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Reinforced Soft Soil with Pineapple Leaf Fiber

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Abstract: Soft soil is commonly known for its high compressibility and low strength properties. This is because, the sediment process in different environmental areas as well as its physical and engineering properties of soft soil, such as vacancy ratio, water content, grain size distribution, compressibility, permeability, and strength, show significant variations. The purpose of this study is to determine the effectiveness of the fiber in determining the strength of the soft soil in the area of Pagoh, Johor. The general properties test includes an Atterberg limit test that was conducted to identify and classify the type of soil used throughout this study. Then, standard compaction and California bearing ratio tests were performed to study the effectiveness of PALF on the geotechnical properties of stabilisation soil. Based on the index properties results, the soil sample used is graded as medium plasticity clay soil, which consists of a liquid limit (LL) of more than 50.00 % and a plastic limit (PI) of not more than 17.00 %. The compaction result showed that the maximum dry density (MDD) decreases but increases at 0.50 % and the optimum moisture content (OMC) increases but drops at 0.50 % when mixed with PALF. The result shows that the CBR value significantly increased from 7.97 % to 12.09 % and it achieved the highest value at 0.75 % of PALF content. The finding shows that the PALF has been proven as a potential material for enhancing soil efficiency.

Keywords: PALF, Improvement, Soft Soil

1. Introduction

Road and bridge engineering have become the most essential aspects of urban development in Malaysia due to Malaysia's rising economic and social growth. As new roads are created to grow the city, numerous obstacles and issues will arise that must be addressed in order for the development to be successful. The quality of the roads created will be determined by the building techniques used, as well as the daily routines of users and the city's image [1].

Soft soil presents a special problem in construction and is widespread. Soft soil foundation is a common issue in the world, especially in Malaysia. These soils with engineering fields have become

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normal because most of the engineering structures were built on this soil type [2]. Excellent road construction needs a solid and strong subgrade, which is a major concern in Malaysia. Because of its fragile and unstable soil foundation, Malaysia has a significant region of lowland that can impose additional stress on building and road structures. Many issues have emerged because of this type of soil, including slope instability and failure to bear loads due to relatively low shear strength and significant compressibility [3].

Today, researchers are learning more about the properties of PALF, which has evolved into one of the composites. PALF has a high specific strength since it is hydrophilic and contains a lot of cellulose. PALF is a natural fiber source with an excellent chemical composition and higher mechanical strength. PALF is a natural fiber that, like flax fiber, has high strength, stiffness, flexural stiffness, and torsion. Because of the unique properties of this PALF, the industry has utilised it as an excellent alternative raw material in the prospect of strengthening composite matrices [11]. Producing natural fiber composites from PALF is a great opportunity to idealize the countries that grow the pineapple plant and have the greatest agricultural potential. Pineapple fiber composites already used in a variety of industries, including automotive, construction, furniture, packaging, consumer goods, and so on. Because the future is "green," and consumers demand more bio-based products on a daily basis, natural fibers will be as green as the future at this time [13].

The pineapple leaf fiber length used is in the range of 5 cm to 7 cm with an average diameter of 0.07 mm, and the ratio of the fiber mixed with the soil sample is 0.025 %, 0.50 %, and 0.075 % due to [8]. The shear strength attained its maximum value at 0.75 % fiber content and dropped to 1.00 %. The PALF used in this study was obtained from a nearby factory, which is Nature Renascent, Johor Bahru. With the collaboration of Sime Darby, the untreated soft soil is collected in the surrounding Hub Pagoh area. Additionally, the tensile strength test of the fiber and the Atterberg Limit Test of the soil sample are used to determine the physical properties. The Standard Proctor Compaction Test and the California Bearing Ratio Test are used to determine the strength improvement of the soil mixed design.

The purpose of this study is to determine the strength improvement of the soil in the area of Pagoh, Johor, Malaysia. Particle size analysis, plastic limit, and liquid limit tests were among the general index qualities identified. The principal geotechnical tests conducted in this study are the standard proctor compaction test and the California bearing ratio (CBR) test. As a result, in addition to boosting road strength, it is expected to improve road quality for future usage.

1.1 Problem statement

Weak foundation happens because of ground soil conditions, especially on soft soil, which is known as having low shear strength, high compressibility, and low permeability. Once issue soils become a part of the pavement or foundation layers, they can have a negative effect on the pavement's performance if not properly managed at the designing stage [4]. Clay can cause challenges for Malaysian road construction [3]. In addition, clay is commonly known for its high compressibility and low strength properties. This is because, the sediment process in different environmental areas as well as the physical and engineering properties of clay, which are vacancy ratio, water content, grain size distribution, compressibility, permeability and strength show significant variations [5].

Other than that, excellent road construction needs a solid and strong subbase, which is a major concern nowadays. Many issues have emerged as a result of this type of soil, including slope instability and failure to bear loads due to relatively low shear strength and significant compressibility. Many problems come after the road was completed, including uneven settlement, pavement distress, road bumps, and so on. As a result, the vehicle bump situation occurred, which not only impairs driving safety, speed, and comfort, but also reduces the vehicle's service life and, as a side effect, increases the possibility of traffic accidents [12]. Therefore, the improvement of soft soil for subbase layer road quality pavement has an effect on the improvement of the road problem, especially the road bump problem.

1.2 Research Objective

The purpose of this study is to investigate the strength of reinforced soil by properties fiber. There are three objectives that as a priority to achieving the purpose of this study. The objective is:

i. To investigate the physical and mechanical properties of PALF.
ii. To evaluate the geotechnical properties of the soil reinforced with PALF.
iii. To examine the optimum ratio of PALF mixed with problematic soil in term of strength compare with previous study.

2. Materials and Methods

2.1 Materials

Two primary materials were used in this study which are soil and pineapple leaf fiber (PALF). The soil sample used was obtained from locally available soil around Pagoh, Johor, Malaysia, which was used as a fill material for road construction. The disturbed sample was used throughout the study and was collected at a depth of 2.0 m to 2.5 m from the ground surface. Then, the collected samples were placed into heavy duty plastic bags and transported to the laboratory. The soil samples were oven-dried at 105 °C for 24 hours. The PALF is a waste from pineapple tree and was obtained from Nature Renascent, Johor Bahru as shown in Figure 1. PALF are thread-like and range in length from 5 – 7 cm and the average diameter 0.07 mm due to [7] mention that 7.5 mm long of bagasse fibers are more effective on the CBR value.

Figure 1: Pineapple leaf fiber

Figure 2: Soil sample dried (a) Original soil sample (b) Dried soil sample

(c) Sample after grained

2.2 Methodology

This study starts with collecting the information from previous studies, articles, books, and others. The materials that were used in this study are PALF and clay soil. The Atterberg limit test is used to evaluate the physical and engineering characteristics of clay soil. Tensile strength is used to determine the physical properties of PALF. Next, the Standard Proctor Compaction Test and California Bearing Test (CBR) tests are performed to analyse the mechanical characteristics of the soil mixed with PALF. In order to achieve the goal of the innovation studies, Figure 3 shows the flow chart for the process of these studies.

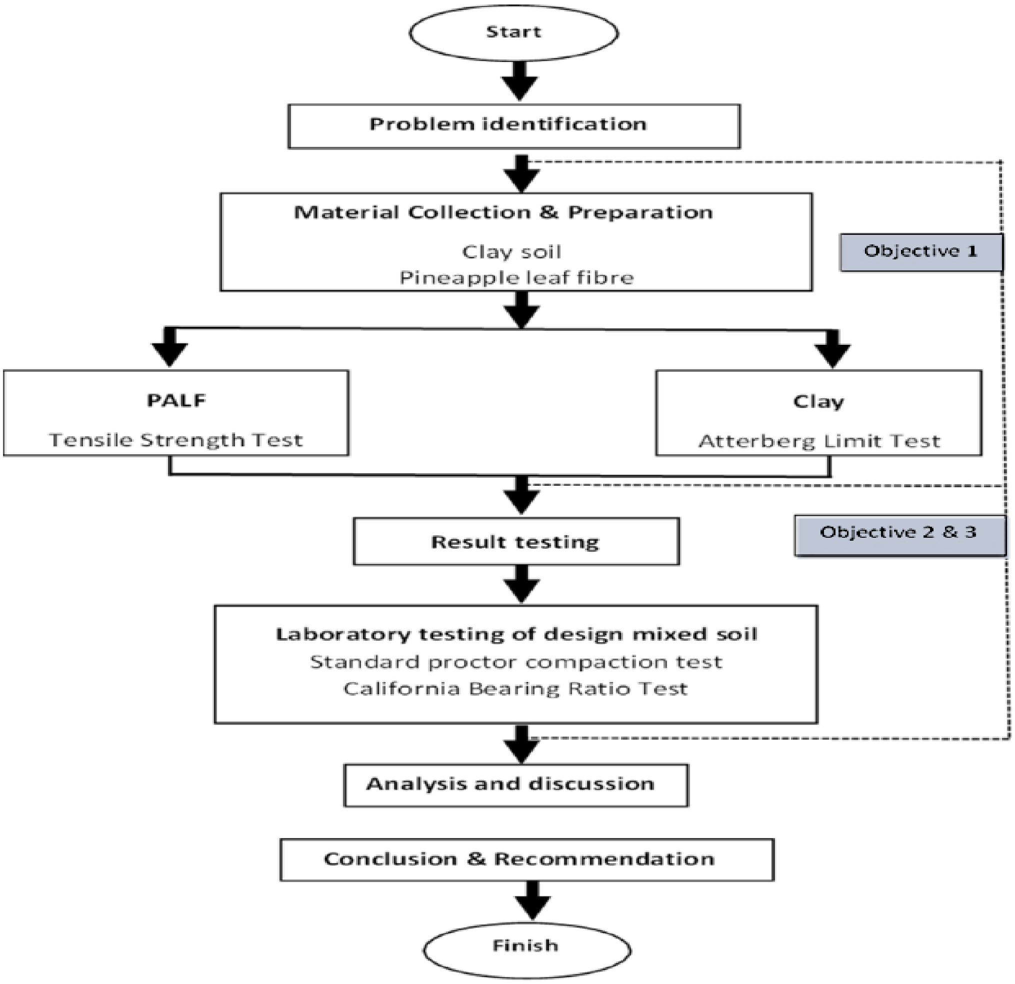

Figure 3: The flow chart of research

2.3 General Laboratory Testing Methods

The present project investigated the efficacy of soft soil stabilisation at various PALF levels (0.00 %, 0.25 %, 0.50 %, and 0.75 %). The present project investigated the efficacy of soft soil stabilisation at various PALF levels (0.00 %, 0.25 %, 0.50 %, and 0.75 %). This study included three tests, which were separated into two parts: properties tests and geotechnical properties tests. The Atterberg limit test, which involves a liquid limit test and a plastic limit test, was used to determine the kind of soil. However, the conventional proctor compaction test and the California bearing ratio (CBR) test were used as the primary geotechnical tests in this study to assess the usefulness of PALF in improving the performance of local problematic soil in Pagoh, Johor. All tests were carried out in accordance with BS 1377-2:1990.

2.3.1 Atterberg Limit Test

The Atterberg limit test was carried out to determine a crucial water content that corresponds to different soil behavior, including liquid limit (LL) and plastic limit (PL) stages. The soil sample was oven-dried at a temperature of 105 °C and passing through a sieve of 0.425 mm. LL was determined based on a dropped cone penetration test with a standard cone of 80 g and an apex angle of 30, which assume penetration at LL. Whilst PL refers to that water content at which the soil sample starts to crumble when rolled into a 3 mm diameter thread. The plasticity index (PI) is the numerical difference between the liquid and the plastic limit (PI = LL – PL), representing the water content spectrum through which the soil remains plastic. Table 1 indicates soil grading by the plasticity index.

Table 1: Soil classification according to plasticity index [6]

Plasticity Index (PI)	Degree of Plasticity	Degree of cohesiveness	Type of soil
0	Non – Plastic	Non-cohesive	Sand
< 7	Low – Plastic	Partly cohesive	Silt
7 – 17	Medium Plastic	Cohesive	Silty clay or clayey silt
> 17	Highly	Cohesive	Plastic Clay

2.3.2 Main Test: Geotechnical Properties

a) Standard Proctor Compaction Test

The purpose of a laboratory compaction test is to determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum. The amount of water is thus called the Optimum Moisture Content (OMC), which can be used for specification of field compaction. This test is referred to as the Standard Proctor Compaction Test and is based on the compaction of the soil fracture passing the No. 4 sieve. The Standard Proctor Compaction Test Procedure (BS 1377-4:1990) starts with a soil sample being obtained of 3 kg that has passed through filter No. 4. The soil along with the mould is weighed (Wm). Then, the soil is placed into a tray and water is added gradually to achieve the desired moisture content (w). Apply lubricant to the collar before inserting the soil into the mould. Next, the soil was put into the mould in 3 layers and the compaction process started with 25 strokes per layer. Then, to establish the compaction curve, the relationship between moisture content and dry density was plotted. The peak point of the compaction curve was obtained from the MDD value and its corresponding moisture content as OMC.

b) California Bearing Ratio (CBR) Test

In road and pavement construction, CBR tests measure the strength of subgrade soil, subbase, and base course material. For the purposes of determining the thickness of road pavement and component layers, the CBR value is typically used in conjunction with empirical curves. A series of unsoaked CBR tests were conducted in this study to assess the strength performance of stabilised soil with PALF percentages of 0.00, 0.25, 0.50, and 0.75 %. Pebbles will have a higher CBR value, which is 25 or above, as required. The CBR procedure due to BS 1377-4:1990 starts with the soil being crushed and being sieved through a 20mm sieve. A maximum of 5.0 kg of crushed soil will be taken and mixed with the optimum moisture content (OMC) values obtained from the compaction test. Then, the soil sample was compacted into five equal layers. Each layer of soil receives 62 blows from a 4.5 kg hammer at a drop height of 300 mm. A data logger automatically recorded the penetration load values when the load was applied to penetrate the soil surface. The CBR machine used for CBR testing is seen in Figure 4. Following the completion of the test, roughly 5 g of soil was obtained for moisture content assessment. The load versus penetration graph is presented. The CBR value was then measured at 2.5 mm and 5 mm penetrations.

Figure 4: CBR machine

3. Results and Discussion

3.1 Soil Classification

The index parameters tested in this study and utilized to identify and categories the soil type are summarized in Table 2. This study's index properties were utilised to identify and categorise the soil type. The particle size distribution of the soil sample is determined using the standard techniques defined in BS 1377:1990. The proportion of soil sample passing through the No. 200 sieve is 48.20 %. According to the USCS classification, the soil utilised can be classified as CL (sandy lean clay), which correlates to particle size and moisture content (Bowles, 1988). Based on the index properties results, the soil sample used in graded as medium plasticity clay soil which consisting of liquid limit (LL) more than 50.00 % and plastic limit (PI) not more than 17.00 %. The compaction result showed that the maximum dry density (MDD) decreases but increase at 0.50 % and optimum moisture content (OMC) increase but drop at 0.50 % when mixed with PALF.

Table 2: Soil Classification soft soil at Pagoh, Johor, Malaysia

Index Properties	Value
Liquid Limit, LL (%)	56.80
Plastic Limit, PL (%)	43.75
Plastic Index, PI (%)	13.05
Fines Percentages (%)	48.2

3.2 Physical and Mechanical Properties of PALF

[9] mention that, pineapple fiber is an excellent alternative for different reinforcing composites. A statistical examination of PALFs based on mechanical strength found an inverse relationship between tensile strength and fiber diameter. According to [10], pineapple leaf fiber among other natural fibers, may be utilized as a viable and affordable replacement for pricey synthetic fibers. Pineapple leaf fiber (PALF) is a natural fiber with high specific strength and stiffness due to its high cellulose content which is 70–80% and relatively low microfibrillar angle, and it has been extensively applied in the composite sector. The most important property of this fiber is its tensile strength. Tests of tensile strength, sometimes called tension tests, are fundamental materials scientists and engineers perform during which a sample is stretched to failure under controlled tension. Tensile test samples were prepared according to ASTM C1557 and testing was performed using a Universal Testing Machine. A tensile test specimen is typically made from a randomly selected fiber, samples from single fiber tests are used. The tensile test specimen mounted on paper tab were shown on Figure 5.

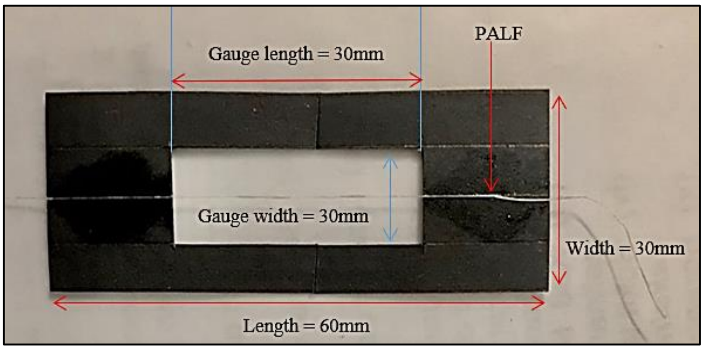

Figure 5: Specimen was tasted

In this test, there was several diameters, but 0.07 mm is chosen for this tensile strength. PALF are thread-like and range in length from 3 cm to 5 cm and the average diameter 0.07 mm. From this testing can conclude that the diameter of the PALF selected for all samples is 0.07, and the area is 0.00385. The load delivered to the fiber has a range of 3 N to 7 N. This tensile testing showed the lowest load of 3.6551 N and the maximum load of 7.8410 N. The lowest deflection measured was 0.62867 mm, while the maximum was 0.96096 mm. The lowest result for stress was 949.05 MPa, while the highest value was 2037.40 MPa. Finally, PALF has a work to maximum load range of 0.00114 to 0.00337.

Based on the result obtained, the tensile strength result is in range 947.9 – 2036.62 MPa which due [9] mention that the tensile strength ranging from 413 to 1627 MN/m². The averages of this PALF that used in this study is 1259.80 MPa. The lower values for young modulus are 48.17 and the highest values is 85.11 as illustrated in Figure 5 and the elongation at break are in ranging 2.10 % to 3.19 % as shown in Figure 6. [9] mention that, PALF exhibits a modulus selection from 34.5 to 82.51 GN/m² and the elongation at break from 0.80 % to 1.60 %.

Table 3: Tensile Strength Result

Index Properties	Value
Tensile Strength (Mpa)	1259.80
Young Modulus (Gpa)	61.255
Elongation (%)	2.81

3.3 Compaction Characteristics

The average of the relationship between the dry unit weight and moisture content for Pagoh clay soil with the OMC value According to Figure 6, the dry density of the Pagoh clay soil varies from 0.00 % to 0.25 %, then increases to 0.50 %, then decreases to 0.75 %. Once it reaches the highest point of the graph, the optimal moisture content (OMC) of soil was calculated based on the maximum dry density (ρ_d, max), which was around 1.316 g/cm^3 and the OMC was approximately 24.80 %. Moreover, the OMC generated from the graph of dry density versus moisture content for Pagoh clay soil was used to produce the soil specimen for the CBR test. The standard compaction test was carried out to determine the OMC and MDD relationship for various pineapple leaf fiber (PALF) mixes (0, 0.25, 0.50 and 0.75 %).

The connection between dry density and moisture content at different PALF results from the compaction test is depicted in Figure 6. The result obtained shows that the OMC of the virgin soil sample is 23.80 %, while the OMC of stabilized soil with 0.25 %, 0.50 % and 0.75 % of PALF are 20.80 %, 25.90 % and 24.00 % respectively. Nevertheless, the MDD value of the virgin soil sample is 1.36 g/cm^3 while for stabilised soil are 1.46 g/cm^3, 1.38 g/$cm^3$and 1.39 g/cm^3, respectively. The OMC drops also the MDD riser at 0.25 % as a result of the machine used during compaction, which causes the soil to become overly compacted and water content to be removed. Because fiber absorbs more water as fiber content increases, the OMC for 0.75 % PALF content is lower than 0.50 % PALF content.

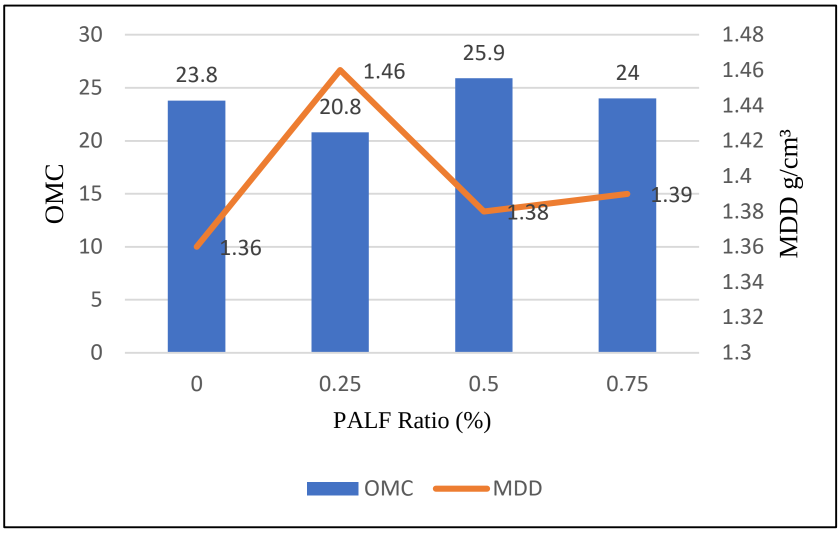

Figure 6: Example of presenting data using a figure

3.4 California Bearing Ratio (CBR)

The effect of PALF on stabilization of soil was strength was assessed primarily through the CBR characteristic. The CBR characteristic was used to evaluate the effects of PALF on stabilised soil strength. In unsoaked conditions, the CBR test was carried out by measuring the pressure required to penetrate a soil sample with a plunger. The outcome was utilised to calculate the soil's load bearing capability. For each equal layer of soil, 62 blows were used to compact it using an automated compaction machine, then the water content measured from the compaction test was added.

Figure 7 represents the relationship between plunger load and penetration at various PALF percentages. The CBR values are obtained for the load corresponding to the 2.5 mm and 5.0 mm penetrations, as summarised in Table 3, and the larger value is commonly used as the CBR value. The results reveal that the CBR values at 2.5 mm penetration are greater for 0 and 0.25 percent than for 0.50 and 0.75 percent at 5.0mm penetration. A CBR value of stabilised soil is shown in Figure 8. for different PALF percentages (0.00, 0.25 %, 0.50 %, and 0.75 %). As can be seen by the curve, the CBR value has improved, but has dropped at 0.25 %. From this, it can be concluded that strength of stabilisation soil increase with increasing percentages of PALF due to the highest value of CBR penetration is at 0.75%.

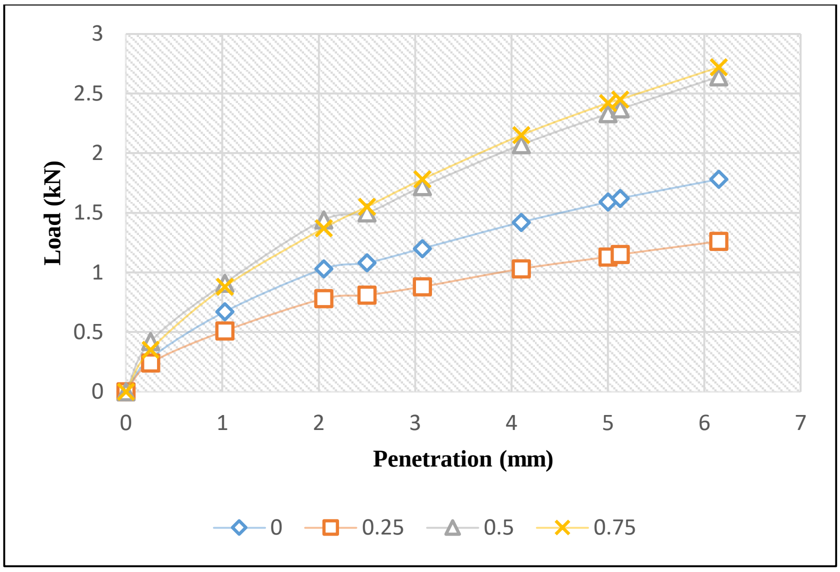

Figure 7: Variability value of load (kN) for soil sample with different percentage of PALF

Table 3: CBR value at 2.5 mm and 5.0 mm penetration

PALF ratio (%)	CBR at 2.5 mm penetration (%)	CBR at 5.0 mm penetration (%)
0	8.17	7.97
0.25	6.10	5.66
0.50	11.40	11.67
0.75	11.76	12.09

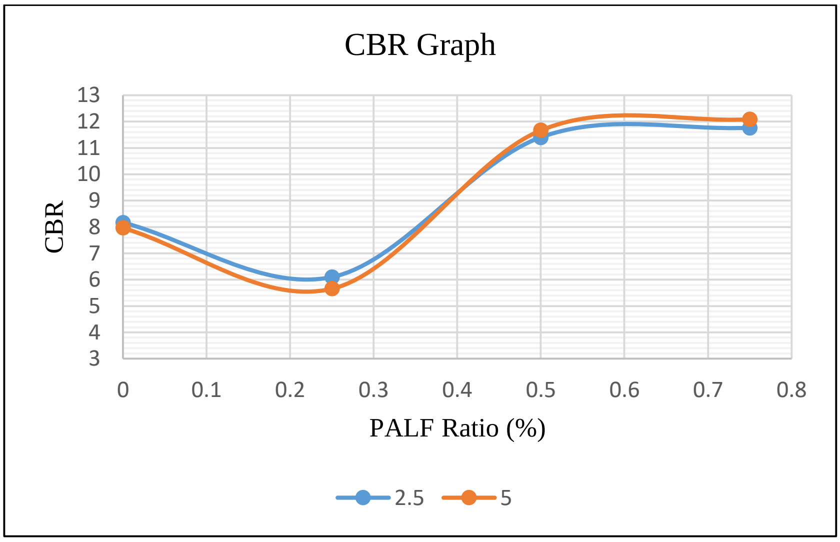

Figure 8: Effect of PALF percentage on CBR value at 2.5 mm and 5 mm penetration

4. Conclusion

The soil sample used in this study can be graded as medium plasticity clay soil with LL more than 50.00 % and PI not more than 17.00 %. To achieve the necessary performance, such soil needs particular treatment. Based on the result obtained, pineapple leaf fiber (PALF) has the potential to modify the engineering behaviour of medium plasticity clay soil and make it suitable for road sub-base construction. The compaction result showed that the maximum dry density (MDD) decreases but increase at 0.50 % and optimum moisture content (OMC) increase but drop at 0.50 % when mixed with PALF. The results reveal that the CBR values at 2.5mm penetration are greater for 0 % and 0.25 % than for 0.50 and 0.75 % at 5.0mm penetration. The CBR values significantly increase from 7.97 % to 12.09 %, with the rise in PALF percentages from 0.00 % to 0.75%. The CBR value achieved the highest value at 0.75 % of PALF content. The finding shows that the PALF has been proven as a potential material in enhanced soil efficiency Thomas et al. (2018) proved that the direct shear test revealed that the value of cohesion and internal friction increases until a fiber content of 0.75 % was reached.

Therefore, the use of pineapple leaf fiber in soil stabilization is an innovative idea due to a few reasons including suitable strength, availability, simple production process, and sustainable practice, good for the environment as well as an efficient way to reduce costs. Besides, the use of pineapple leaf fiber will also promote environmental incentives to provide a way to recycle large quantities for engineering purposes.

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