. As defined by Garber and Hoel, subgrade or soil stabilisation is an improvement of existing natural subgrade or soil to enhance its material characteristics via engineering processes. Laterite is a reddish-brown tropical soil that is highly in iron oxide and is formed by a range of rocks weathering processes. It grows in humid climates such as tropical and sub-tropical countries [1]. Adding cement into the existing sub grade or soil as a binding agent is known as cementitious stabilisation.

II. Literature Review

A. Laterite History

In 1807, a geologist named Buchanan first described the term "laterite" from the word "later" in Latin. He calls it laterite because it is a soft ferruginous mineral quarried in southeast India for building blocks [3]. Laterite is an appropriate title for various combinations of clays, sands, and gravels. According to Bridges (1970)[4], the term laterite refers to "a huge vesicular or concretionary ironstone deposit nearly usually associated with uplifted peneplains originally associated with locations of low relief and high groundwater" [5].

B. Physical and Mechanical Laterite Soil Properties

It is essential to analyse lateritic soils and identify material characteristics. The consideration process shall start with design and then construction materials for the limitations and effects.

The engineering properties of subgrade or soil are involved in the strength of soil stabilisation. The standard method for determining stabilised materials' strength is unconfined compressive strength (UCS). The maximum axial compressive stress that a cohesive soil specimen can withstand under zero confining force is called UCS.

Table 1: Various Additives for Stabilisation of Soil

Group	Binder Agent
Cementitious	Lime, fly ash, ground-granulated blast furnaced (GGBS), cement, kiln dust and silica fume.
Chemical	$CaCl_2$, KCl, Na_2SiO_3, $FeCl_3$, $Mg(OH)_2$, Na(OH), NaCl, $MgCl_2$, and $AlCl_3$
Non-Cementitious	Stone dust, quarry dust, aggregate waste, rock waste powder, crusher dust, granite sawdust and sand.

C. Cement Stabilisation

This cement stabilisation is suitable for laterite soils, including granular. Mengue researched the mechanical qualities of Cameroon's fine-grained lateritic soil in 2017 and determined that 3% and 6% cement are sufficient to achieve the acceptable mechanical performance of stabilised lateritic soil for usage as sub-base and base layer, respectively [6].

Table 2: UCS Results After 7 Days Curing Time

Cement Content (%)	UCS Results After 7 Days Curing Time (kPa)		
	(Dabou et al., 2021)	(Wahab et al., 2021)	(Marathe et al., 2015)
0	580	200.74	556
3	1420	391.35	934
6	2880	1233.15	1858
9	3400	1737.52	2077
12	3590	1899.6	2164
Optimum (%)	6	6	6

The cement content is 3%, 6%, 9% and 12% to find the optimum content of cement as a stabiliser. Based on Table 2, the comparison between UCS results is based on the cement content via UCS test. It can be easily seen that the cement is more effective than other types of stabiliser agents [7]. From studied, it overall chosen that the optimum content of cement is

6% for use as subgrade, with values more than 800kPa, stated by Malaysian Standard. Even though the UCS of cement content is 3%, which is more than 800kPa, according to Marathe, OMC and MDD of 6% cement content were optimum. MDD values obtained for the lateritic soil treated with cement, from both modified and standard proctor compactions, immediately after mixing, showed an increase to 6% of cement, and then it decreased. Similarly, OMC values obtained for the various percentages of cement (0, 3, 6, 9 and 12%) with lateritic soil immediately after mixing decreased to 6% of cement and then increased gradually. The mix design report also stated that the minimum requirement for the strength of the stabilised layer was obtained when four per cent (4.0%) of cement was utilised as a soil stabiliser [8]. Thus, this study focuses on finding 3%, 4 %, 5%, and 6%.

III. Methodology

This research is based on laboratory testing. Moisture Content, Particle Size Distribution, Atterberg limits, Compaction, and pH Test are among the laboratory studies performed on sub-grades or soil. While the modified soil test is the same as the existing natural soil test, UCS is required for strength.

A. Sample Preparation and Design Mix Configuration

Most of the methods above used in the preparation of the natural soils are sieving and oven drying.

The method of sample preparation is in accordance with BS 1377: Part 1-2, 1990. Meanwhile, the preparation method for mixing soil samples was according to BS 1924: Parts 1-2, 1990. Soil samples are mixed with Ordinary Portland Cement (OPC), and a specified percentage of water is added to act as a medium for the reaction process. The design mix configuration (OPC) is 3%, 4%, 5% and 6% as stated in Table 3. To prevent segregation, the mixing was done thoroughly through the engineering process.

Table 3: Mix Design Used In This Study

Batch	Sample	Type of Laboratory Tests
Control sample	Natural Subgrade/Soil, i.e. Laterite Soil (100%)	• Moisture Content (MC) • Specific Gravity • Particle Size Distribution (PSD) • Atterberg Limit Test • Proctor Compaction Test • Unconfined Compressive Strength (UCS) test
1	Laterite + 3% OPC Cement	• Proctor Compaction test
2	Laterite + 4% OPC Cement	• Unconfined Compressive Strength (UCS) test
3	Laterite + 5% OPC Cement	
4	Laterite + 6% OPC Cement	

IV. Results and Discussion

A. Summary of Laterite Soil Properties

According to Table 4, the moisture content for laterite soil ranges from 18.25% to 18.86%, with an average value of 18.50%. These outcomes are consistent with research ranges, said Bell and Gidigasu.

The average moisture content around Ayodele in 2020 in Osun State, southwest Nigeria, which was 18%, can be compared to the laterite of this study. A specific area's natural moisture content can be determined, and this knowledge can be used to determine the optimum way to apply it to engineers.

Additionally, it is necessary to test the hydrometer test and the Atterberg limit. Consequently, the particle size distribution graph was plotted using the hydrometer test and sieving. Material of Gravel, sand, silt, and clay made up 0.6%, 1.4%, 94.91% and 2.91% of the particle size distribution graph, respectively. The results shown that the laterite soil was a fine soil with a significant clay and silt content. The soil classified as well-graded clayey SILT.

The LL and PL values were 40.85% and 25.84%. It can be said that the kaolinite clay material is contained in the soil samples. This is due to the fact that kaolinite soils have liquid limit values of between 35 and

100%, and plastic limit values of between 20 and 40% [9]. The liquid limit which was from 20mm of the penetration to the linear line. The PI is variable between the LL and PL values which was 12.01%.

Table 4: Summary of Material Properties for Laterite Soil

Physical and Mechanical Properties	Value
Moisture Content (%)	18.5
Gravel (%)	0.6
Sand (%)	1.4
Silt (%)	94.91
Clay (%)	2.91
Liquid limit (%)	40.85
Plastic limit (%)	28.84
Plasticity Index (%)	12.01
Classification	CI
Maximum Dry Density, MDD (Mg/m^3)	1.62
Optimum Moisture Content, OMC (%)	25.92
Unconfined Compressive Strength After Curing 7 Days (kPa)	195

A. Compaction

Figure 1 illustrates how more water was added to the soil, effectively replacing the soil particles with water and lowering the soil's density.

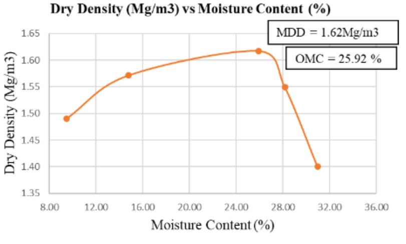

Figure 1: Graph of Dry Density (Mg/m^3) vs. Moisture Content (%)

The sub grade or soil material become denser by compaction, increasing their dry unit weight when more water is added. This improves shear strength, reduces permeability, and lessens the effect of the settlement. The MDD beyond which soil starts to lose density is the biggest restriction when water assists in maximising the dry density. The moisture level that corresponds to that is the OMC for that specific soil. From the compaction test, the MDD and OMC were 1.62 Mg/m^3 and 25.92% based on Figure 1.

Figure 2 shows the Stress-Strain Curve in kPa of a soil samples for 0%, 3%, 4%, 5%, and 6% of cement content. From the results shown in Table 5, the maximum stress was 195 kPa, 480 kPa, 728 kPa, 1140 kPa, and 1365 kPa for cement content with axial strain of 11.7%, 3.35%, 3.01%, 1.95%, and 2.79%. The dry density for cement content were 1.94 Mg/m^3, 1.79 Mg/m^3, 1.96 Mg/m^3, 1.92 Mg/m^3 and 1.96 Mg/m^3. The shear strengths in kPa for cement content were 97, 240, 364, 570 and 683.

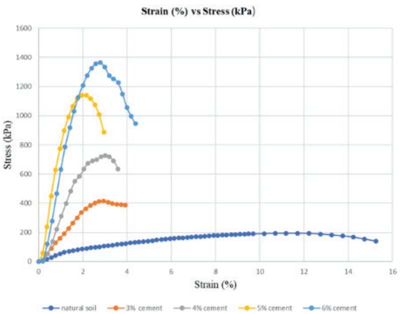

Figure 2: Strain (%) vs Stress (kPa) for Unconfined Compression Strength (UCS)

Table 5: Results of UCS After Curing 7 Days

Cement Content (%)	UCS after Curing 7 days (kPa)		Dry Density (Mg/m^3)	Axial Strain (%)
	Sample 1	Sample 2		
0	161	195	1.94	11.7
3	386	416	1.93	2.93
4	659	728	1.96	3.01
5	1010	1140	1.92	1.95
6	1145	1365	1.96	2.79

The UCS test was conducted using the OMC as shown in Figure 2. According to Table 5, natural laterite soil without mixed with cement had an UCS of 195kPa after 7 days of curing, making it unsuitable for use as a subgrade. Then, the laterite soil required to stabilise with cement. From previous studies, all laterite soil was not suitable as subgrade and needed to stabilise at a range of 128.88kPa to 580kPa. As the cement amount and curing period increased, the strength parameters (CBR and UCS) also rose, causing the UCS to increase from 195kPa to 1365kPa when stabilised.

Additionally, based on Table 5, the cement content was 5% and 6% greater than 800kPa, which was 1140 and 1365kPa, respectively. However, although having 6% greater strength than 5% of cement, 5% of cement is the most acceptable optimum cement content for stabilising. The compacted material has obtained the 95% range density for compacted fill, which is between 1.8Mg/m^3 and 2.1Mg/m^3, and the required UCS is 800kPa, equivalent to 13% CBR. Table 5 shows that all dry densities fall between 1.8 and 2.1Mg/m^3. Additionally, the shear strength of laterite soil was 97kPa, but it rose when mixed with cement. The shear strength was 570kPa and the axial strain was 1.95% with a 5% cement concentration.

V. Conclusion

This research is carried out to analyse the effect of sub grade/soil stabilisation using cement in altering existing material which is laterite soil properties to provide high strength and durability as a subgrade of a pavement.

This study concentrated on building a strong foundation for laterite soil as a material for subgrade's pavement. Thus, the result of this research can influence people on how to use natural resources towards reprocessing materials for soil treatment to create innovative and cost-effective solutions for the pavement's infrastructure demands. In this study, cement can be proven as a binder agent for soil stabilisation method that can treat laterite soil to be a reliable base for any pavement's construction.

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