

The Strength Performance of Polyurethane Cellular Foam (PUC) Block as Soil Improvement

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Abstract

Weak subgrade caused by clay soil poses instability problems for embankment structures due to excessive soil compression and insufficient shear resistance. This study analyzes how Polyurethane Cellular Foam (PUC) blocks serve as a solution to this problem. In addition, this study can see that existing geofoam materials have low strength combined with poor material quality and deformation caused by pressure. To address these limitations, PUC blocks were developed by mixing rigid polyurethane waste with flexible polyurethane in varying proportions (0%, 7.5%, and 10%), under treated and untreated conditions. Compression tests for PUC blocks were conducted following ASTM D3574-8 standards, while unconfined compressive strength (UCS) tests for soft clay overlain with PUC blocks adhered to ASTM-D 2166 standards. The results showed that the compressive strength and Young's modulus of PUC blocks varied depending on the mixing ratio and treatment conditions. In the compression tests, the highest stress value was recorded for 7.5% treated PUW at 41.874 kPa, with a Young's modulus of 10.07 kPa. Conversely, the lowest stress value was observed for 10% untreated PUW at 26.919 kPa, with a Young's modulus of 14.41 kPa. The strain value for all samples was 2.70%. For UCS tests, the highest stress value was obtained for 7.5% untreated PUW at 25.00 kPa, with a Young's modulus of 1.7279 kPa. The lowest stress value was observed for 10% untreated PUW at 15.00 kPa, with a Young's modulus of 3.2119 kPa. All samples in this test exhibited a strain value of 18%. Overall, the findings of this study indicate the inappropriateness of using PUC blocks to improve the stability of road embankments built on clay subgrade for road construction projects.

1. Introduction

Constructing road embankments on clay soil is often challenging due to the inherent properties of clay, such as low bearing capacity and high compressibility. These characteristics lead to excessive load-bearing issues and stability problems, which are further exacerbated when the clay subgrade supports road structures [8]. The impacts include road settlement and structural failure, which necessitate the development of effective solutions to mitigate these challenges and improve the performance of roads built on clay subgrades.

Geofoam, a lightweight material with high compressive strength and excellent load distribution characteristics, has been recognized as a viable solution in road construction. It supports traffic loads without

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overburdening weak subgrades and reduces the strain on clay soils [5][1]. Geofom's advantages extend to its ease of installation, cost-effectiveness, and ability to minimize project expenses by reducing heavy equipment usage and construction time. Moreover, its durability and adaptability to various shapes and sizes enhance its applicability across diverse geotechnical conditions [8]. Analysis also indicates that geofom's high stress strength makes it particularly effective in areas with low bearing capacity [12].

This research explores the potential of Polyurethane Cellular Foam (PUC) blocks as an innovative material to improve road stability on weak subgrades. By leveraging the lightweight, durable, and adaptable properties of PUC blocks, this study aims to address the challenges of soil instability and investigate their ability to enhance the structural performance of road embankments. The findings will contribute to the development of sustainable road infrastructure, especially in areas where subsoil conditions are inadequate.

2. Materials and Methods

The methodology can be defined as one of the major aspects of the project process. Without a doubt, it involves the proper management of the project. This chapter describes more comprehensively the characteristics and preparation of the materials used in this study, sample preparations, the testing process, and the data analysis techniques that were adopted in the study. The outlined methodology is expected to observe the objectives as a way of enabling consistency between the methodology under implementation and the one required. So, there is a very good, systematic, and authoritative structure from which the project can be developed. This careful approach enhances the reliability and validity of the outcomes, ultimately contributing to the overall success of the project.

2.1 Sample Preparation

In this experiment, the polyurethane cellular samples were produced using the following main components are rigid PU waste, clay, polyol (part A) and isocyanate (part B). The PU waste collected from a local supplier, Double Cool Trading Sdn. Bhd. insulation material and furniture industry in Muar, Johor. The clay soil used samples obtained from the Edu Hub Pagoh area in Muar, Johor. The clay was then grind and passed through a sieve of 4.75 mm. Some of the characteristics include smoothness when wet, it hardens and becomes compact when dry and the product is light orange in color. Flexible PU was obtained by mixing polyol Part A and isocyanate Part B respectively in a large mixing vessel. These chemicals were purchased from Saintifik Bersatu (M) Sdn. Bhd., store location at Batu Pahat, Johor.

2.1.1 Preparation Soil

The clay sample from the Edu Hub Pagoh area in Muar, Johor is 30 kg. Then the clay sample is first reduced and levelled before being dried in an oven for 24 hours at a temperature of 110 C so that when the soil size is small it can be easily inserted into the grinding machine in the pipe technology laboratory. After the clay sample is ground for 20 minutes, the clay sample in the form of powder and passed through a sieve of 4.75 mm.

2.1.2 Preparation PUC Block

Polyurethane foam is created by stirring a mixture of polyol and an isocyanate component to cause foaming. The polyol component is blasted with water to create a blowing agent, and at least one of the polyol and isocyanate components contains hydrous thermoplastic synthetic resin particles. The resulting polyurethane foam contains porous thermoplastic synthetic resin particles with communicating pores that are formed by the evaporation of water from the hydrous thermoplastic synthetic resin particles.

2.1.2.1 Untreated Sample

The rigid PU waste (PUW) was initially cut into cubes of 10mm x 10mm and cut cubes were fed into a Riino Multifunction Blender with a maximum speed of 550 rpm. The grinding process which also involved a milling time of about 5 hours produced 50g of rigid PUW powder. The PUW powder was sieve range at size from 0.1 mm to 0.2 mm before proceeding to laboratory testing. This PUW powder as shown in figure 1.

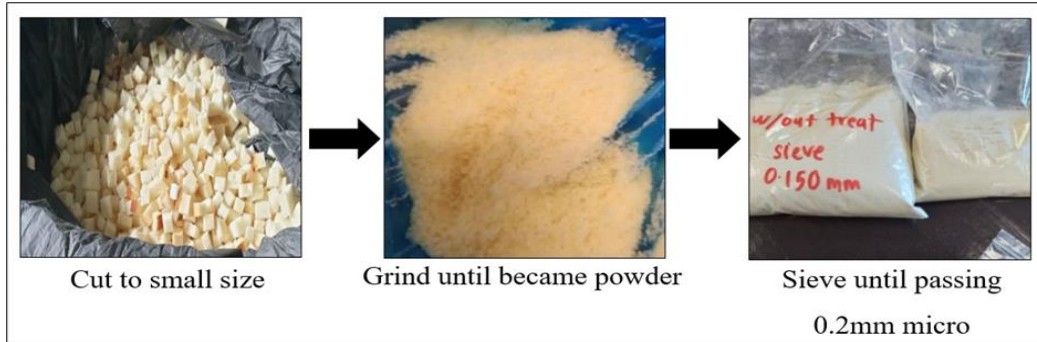


Fig. 1: This PU powder normally as PUW powder

2.1.2.2 Treated Sample

The treatment of PUW was cut into cubes of 10 mm x 10 mm. The treatment process of PU waste start by mixing 800 ml of ethanol and 200 ml of distilled water and add a 5 drops of silane coupling agent. After that, ensure the pH control in the range of 4 to 6 by adding 3.5 drops of acetic acid until the pH is stable. Soak the rigid PU waste cubes in the available chemical mixture for 3 hours, filter and then left in the oven for 24 hours. The ordinary grinder was used to grind the PU waste, as shown in figure 2. The powder size should be between 0.1 mm to 0.2 mm before proceeding to the laboratory test. This powder is namely PUC treated.

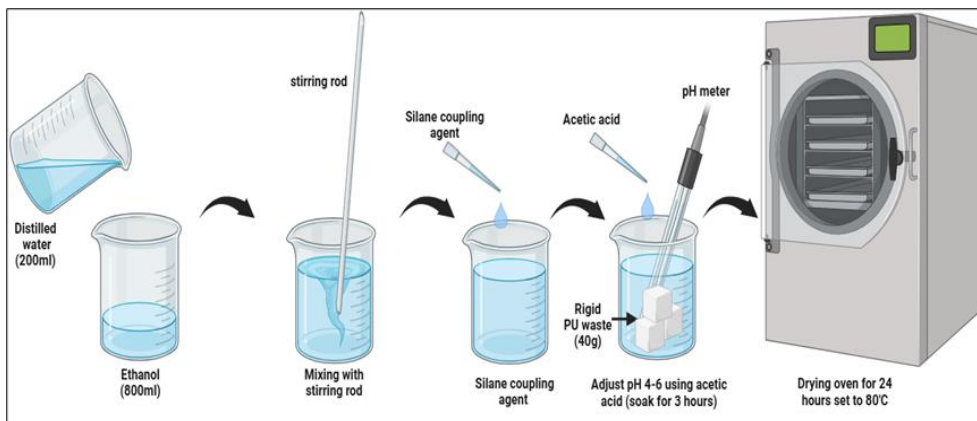


Fig. 2: The process of PUW treated by silane coupling agent treatment

2.2 Mechanical Characteristic of PU Block

PUC blocks are created by preparing 15 ml of polyol (part A) and stirring for 30 seconds using a hand mixer. Then add PUW of 7.5% of PUW untreated and mixed for 20 seconds. After that, add distilled water of 0.9 ml and mixing for 20 seconds. Finally, pour isocyanate (part B) of 15 ml and mixing for 20 seconds to reach homogeneous solution. Isocyanate component can to cause a foaming. The polyol component is blown with water to create a blowing agent, as shown in figure 3.

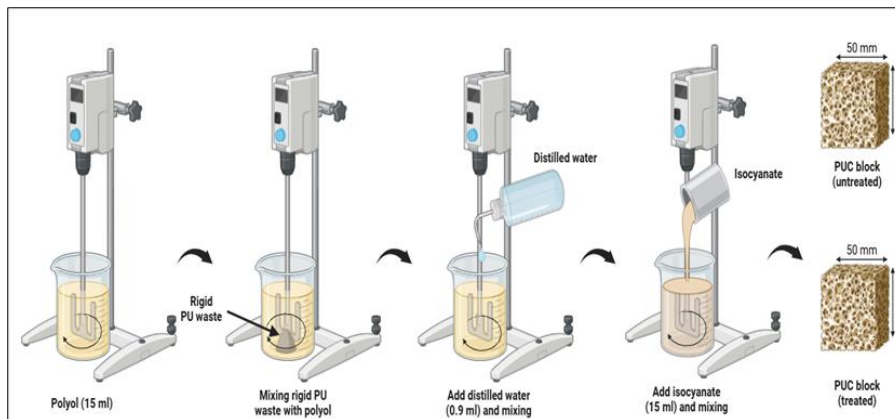


Fig. 3: The Process of fabrication of PU block with untreated and treated PU waste

2.2.1 Proctor Compaction Testing

The study began with the preparation of samples for the Proctor test. The clay samples were oven-dried for 24 hours and passed through a 4.75 mm sieve. The soil was compacted to a known moisture content into a cylindrical mould of standard dimensions using a controlled magnitude compaction effort [2].

A compaction curve was then generated by plotting the relationship between dry density and moisture content. The maximum dry density was obtained by identifying the peak point on the compaction curve, together with the corresponding moisture content, known as the optimum moisture content. The objective of the Proctor test was to determine the highest dry density and optimum moisture content.

Before conducting each Proctor test, 10 ml of water, equivalent to 30% by weight of the soil, was added to 3 kg of air-dried soil sample to achieve the specified moisture content. The soil samples were compacted in three layers, each with 27 blows, using a standard Proctor compaction mold with a diameter of 105 mm.

The test setup was in accordance with BS 1377. It required ensuring that the mould, base plate, joints, collar and rammer met the specifications. A metal rammer with a face diameter of 50 mm and a weight of 2.5 kg was used.

During the test, the mould was weighed to the nearest gram, and its internal diameter (105 mm) and height (115 mm) were measured. The inner surface of the mould was coated with oil to facilitate later removal of the soil. After the compaction process for all 8 samples, the mould filled with soil was weighed and recorded. The total number of samples was 24 samples. The soil was then extruded from the mould, and the sample was oven dried to determine the exact moisture content.

2.2.2 Compression Test

The UTM applies a controlled force to the specimen, and records the deformation caused by that force. The load frame houses a movable crosshead and fixed grips at both ends. The specimen is placed between a standard and specially developed grip, the specimen experiences tension, compression or bending forces each time the crosshead moves. The UTM, equipped with a load cell or load sensor and an extensometer or displacement sensor, is used to apply the force and monitor the deformation of the specimen. This process will produce a linear stress-strain curve that is very important for monitoring its behaviour under pressure in rigid foam. If observed closely, the structural will undergo changes and failure will occur. The test is performed many times on various foam samples to ensure accuracy.

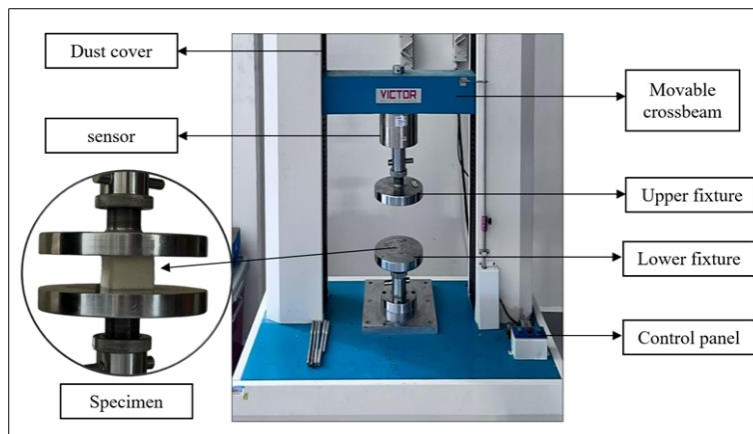


Fig. 4: UTM Machine

This measurement allows one to evaluate stress and strain as well as other mechanical properties. UTM testing is carried out according to Standards such as ASTM D3574-8 standard operating procedures and procedures set by different organizations and testing bodies [6]. This UTM testing will be done in the Automotive System lab. The polyurethane block has 15 samples at each ratio. The selected ratio is 7.5%, and 10% treated and untreated. Each sample has a size of 50mm x 50mm in the form of a cube and will be in the compression machine and make for 25 samples. The compression test speed used is 500 mm/min. Each 1 sample takes 6 minutes. Similarly, the measurements made by UTM allow one to determine the value of stress (σ) and strain (ϵ). The equations for stress, strain, and young modulus are as follows:

$$\text{Stress } (\sigma) = \frac{\text{Force } (F)}{\text{Cross-Sectional Area } (A)} \quad (\text{Equation / Eq 1})$$

$$\text{Strain } (\epsilon) = \frac{\text{Change in Length } (\Delta L)}{\text{Original Length } (L_0)} \quad (\text{Equation / Eq 2})$$

$$\text{Young's modulus } (E) = \frac{\text{stress } (\sigma)}{\text{Strain } (\epsilon)} \quad (\text{Equation / Eq 3})$$

2.2.3 Unconfined Compression Strength (UCS)

Treated and untreated samples need to be tested for strength. This compression test is one of the most important tests in this study because it determines whether the resulting mixture for treating soft soil can achieve the expected target strength or not. The strength test used in this study is the unconfined compression strength with the ASTM-D 2166 standard as a reference to determine the strength of the clay sample [7]. PUC blocks that have been fabricated are cylindrical in shape with a height of 37 mm and a diameter of 38 mm [10]. Samples of PUC blocks with a treated and untreated ratio of 7.5%, and 10% will be placed on soil that has been made with the UCS process in the shape of a cylinder with a height of 78 mm and a diameter of 38 mm and a total of 15 UCS samples. The soil and PUC blocks that have been formed will be tested with a UCS testing machine after curing for 1 day. The mold used in this compression test is 38 mm in diameter and 78 mm in height for each sample will be tested on the Utest C100 machine. Each sample takes 15 to 17 minutes to complete. The test will be stopped when the strain reaches 18%. After testing is complete, the UCS sample will be re-measured for height and diameter.

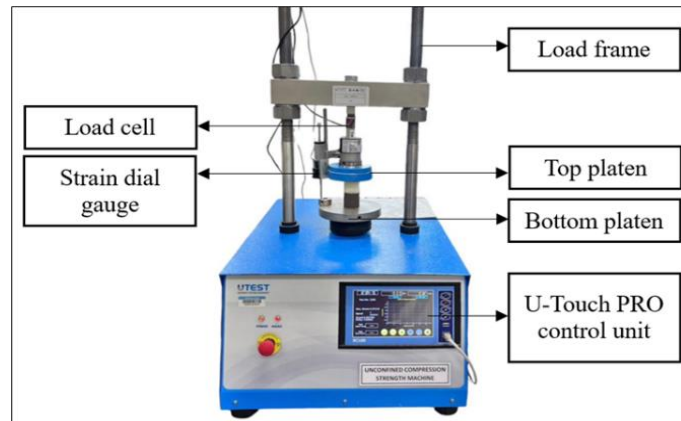


Fig. 5: Unconfined compressive strength machine

3. Result

The results and data analysis. The results were obtained from laboratory tests and presented as graphs and data. All data was conducted to achieve the objectives of this study by conducting laboratory tests. PUC block samples were determined with different mixed ratios to achieve the objectives of this study. Next, this study will test the stress on the PUW block, such as Compression Test (UTM) and Unconfined Compression Strength (UCS). However, a compression test is used to determine the stress, strain and young modulus of the PUC block.

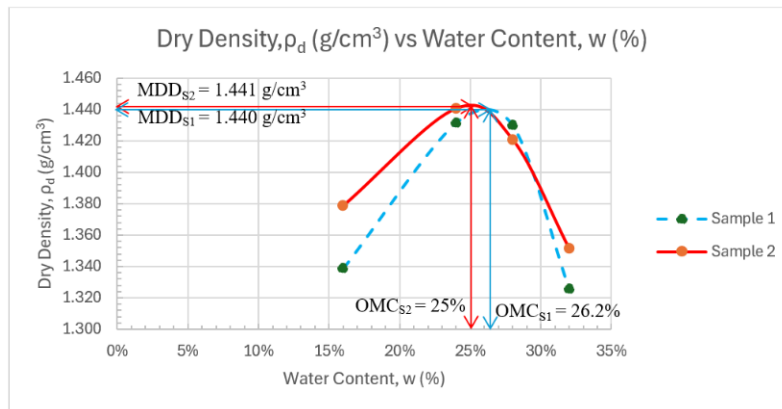
3.1 OMC and MDD

Proctor tests were also conducted to increase the density of clay by reducing the number of pores in the sample. This test was conducted to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the soil. The results of the compaction test are depicted in tabular form below in Table 1.

Table 1: Data of compaction test for clay soil

Water Content, w (%)	Dry Density, ρ_d (g/cm^3)	
	Sample 1	Sample 2
16	1.379	1.339
24	1.441	1.431
28	1.421	1.430
32	1.352	1.326

From Table 1, at 16 percent water content, the dry density of clay from Sample 1 and Sample 2 was $1.379 \text{ g}/\text{cm}^3$ and $1.339 \text{ g}/\text{cm}^3$ respectively. At 24% water content the dry density became $1.441 \text{ g}/\text{cm}^3$ and $1.431 \text{ g}/\text{cm}^3$. However, at 28% water content the dry density decreased slightly to $1.421 \text{ g}/\text{cm}^3$ and $1.430 \text{ g}/\text{cm}^3$. Thereafter at about 32% water content the dry density was reduced to $1.352 \text{ g}/\text{cm}^3$ and $1.326 \text{ g}/\text{cm}^3$ respectively.

**Fig. 6:** Graph of dry density versus water content for clay soil

From this data, the graph of dry density versus water content is as in Figure 6. The results of the graph analysis obtained show that the average MDD for both samples is $1.441 \text{ g}/\text{cm}^3$ and the average OMC is 25.6%. For compacted field conditions in road construction, a value of 95% of the aggregate MDD is acceptable. Therefore, in preparing soil samples for compaction and consolidation tests, a water content of 30 percent was adopted.

It is important to analyze the relationship between water content and dry density when working with soil materials in construction. Compaction test data is very useful for determining the adequate status of the soil in terms of stability and load bearing. Further work should continue to focus on the advancement of various materials and approaches to improve the characteristics of the soil used.

3.2 Mechanical Characterization of PUC Block Treated/Untreated

Figure 7 represents a 0% stress value which is 30.907 kPa. The stress value of 0% is higher than the value of 10% untreated. The compressive strength of PUW block composites with the same amount of stress of 7.5% treated and 10% treated polyurethane powder. In general, the compressive strength shows a significant increase when the loading of 10% treated and 7.5% treated in PU block composites increases compared to other ratios. The compressive strength is 41.874 kPa for 7.5% treated and 10% treated. The lowest stress value is 26.919 kPa for 10% untreated. A difference of almost 26 kPa in compressive strength [3] In general, the achievement of good strength characteristics in the filling is determined by the distribution and dispersion of the filler in the polymer matrix.

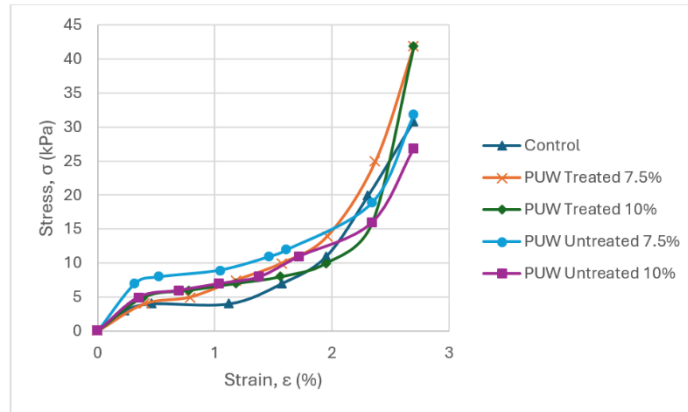


Fig. 7: The result of different for compression test on ratios

For the 0% control, the Young's modulus value is 12.89 kPa, for the 7.5% treated sample it is 10.07 kPa, the lowest stiffness value among all samples. While for the 10% treated sample it is 12.75 kPa. For the untreated 7.5% it gets 22.09 kPa, the highest stiffness value and for the untreated sample it shows a value of 14.41 kPa, the second highest value after the untreated 7.5% sample.

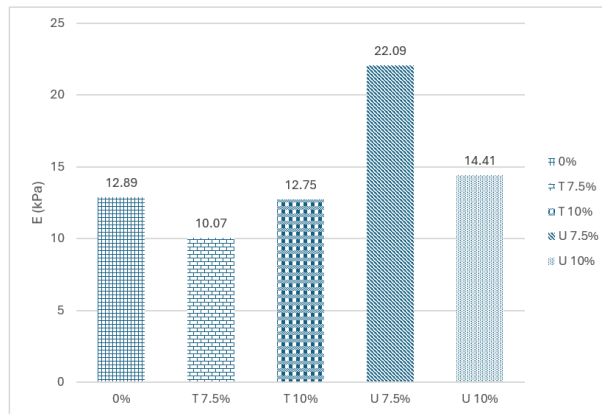


Fig. 8: The different of young's modulus bar chart for compression

To exceed the die value according to ASTM D3574-08 and ISO 1798, the minimum size value is 50 mm x 50 mm and a thickness of 25 mm. For the study conducted, the size of this PUC block exceeds and complies with the established standard with a size value of 50 mm x 50 mm and a thickness of 50 mm and can-do compression testing.

After 1 minute of compression testing, the treated and untreated PUC blocks of all ratios experienced a rebound of only 3 mm after 1 minute, only 0% experienced a rebound of only 7 mm. This is because 0% has smaller pores compared to the PCW block which has a mixture of rigid PU waste.

Table 2: Rebound PUW block for compression

Ratio	Height	Less	Rebound
0%	50 mm	7 mm	43 mm
T 7.5%	50 mm	3 mm	47 mm
T 10%	50 mm	3 mm	47 mm
U 7.5%	50 mm	3 mm	47 mm
U 10%	50 mm	3 mm	47 mm

The rebound value is 94% of its original shape and this value is good for the elastic properties of this PU waste mixture. If the compression testing is repeated using the same sample, the rebound value will probably decrease slightly. This is because its properties are the same as other geofoam and its effect is over a long period of time.

In this study, the compressive strength of PUW composite blocks with various percentages of polyurethane (PU) waste was analyzed to understand the effects on stress, strain, and Young's modulus. The test results showed that the stress value for the 0% sample was 30.907 kPa, higher than the stress value for the untreated 10% sample, which recorded the lowest value of 26.919 kPa. The compressive strength increased significantly when the

percentage of treated rigid PU waste was increased to 7.5% and 10%, with the compressive strength reaching 41.874 kPa for the treated sample, respectively. This indicates that the distribution and dispersion of the filler in the polymer matrix is important to achieve good strength characteristics.

The Young's modulus of the samples also showed significant variations, for the 0% control, the Young's modulus value was 12.89 kPa, while for the sample treated at 7.5% it was 10.07 kPa, showing the lowest stiffness among all the samples. On the other hand, the untreated sample at 7.5% recorded the highest value of 22.09 kPa, indicating that the presence of untreated filler can increase stiffness even though it reduces the overall compressive strength.

The rebound of PUC blocks after compression test was also observed, all blocks experienced a rebound of only 3 mm after one minute of testing, except for the 0% sample which experienced a rebound of 7 mm. This is due to the smaller pores in the 0% sample compared to the PUC block which has a stiffer PU waste mixture. The rebound value of 94% of the original shape indicates good elastic properties of this PU waste mixture.

A study from [11] used PU blocks mixed with rigid waste. The results of the study [11] can be seen in 2.10 where the highest stress data was 37.886 kPa on the 7.5% Untreated sample and the lowest stress was 13.958 kPa on the 2.5% treated sample. The difference between this study and the study [3] is almost the same value. However, the study is ahead in the highest stress, which is in the 7.5% treated and 10% treated samples, which is at a stress value of 41.874 kPa.

Overall, PUC block can be further improved in terms of stress, strain, and young modulus if the waste mixture exceeds 10%. This is because, from this result, the strength when waste is mixed will increase following the guidelines that do not exceed excessive percentages.

3.3 Unconfined Compression Strength (UCS)

The UCS value and strain results for the clay samples showed an average unconfined compressive strength (UCS) of the control of 16.62 kPa at 18% strain. The curves for all samples showed brittle behavior, where the UCS decreased rapidly after reaching its peak value. The purpose of testing the clay samples was to serve as a control to evaluate the effectiveness of the treatment.

For the clay mixed with 7.5% treated and cured for one day, the UCS value and strain results were obtained for the samples tested in both wet and dry conditions. The UCS value and strain curves showed a soft behavior for all samples, with an average UCS value of 15.82 kPa at 18% strain. For the clay treated with 10% PU Block and cured for one day, the UCS value and strain results also showed a soft behavior. However, the average UCS value increased to 18.00 kPa at 18% strain, indicating better performance with higher percentage of PU Block.

The UCS value and strain results for the clay samples treated with 7.5% untreated PU Block and cured for one day showed a soft behavior, with an average UCS value of 25.00 kPa at 18% strain. In contrast, the clay samples treated with 10% untreated PU Block for one day of curing showed soft behavior with an average UCS value of 15.00 kPa at 18% strain. These results indicate that the untreated PU Block treatment can increase the compressive strength of the clay samples, especially at the 7.5% untreated level, compared to the treated PU Block mixture.

Table 3: The result of different for UCS test

Ratio	Stress (kPa)	Strain (%)
0%	16.52	18
T 7.5%	15.82	18
T 10%	18.00	18
U 7.5%	25.00	18
U 10%	15.00	18

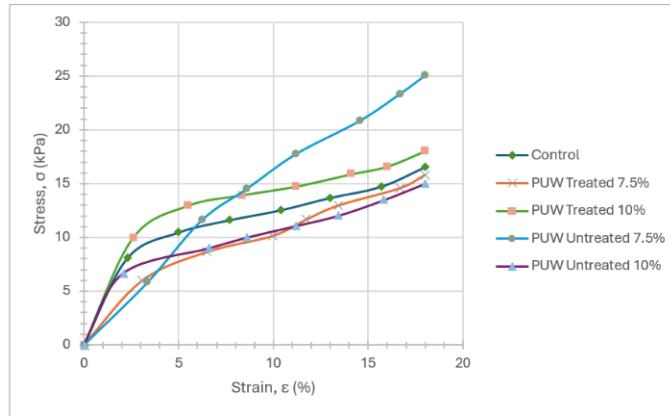


Fig. 9: Graph of treated and untreated UCS testing

For untreated PUC blocks, a consistent and significant increase was recorded in experiments where 7.5% of the material was untreated. This is because with the use of PUC, the pore size in the material is minimized, thus increasing the bonding force between the particles. However, the reduction in UCS values for the 7.5% treated and 10% untreated blocks proves the insufficiency of the binder to strengthen the PUC blocks while maintaining constant softness and the inability to withstand pressure. On the other hand, untreated PUC, also with a content of 7.5%, showed higher compressive strength because the blocks contained tightly bound particles.

For the 0% control, the Young's modulus value is 3.4933 kPa, the highest value for stiffness, for the 7.5% treated sample it is 1.9448 kPa, the lowest stiffness value among all samples. While for the 10% treated sample it is 3.828 kPa, the second highest value after the 7.5% untreated sample. For the 7.5% untreated sample it is 1.7279 kPa and for the untreated sample it shows a value of 3.2119 kPa.

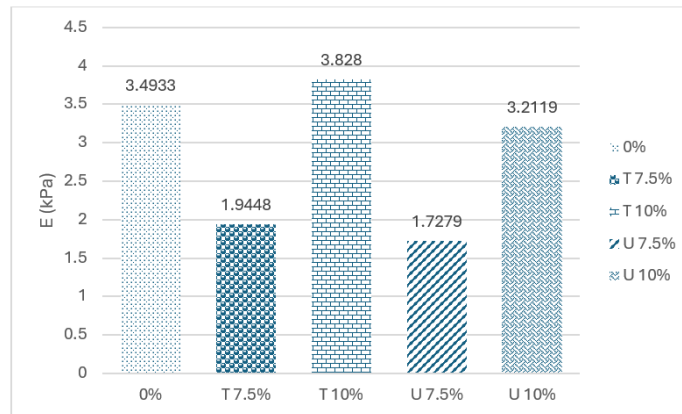


Fig. 10: The different of young's modulus bar chart for UCS

After 1 minute of UCS testing, the PUW block experienced a rebound of only 3 mm and the ground condition was the same after 1 minute, with no change in diameter of 38mm and height of 39 mm and no defects on the ground surface. This is because the UCS value is concentrated on the PUW block only. Although the UCS analysis and the results obtained are too soft to apply to roads.

Table 4: Rebound of PUW block for UCS

Ratio	Height	Less	Rebound
T 7.5%	78 mm	2 mm	76 mm
T 10%	78 mm	3 mm	75 mm
U 7.5%	78 mm	2 mm	76 mm
U 10%	78 mm	2 mm	76 mm

The soil strength of the PUC block, although there is no effect on clay soil after doing UCS testing, the PUC block has obtained UCS value in this study is too low to be used for road construction embankment, especially as a road base layer that requires a stronger foundation [9]. The use of untreated PU waste at a rate of 7.5% gave the highest strength of 25.00 kPa compared to all other samples. This shows that untreated PU waste can increase the compressive strength of the soil.

An increase from the treated PU waste rate of 7.5% to 10% showed an increase in UCS value from 15.82 kPa to 18.00 kPa, but the Young's modulus also showed an increase from 1.94481 kPa to 3.8283 kPa, making it stiffer compared to the lower rate.

On the other hand, for untreated PU waste, an increase from 7.5% to 10% showed a decrease in UCS value from 25.00 kPa to 15.00 kPa, indicating that the higher rate may not provide additional benefits in compressive strength.

The absence of filler in the mixture gave a lower result in compressive strength compared to the mixture containing fillers such as treated and untreated PU waste. This shows that the filler can increase the interaction between particles and thus increase the strength.

High PU waste content such as 7.5% and 10% has different effects on UCS value and strain. For the treatment rate, increasing to 10% gives an increase in UCS value but the Young's modulus also increases. For the untreated rate, although the 7.5% rate shows better compressive strength, the 10% rate experiences a decrease in compressive strength.

Overall, the use of PU waste at a certain rate can significantly affect the mechanical properties of the soil, and the selection of the right rate is important for effective engineering applications.

When PUC block is placed on clay soil, it will receive insufficient load to accommodate. With the highest PUC block result from UCS testing which is on the 7.5% treated sample and stiffness 1.7279 kPa even though the soil is in good condition, it will consume the cost for maintenance on the road. It is not 100% load on the soil, but the one that receives more load is on the PUC block even though the rebound rate is 76 mm instead of 78 mm. The cost for pavement will be more expensive than it is now.

For example, referring to 2.4, where the EPS experienced failure due to insufficient density and compressive strength. In addition, the UCS value is 15 kPa to 128 kPa. This pressure was also used to study the extent to which EPS geofabric could reduce the settlement of soft soil under the fill. Lightweight geofabric will reduce the vertical bearing pressure on clay soil and further increase the stability of the embankment [12] If this result is compared with the current study, which is UCS value is 22.74 kPa and strain 18%, almost six times the higher value.

In addition, the results of UCS testing showed that the PUW block did not comply with the minimum UCS value requirement by JKR Malaysia for stable subgrade. The average unconfined compressive strength (UCS) of the soft clay sample conducted after 1 day of curing was 25 kPa, which was 32 times lower than the strength obtained from laboratory testing (800 kPa) and complied with the requirements of JKR Malaysia [4].

The results of this UCS study can be given a clear explanation when the results of this PUC block are not suitable for a long time, it will have a damaging effect on the soft soil foundation and result in the failure of the embankment.

4. Conclusion

All tests in this study were conducted according to the established procedures to achieve the study objectives. The tests performed included Proctor Compaction Test, Compression Test (UTM) and Unconfined Compression Strength (UCS) tests. The objective of this research was to determine the compressive strength of PUC block layers with different ratios of rigid fillers using the UCS test. Based on the results, the untreated PUC block with a ratio of 7.5% PU showed the highest compressive strength. This was due to the smaller pore size and better bonding between particles. However, the compressive strength values achieved were still too low to meet the application requirements as backfill material in road construction. The PUC block showed brittle properties and was not strong enough to support the load, which could cause structural failure in the long term.

In addition, the objective of the study was to determine the compressive stress of polyurethane cellular foam (PUC) at different ratios using compression tests. This test provided information on the tensile stress properties of PUC blocks with treated and untreated PU ratios. The test results showed that the highest compressive stress was obtained at the ratio of 10% untreated PU and 7.5% treated with the same value of 41.87 kPa, while the ratio of 10% treated PU showed a lower compressive stress value of 26.92 kPa. The higher compressive stress for untreated PU was associated with a smaller pore structure, thicker cell walls, and better ability to withstand pressure.

In conclusion, although this study successfully identified the optimal ratio to increase the strength of PUC blocks, the mechanical properties of this material are still not sufficient for application as a fill material in construction. Further studies are needed to improve the strength and stability performance of this material.

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