Progress in Engineering Application and Technology Vol. 4 No. 1 (2023) p. 934-941
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PEAT

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Shear Strength Characteristics of Acidic-clay stabilised with Ca-based Binding Agent

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DOI: https://doi.org/10.30880/peat.2023.04.01.097
Received 15 January 2023; Accepted 12 February 2023; Available online 12 February 2023

Abstract: Road mobility be in demand since it improves access to economic resources, jobs, healthcare facilities, and educational institutions. The construction of a road on acidic soil with low-strength and highly compressible soils can lead to settling and collapse issues. Construction on acidic soils with low strength can cause settlement problem and collapse on the building and roads. This has become a difficulty for engineers and the road users, who must ensure the safety and quality of the construction on this soil. This research aims to determine the shear strength characteristics of the stabilized acidic soil with field application considerations and to formulate the optimum Fibrobase binding agent dosage for strength enhancement of acidic clay. Unconfined compression strength was the strength test employed in this investigation to evaluate the strength of treated samples. Acidic soil samples are treated and then allowed to cure for 3, 7, 14 and 28 days. From the analysis done in the UCS test, it can be concluded that the best mixed ratio is 5RS:5S, as it achieves high compressive stress with the optimum dosage of 4% of Fibrobase and the optimum curing period achieves the best compressive strength performance, which 2177 kPa. when the mixed ratio of the acidic soil reached its highest strength during the optimum curing period at 28 days with an optimum dosage of 4% of Fibrobase. From the overall data, it shows that the Fibrobase can increase the soil's strength, even in an acidic state and the higher the dosage of the Fibrobase, the higher the compressive strength of the soil.

Keywords: Acidic Soil, Soil Stabilisation, Unconfined Compressive Strength (UCS) , Soil Binder

1. Introduction

Road mobility be in demand since it improves access to economic resources, jobs, healthcare facilities, and educational institutions. Infrastructure over low-strength soil requires annual maintenance and restoration costs in the billions of dollars. The strength and stability of the road surface are influenced by the soil, even in unfavourable environmental conditions. In addition to the structural design of the pavement, the subgrade support conditions and sub base layers also affect how well the

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finished road performs. The construction of a road on acidic soil with low-strength and highly compressible soils can lead to settling and collapse issues. This inappropriate soil for road development must be addressed by soil improvement. To reinforce road surfaces and other geotechnical applications, improvements include raising the dry unit weight, bearing capacities, volume changes, and the effectiveness of in-situ subsoils, sands, and other waste materials [1].

This research describes the findings of an experimental investigation on acidic soil and the stabilising agents that admixed with various sand ratios. For long run, this would ensure reduced maintenance costs and more importantly is the safety of road users plying the road free of endangering potholes and other defects that attributed to the poorly road foundation layer of acidic soils. The project is carried out to examine the shear strength of acidic soil with different content of sand and the effective of the stabiliser increasing it shear strength. When soft soils like sand, clay, and peat are present, existing soil may not necessarily be appropriate for road development. High compressibility, high moisture content, weak shear strength, and low bearing capacity [2]. Therefore, the problem associated with acidic soil can be avoided by stabilising the existing soils prior to development. This research aims to determine the shear strength characteristics of the stabilized acidic soil with field application considerations and to formulate the optimum Fibrobase binding agent dosage for strength enhancement of acidic clay. This research aims to determine the shear strength characteristics of the stabilized acidic soil with field application considerations and to formulate the optimum Fibrobase binding agent dosage for strength enhancement of acidic clay.

Before starting the main laboratory test to determine the shear strength, some index properties tests need to test on red soil and sand. The index properties of red soil, such as pH value, particle size, specific gravity, atterberg limit, organic content and maximum moisture content, were investigated according to British Standard 1377 (1990) [3][4][5]. The primary geotechnical experiments in this study is Unconfined Compressive Strength Test, which are used to evaluate the soil stabiliser's performance in increasing the shear strength in acidic soil. To determine shear strength, the acidic soil was combined with Fibrobase Stabiliser at dosage 0%, 2% and 4% [6]. This study's findings benefit society by decreasing the expense of road maintenance. Additionally, it can reduce the risk of being involved caused by deteriorated roadways. The settlement of the roadway can result in pavement surfaces that are uneven and unstable. Any vehicles passing by will experience a turbulent ride. Indirectly, the driver will gradually feel as though they have lost control of their vehicle, especially when transporting heavy loads. The primary objective of the project was to increase the stability of the road surface and increase the strength of acidic soil for road users.

This research formulates optimum dosage binding agent for mixed ratio of acidic soil to serve as high performance subgrade layer. So that, the inclusion of a stabiliser has the potential to make road surfaces more durable as strengthening develops gradually over time as treated soil cures. Finally, instead of using other soil improvement technique, the in-situ soil can be treated with soil stabilisation. As a result, the additive soil stabiliser give many advantage for soil treatment in making the road surface more durable, high strength, less permeable, and less compacted than the usage of native soil.

Dealing with soft subgrade or clay soil is one of the main issues [7][8]. Numerous research has been conducted in an effort to identify less expensive solutions to this issue because replacing the materials would be quite expensive [7]. A chemical or mechanical procedure called soil stabilisation alters the soil in a way that makes it more suitable for engineering. The mechanical stabilisation of soil processes include compaction and densification. These methods can all make use of mechanical energy sources, such as rollers, rammers, vibrational techniques, and blasting. One of the simplest methods for increasing soil performance through mechanical stabilisation is compaction. Without a chemical reaction, adding something to porous soil will alter the physical characteristics of what was already there. Chemical stabilisation involves altering the behaviour and appearance of the soil through chemical processes. Chemicals and emulsions are two techniques for chemical stabilisation. It binds the clay together, prevents water from entering, and modifies the clay's behaviour. Additionally, it may facilitate the formation of robust chemical linkages between the constituent particles of the aggregate.

The goal of stabilising the soil wasn't just to make it stronger so it could hold more weight. Additionally, it was done to improve the soil so that it could support engineering work [9]. By treating acidic soil with a mixture of commonly used chemical stabilisers, such as lime, cement, coal ash, and fly ash, the shear strength of the soil can be increased. This pass research has summaries in Table 1.

Table 1: Shear strength of soil clay treated with different stabiliser

Stabiliser	Description	Authors
Reed ashes	• Increase in liquid and plastic limit, decrease in plasticity index • Increase in UCS and CBR • A decrease in the soil's specific gravity • Enhance compressibility	Hussien *et al.*, 2015
Bentonite and Nano clay	• Decrease the void in BPSC while increasing the CBR value for BPSC.	Idrus *et al.*, 2016
Lime	• Increase the strength, plasticity index, liquid limit, and plastic limit.	Saifuddin & Amran, 2015
Brown Clay and Cement	• Mix stabilised clay study can enhance soft clay	Mousavi and Sing, 2015

Based on earlier study by Idrus et al. (2016), bentonite and nanoclay were added to soft clay in order to improve the geotechnical soil qualities. The study established that increasing the admixture percentage causes the void in Batu Pahat Soft Clay (BPSC) to reduce, and that as a result, the rate of water also reduces, improving the soil's qualities. The CBR value for BPSC will grow concurrently with the increase in admixture percentage, demonstrating the excellent soil strength. The study came to the conclusion that the combination is useful for enhancing the quality and strength of weak soil [10].

2. Materials and Methods

For calculating the dosage of Fibrobase binding agent as a soil stabiliser, the research approach includes planning, literature review, materials selection, sample preparation, testing, procedure, and data analysis. Red soil, sand, and soil stabiliser are the main components used in this experiment. The flow chart in Figure 1 shows the description of raw materials and bamboo used in this study was This study was divided into the following three phases which first phase is materials collection and preparation. Next is examinating the physical and mechanical properties of soil with and without soil stabilizer and lastly, study of the potential of Fibrobase as a binding agent in improving soil strength.

2.1 Materials Selection and Preparation

This study used a lot of Red Soil (RS), which has a lot of clay, sand, and soil stabiliser. Samples of typical red clay can be found in hot, humid places like Malaysia. The soil was taken from the slope behind the residential college of Universiti Tun Hussien Onn (UTHM), Pagoh, Johor at a depth of 1 metre. Red clays, which might be brownish red or brownish yellow, are created by laterization from exposed carbonate rocks, according to studies by Xue [11]. Due of its poor technical properties, acidic soil is considered problematic for this investigation. Reports and evaluations of the stabiliser's impact on the physical and chemical characteristics of acidic soil are provided.

In this research, the ideal soils were made by mixing red soil with sand that passed a 2 mm sieve in order to study soil behaviour. In this laboratory study, controlled soils are used, which are soil combinations that must include a lot of clay in order to behave "clay-like." The red soil must predominate in this study. As a result, the sand must be fixed at less than 50%, whereas the red soil must be fixed at 50% or higher as in Table 2.

Table 2: Sample Ratio

Sample Code	Ratio		Fibrobase(%)	Define
	Red Soil (RS)	Sand (S)		
5RS:5S	5	5	0	50 % of red soil and 50 % of sand with 0 % of Fibrobase
			2	50 % of red soil and 50 % of sand with 2 % of Fibrobase
			4	50 % of red soil and 50 % of sand with 4 % of Fibrobase
7RS:5S	7	3	0	70 % of red soil and 30 % of sand with 0 % of Fibrobase
			2	70 % of red soil and 30 % of sand with 2 % of Fibrobase
			4	70 % of red soil and 30 % of sand with 4 % of Fibrobase
9RS:1S	9	1	0	90 % of red soil and 10 % of sand with 0 % of Fibrobase
			2	90 % of red soil and 10 % of sand with 2 % of Fibrobase
			4	90 % of red soil and 10 % of sand with 4 % of Fibrobase
10RS:0S	10	0	0	100 % of red soil and 0 % of sand with 0 % of Fibrobase
			2	100 % of red soil and 0 % of sand with 2 % of Fibrobase
			4	100 % of red soil and 0 % of sand with 4 % of Fibrobase

The soil stabiliser, also known as Fibrobase, is a product of Reinforce Soil Engineering Sdn. Bhd. and comprises of a Ca-bases stabilising agent that is supplied in fine powder form. The sample was prepared using several standard codes, as shown in Table 2. The sand must be dried in a metal tray and heated for 24 hours at 105 degrees Celsius before the laboratory testing.

2.2 Methods

To prepare mixed ratio 5RS: 5S, 50% of mixed sand is added with 50% of the Red Soil (RS). The sand and clay mixture was then mixed with 2% Fibrobase until it was homogenous, then the ideal amount of distilled water was added based on the data optimum moisture content from compaction test. Next, the sample compacted and removed from the mould that is 76 mm in height and 38 mm in diameter. Acidic soil samples are treated and then allowed to cure for 3, 7, 14 and 28 days. The sample preparation followed with another mixed ratio 7RS:3S, 9RS:1S and 10RS:0S. Then, it continues with 4% Fibrobase and the controlled sample. For this compression test, each sample is placed in a mould that is 76 mm in height and 38 mm in diameter. The sample that exceeds the dimension should be cut to the required size.

After the curing complete, the unconfined compression strength was the strength test employed in this investigation to evaluate the strength of treated samples. The deformation dial value will reach its maximum value after the tested sample experiences shear failure. To obtain the overall graph of the sample, it is also necessary to record the value of the drop. To determine the best mix ratio for the entire study, the average value of the two samples evaluated for each different mix ratio will be used.

3. Results and Discussion

3.1 Unconfined Compressive Strength Test (UCS)

After stabilisation, an Unconfined Compressive Strength Test (UCS) was performed to evaluate the strength of red soil with various sand ratios. To determine the value of the maximum compressive stress, it is necessary to analyse the data collected during this test. For each tested sample, UCS values were calculated using the tension and pressure data as a result. Four separate mixed samples of the material after stabilisation were evaluated with curing at days 3, 7, 14, and 28.

3.1.1 Effect of Mixed Ratio and Different Dosage to Unconfined Compressive Strength with Curing Time

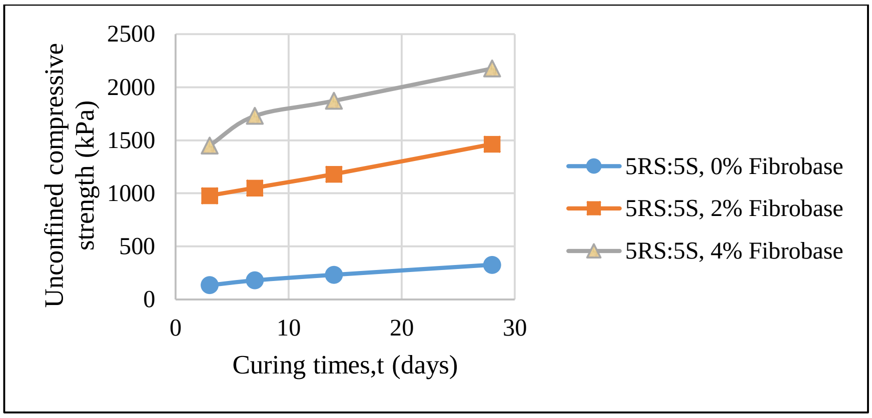

Figure 3: Unconfined Compressive Strength against Curing time at ratio 5RS:5S

Figure 3 shows the effect of the ratio 5RS:5S with different dosages of fibrobase on the unconfined compressive strength (UCS) with respect to curing time. In this ratio, it contains 50% red soil (RS) and 50% sand (S). As shown in the graph, the control sample increased with the curing time even without the stabilizer, and the different dosage of the stabiliser left a large gap in the UCS value of the mixture. It was also shown that the value of UCS increased as the dosage of fibrobase increased. The graph shows that the 5RS:5S with 4% fibrobase has the highest UCS value of 2177 kPa in a 28-day period, followed by 2% fibrobase with a UCS value of 1464 kPa.

3.1.2 Effect of Different Dosage of Fibrobase to Maximum Compressive Stress with Curing Time

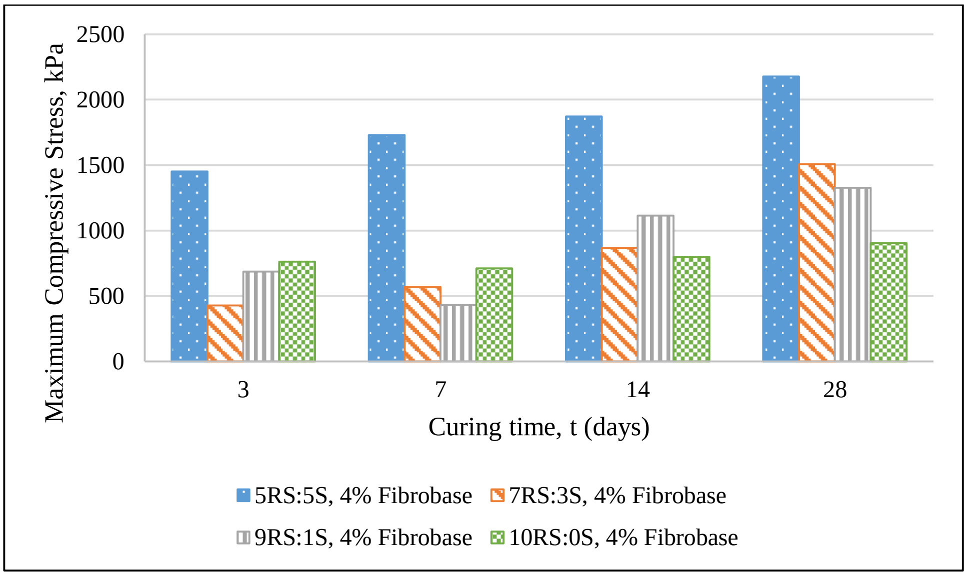

Figure 4: Maximum Compressive Strength against Curing time at 4% Fibrobase

Show the maximum compressive strength of a mixed ratio with 4% Fibrobase in Figure 4. The graph illustrates that the maximum compressive strength of the mixed soil increases as the curing time increases. The highest ratio has been observed to be 5RS:5S, which also has the highest maximum compressive stress in every curing period compared to other ratios. For the 10RS:0S, the value of the maximum compressive stress has increased a little until the optimum curing time of 28 days.

4.1.3 Effect of Different Mixed Ratio to Maximum Compressive Stress with Dosage of Fibrobase at curing time

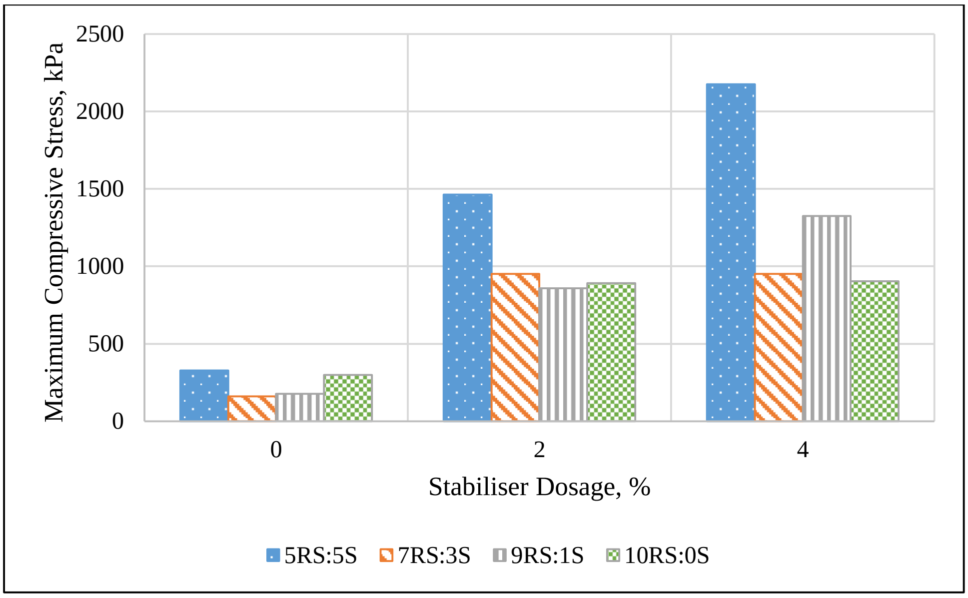

Figure 5: Maximum Compressive Stress against stabilizer dosage with different mixed ratio at 28 days curing time

The 28-day curing period is a time frame for the sample to react with the binder. The maximum strength of the tested sample is usually reached after 28 days. In Figure 5, the control sample still has low compressive stress, while the mixed ratio sample has a higher maximum compressive stress than the value at 14 days of curing. From the graph above, the 5RS:5S ratio also increases the value of compressive stress with 2% and 4% Fibrobase dosage, respectively.

According to the observations, the maximum compressive stress rises as the stabiliser dosage rises. It demonstrates that Fibrobase can help to strengthen the soil in any mixed ratio with the proper curing method.

3.3 Summary for Unconfined Compressive Strength (UCS) Test

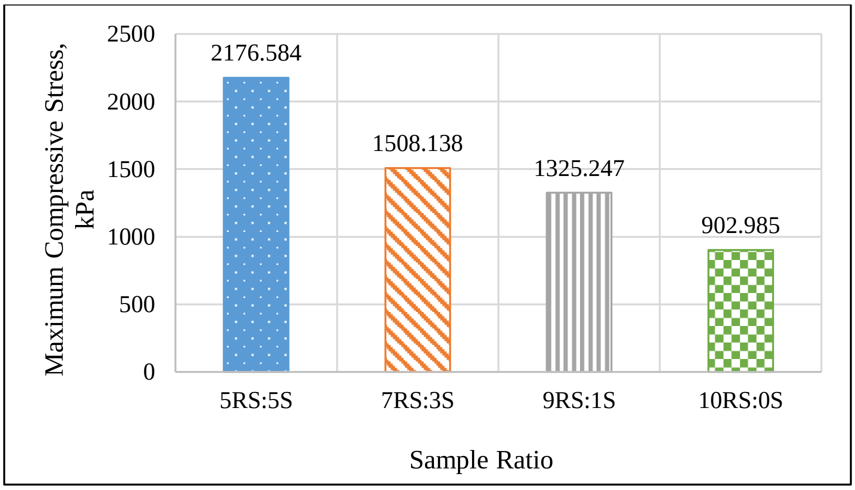

Figure 6: Sample Ratio against maximum compressive stress at 28 Days with 4% fibrobase

From the analysis done in the UCS test above, it can be concluded that the best mixed ratio is 5RS:5S, as it achieves high compressive stress in each analysis. With the optimum dosage of 4% of fibrobase and the optimum curing period, the 5RS:5S achieves the best strength performance, which gives the highest value of UCS of 2177 kPa. However, 7RS:3S also gives the best strength among the other ratios, which give the second highest value of UCS in the optimum curing period, which is 1508 kPa. From observation, the strength of the sample depends on the ratio of sand content in it. So, the less the sand content, the less the strength of the sample.

The study indicated that choosing the appropriate mix or using an appropriate quantity of red soil can help achieve the required shear strength. A very moist clay-sand mixture showed a steep drop in both cohesion and angle of internal friction when the clay content was high. This can be concluded that there is a general increase in cohesion with clay content. As more clay is added to the sandy materials, the clay particles fill the void spaces between the sand particles and begin to induce interlocking behaviour in the sand. Hence, clayey sand soils are expected to exhibit low cohesion, whereas cohesion increases with high clay content. Choosing appropriate quantity of sand can help to achieve required shear strength.

4. Conclusion

Following the completion of the research, some conclusions were reached. The conclusions drawn from this research are the red soil (RS) used in this research was classified as inorganic clay based on analysis from the specific gravity, hydrometer, organic content, and plasticity index The data from the compaction also shown that the dry density increases as the percentage of sand in the compaction increases. From the overall data, it shows that the Fibrobase can increase the soil's strength, even in an acidic state and the higher the dosage of the Fibrobase, the higher the compressive strength of the soil.

Acknowledgement

The authors would also like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

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