Journal of Engineering Science and Technology
Vol. 19, No. 4 (2024) 1142 – 1155

SOFT CLAY IMPROVED WITH CIGARETTE BUTTS

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Abstract

Cigarette butts are the most common type of waste material disposed of worldwide. Globally, an estimated 5.7 trillion cigarettes were consumed in 2016. This works the use of cigarette butt waste as a reinforcement to enhance the mechanical characteristics of soft clay soil. The natural soil was collected from a site in Garmit Ali by the Basra Government (South of Iraq) and blended with different percentages of cigarette butts, corresponding to 2, 3, and 4% by weight of dry soil. The properties of soft clay were determined by measuring the consistency of the soils before and after adding a different percentage of cigarette butt waste, in addition to unconfined compressive strength. It was observed from the results that utilizing Cigarette butt waste reduced the maximum dry density of soft clay and increased the optimum water content. The inclusion of the cigarette butts increased the undrained compressive strength, and the maximum increment approached 148% and also increased the angle of internal friction. This type of improvement can be used for subgrade improvement which reduces the thickness of the layers and consequently reduces the initial and maintenance cost of highways.

Keywords: Cigarette butts, Soft clay, Soil improvement.

1. Introduction

Soft clays are abundant in Iraq's central and southern regions. The texture of these soils is characterized by fine silty clay loams, silty clay, and clay fractions containing up to 50-70 percentage clay [1]. These constituents with a higher water table throughout the majority of the basins' southern sections revealed fair to poor soft deposits.

Construction of any engineering structure (road, railways, etc.) on this type of soil usually involves problems such as excessive settlements, deformation, and stability. To avoid, reduce or control these problems, there are several methods were used from ancient times to alter the unwanted properties of this type of soil, and these methods can be mechanical stabilization, chemical, and soil reinforcement, which are the best methods used for improving the soil in geotechnical applications.

Since 1969, the use of strips as reinforcements in the earth system has caused an increase in the shear strength of soil. Since then, the use of geomaterials to modify the soft soil has increased, especially in executing geotechnical construction such as embankments, retaining walls, and pavement, etc. [2]. The primary problem with reinforcement is introducing tension-resisting parts to the soil to increase its strength and stability of the soil. Soils, in general, can resist great compressive strength but not tensile strength. Therefore, the basic goal of soil reinforcement is to use reinforcement components to make soils withstand tension loads and stresses of shear. As a result, the stability of the geotechnical structure could be achieved.

Hejazi et al. [3], give a review on the concept of using discrete randomly distributed fibres in soil using natural and synthetic fibres and most research proved that these materials can be used successfully in reinforcing the soil and the primary conclusion reached, all material used give an increase in strength and stiffness and this increment as:

- The function of fibre characteristic (aspect ratio, elasticity modulus, and the skin rubbing).
- Shape, grain size, and gradation of sand are examples of sand properties.
- Condition of the test like confining stress.

Fibres were early used when reeds were used in the olden days, and ropes, grasses, and wood were utilized to reinforce the soil elements by blending them with the soil to improve the soil qualities. Hossain et al. [4] investigated the use of jute fibre to improve subgrade qualities. The experimental works were carried out using different percentages of jute fibres, which were 0.3, 0.6, 0.9 and 1.2, with jute lengths of 15 mm and 30 mm. Two diameters of jute fibre, 4 mm and 8 mm, were used.

The main conclusion that for every length and diameter of jute fibre, the optimum moisture content rises, and the max dry density falls as the jute fibre content increases. The CBR value of soil reinforced with jute fibres shows that the CBR values increase with the increase in the jute fibre length. Jute fibre diameter has a significant effect in increasing the CBR, and this increase is fundamental at the fibre content of 1.20% for an aspect ratio of 3.750 at a length of 30 mm and diameter of 8 mm.

Furthermore, using waste materials in soil reinforcement applications has the extra benefit of preventing these materials from being put into landfills, sparing already scarce landfill space. Many waste materials have recently been introduced as environmentally acceptable soil stabilization to prevent waste material growth and provide soil that can handle large loads. Improving Clayey Soil properties with Fly Ash and Waste of Ceramic are 2 of these items [5].

Salim et al. [6] experiment on soft clay using 1, 3 and, 5% of nylon carry bags by product. The results show that as the nylon fibre contents increase as the plasticity index drops, the liquid limit tends to decrease whilst the limit of plastic increases. Moreover, as the amount of nylon fibres increases, the maximum dry density drops while the optimal moisture content increases. The maximum reduction in compression index (approaches 43% by adding 5.0% Nylon's fibre. Un-drained shear strength increases as % of Nylon's fibre increases.

Recycled gypsum (plasterboard) also was used by Al-Adili et al. [7]. The authors stated that the major benefits of short fibre composite soils include availability, economic benefits, ease of work, speed of execution, and the ability to be used in all-weather situations. They also stated that fibre reinforcement improves composite soil strength and stiffness. They concluded that fibre features including aspect ratio, skin friction, weight fractions, and elasticity modulus play a role in increasing strength and stiffness [8-10].

The ideal ratio of natural fibres to affect compaction qualities was investigated by Bawadi et al. [11]. The chemical makeup of natural fibres and the compaction characteristics of soil samples were ascertained using the X-ray fluorescence (X-RF) test and the conventional Proctor compaction test, respectively. To enhance the characteristics and stability of the soil samples, natural fibres such as banana, kenaf, and coconut fibres were added to the soil mixture in varying weight proportions (0.3%, 0.5%, and 1.0%).

The optimum moisture content (OMC) and maximum dry density (MDD) for each natural fibre are 0.5%, according to experimental data gathered from the compaction test. This is because, when 1.0% natural fibres were added to the soil sample, the fibres absorbed a significant quantity of water from the soil grains, lowering the maximum dry density (MDD), according to Bawadi et al. [11]. Consequently, 0.5% is the ideal amount of natural fibre.

Research on the impact of randomly oriented natural fibre reinforcements on the soil strength parameter was carried out by Mohan and Manjesh [12]. Fibres made of coconut and jute, with varying aspect ratios and doses of 0.25%, 0.50%, 0.75%, and 1.0% of the soil's dry weight. To ascertain the strength characteristics of natural fibre-reinforced soils, the Proctor Compaction Test, California Bearing Ratio (CBR) Test, Fatigue Load Test, and Unconfined Compressive Strength (UCS) Test were performed.

Results indicate that incorporating coir and jute fibres into the soil enhances its strength characteristics [12]. When coir and jute content rise, the maximum dry density (MDD) of the soil falls and the optimum moisture content (OMC) rises. Furthermore, the addition of fibres raised the soil sample's Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR).

Billions upon billions of cigarette butts are now discarded in the environment, where they leech nicotine and heavy metals before decomposing into microplastic pollution. Cigarette butts are a serious waste disposal and pollution issue since they mostly include non-biodegradable cellulose acetate; 5.8 trillion cigarettes are smoked globally each year, resulting in more than 800,000.0 tons of cigarette butts [13].

Typically, cigarette filters are comprised of cellulose acetate fibre, although they can also be made of paper or activated charcoal (either as a cavity filter or embedded into the cellulose acetate). Acetate of cellulose It is manufactured by combining acetic acid with bleached cotton or wood pulp [14]. By adjusting the amount of acid, three cellulose hydroxyl groups that are available for esterification, ranging from two to three, are esterified (degree of substitution (DS) 2.35-2.55). The ester is spun into fibre and bundled together, as shown in Fig. 1.

Cellulose acetate fibres are used to make cigarette filters. The filter's white, densely packed cellulose acetate fibres might resemble cotton, have different lengths, and have different lengths ranging from 4 to 25 mm, with a diameter of 0.031 mm and a density of 0.81 g/cm^3 and are thinner than sewing thread. Each cigarette filter contains approximately 15,000 microplastic fibres [15].

In this research, a new material was tried to strengthen soft clay soil represented by cigarette butt waste materials, the cigarette butts were gathered at roadside locations, smoking areas, cafes, and streets. Every day, the collecting boxes were picked up from various locations. The obtained cigarette butts underwent pre-processing to remove the paper cover and extract non-degradable cellulose. The uppermost layer of the butt paper layer was eliminated, and for the experimental procedure, just cigarette butts cellulose fibre was utilised. Different percentages of cigarette butt waste going to be randomly mixed with soft clayey.

The main objective of this study is to investigate the physical and mechanical properties of soft soil stabilized with cigarette butt waste. An experimental study was carried out by using 2%, 3%, and 4% cigarette butt mixed with soft clay soil. Physical and mechanical properties were measured before and after adding different percentages of a cigarette butt.

Fig. 1. Cigarette butt.

2. Laboratory Studies

A brown clayey soil was brought from a site in Garmit Ali from Basra Government (South of Iraq) at a depth of 0.5 m to 1.5 m with an initial water content of 31%. Standard tests were carried out to find the physical and chemical characteristics of the soil. Details are shown in Table 1. The grain size distribution of soil used indicated 2% of sand, 33% of silt, and 65.0% of clay as given in Fig. 2. The soil is classified as CH (the high plasticity fine grained soil) according to USCS.

Table 1. Engineering properties of the used soil.

Index property	Test standard	Index value soil
Liquid limit (L-L) (%)	ASTM D-4318	51.0
Plastic limit (P-L) (%)	ASTM D-4318	30
Shrinkage limit (S-L) (%)	ASTM D-437	20
Plasticity index (P-I) (%)	ASTM D-4318	21
Activity of clay (At)	Skempton-formula*	0.46
Specific gravity (G.s)	ASTM D-854	2.7
Gravel (⩾4.75.0 mm) (G) %	ASTM D-422	0
Sand (0.0750 to 4.75.0 mm) (S) %	ASTM D-422	2
Silt (0.0050 to 0.0750 mm) (M) %	ASTM D-422	33
Clay (⩽0.0050 mm) (C) %	ASTM D-422	65
Classification (USCS)	ASTM D-2487	CH
Organic matter (O-M) %	ASTM D-2974	< 0.01
Calcium oxide (CaO) %	ASTM C-25	21.12
SO_3 content %	ASTM C-563	0.38
Total dissolved salt (TDS %)	ASTM D-5907	1.73
Total suspended salt (TSS %)	ASTM D-5907	6.89
pH value (%)	ASTM D-5972	8.69
MDD (kN/m^3)	ASTM D-698	16.5
OMC (%)	ASTM D-698	20.5
MDD-modified (kN/m^3)	ASTM D-1557	17.8
OMC-modified (%)	ASTM D-1557	16
Skempton-formula*: - At = (PI/{% of clay <0.0020 mm})		

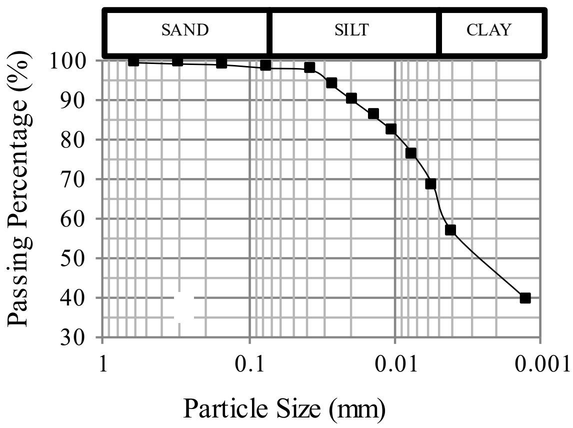

Fig. 2. Grain size distribution.

Natural soils were examined for categorization and index qualities, and also consistency properties, in accordance with conventional methods. In addition, the testing was also repeated on the soil with the different percentages of cigarette butte, including limits of Atterberg, compaction, Specific gravity, and van shear test.

3. Experimental Works

To generate disruptive testing samples, the chosen clay was dried and pulverized, and a compaction test of the sieved clay was carried out on the clayey soil only and the relationship between the dry density and moisture content was acquired by standard experiments. In the present work, the optimum moisture content was 20.8 and the max dry unit weight was 16.5 kN/m^3 as shown in Fig. 3.

Different percentages of cigarette butt fibre were mixed with clayey soil, these percentages are 2%, 3%, and 4% of the dry weight of the clayey sample. Each sample's dry clay was mixed with the specified amount of a fibre in a good way by a mixer machine as shown in Fig. 4 to ensure that the fibre was equally spread in the clay.

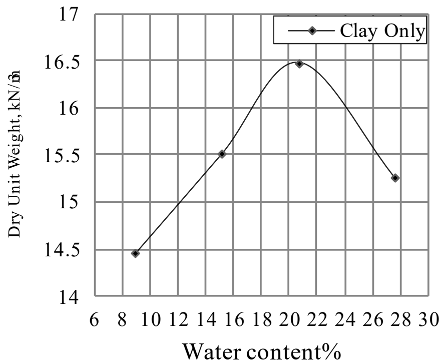

Fig. 3. Compaction curve of soft clay only.

Fig. 4. Mixer for preparing soil samples.

4. Results Presentation and Discussion

4.1. Effect of additive cigarette butt waste fibre on specific gravity

Figure 5 shows the values of specific gravity of the mixed-soil cigarette butt with different percentages. It is plainly demonstrated that there is a decrease in specific gravity with an increase in cigarette butt percentage. Table 2 summarizes the impact of adding a different % of cigarette butt fibre on specific gravity. This reduction due to the addition of cigarette butt waste of light weight (specific gravity of 1.9) compared to soft clay soil weight (of specific gravity of 2.7).

Table 2. Specific gravity with and without additive of cigarette butt fibre.

Cigarette butt fibre %	0	2	3	4
Specific gravity G_s	2.7	2.68	2.66	2.65
% of decrease in G_s %	-	0.74	1.5	1.85

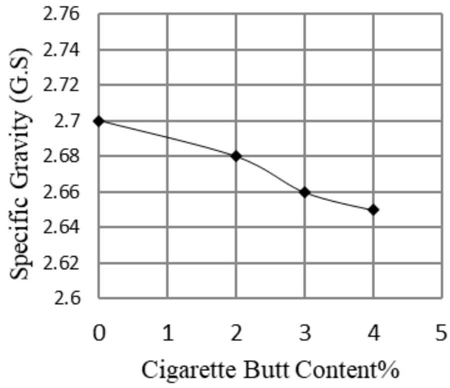

Fig. 5. Relation between specific gravity and cigarette butt waste fibre.

4.2. Effect on compaction characteristics

Figure 6 shows the impact of adding different percentages of cigarette butt waste on the compaction curve of improved soils. It is clearly shown that adding randomly different percentages of cigarette butt waste to clayey soil causes a change in unit weight and optimum moisture content. Natural soil has a maximum dry unit weight of 16.5 kN/m^3 according to the compaction curve with 20.8 optimum water content.

Figures 7 and 8 summarize the compaction curve results and illustrates the impact of adding various percent of cigarette butt waste on the max dry unit weight and the optimum moisture content. The results revealed that as the cigarette butt waste increases, the max dry unit weight reduces while the optimums moisture content increases. The percentages of decrement in dry unit weight were 2.7%, 6.4%, and 8.8% for 2, 3, and 4% of cigarette butte additives respectively.

This reduction in max dry unit weight was due to the addition of a cigarette butte of light weight (specific gravity of 1.9) compacted to the soft clay soil in prepared soils (of specific gravity of 2.7) compared to that of the soil. The optimum moisture content increases due to the high-water absorption properties of the waste fibre. Figure 6 shows the increase in optimum water content with the increase in the percentages of cigarette butt waste fibre. Also, the effect of including different percentages of cigarette butt waste fibre on the maximum dry density was clearly shown.

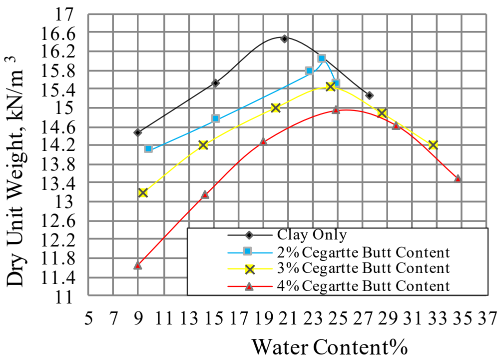

Fig. 6. Compaction curves for treated untreated soils.

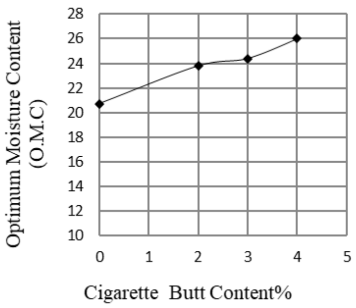

Fig. 7. Optimum moisture content at different percentages of cigarette butt waste fibre.

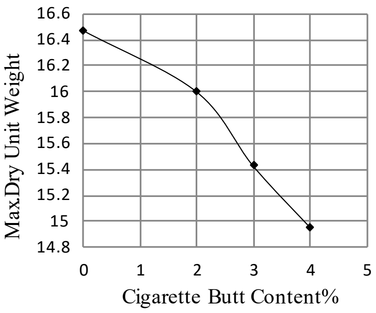

Fig. 8. Maximum dry density at different percentages of cigarette butt waste fibre.

4.3. Effect on Atterberg's limits

Figure 9 illustrates the impact of adding various percentages of Cigarette butt waste fibre on limits of consistency (LL; PL; and PI), respectively. It is abundantly clear that the liquid limits (LL) increase with the increase in cigarette butt waste fibre while the plastic limit (PL) decreases with an increase in cigarette butt waste fibre. So, because of a variation in liquid and plastic limits, an increase in the plasticity index was noticed as cigarette butt waste increased. Figure 10 shows the liquid limit and the plastic limit.

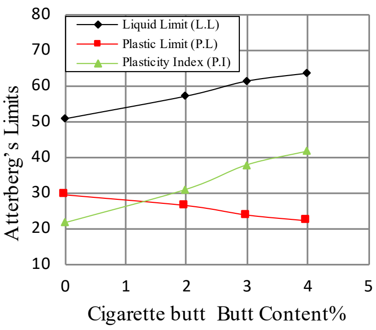

Fig. 9. Effect of cigarette butt waste fibre on Atterberg's limits.

(a) (b)

Fig. 10. (a) the liquid limit and (b) the plastic limit.

4.4. Effect on unconfined compressive strength

The unconfined compressive strength was measured according to (ASTM D2166 / D2166M). The results of the unconfined compression test on stabilized soil with 2, 3, and 4% cigarette butt waste fibre are presented in Fig. 11. The results revealed that as percentages of cigarette butt waste fibre increase, the unconfined compressive strength increases this increment due to an increase in the shear parameters which enhances the interaction of soil particles of the reinforcing parts and clay particles and improves the shear strength of the reinforced clay [16].

The contact area between soil particles and fibres that are forced against one other is proportionate to the load that is applied. These imprints make it possible for adhesion to take place inside the mass of the reinforced soil. There is an increase in the ability to retain the particles, which in turn allows adhesion to grow. This is because the fibre prevents the soil particles from pacing tightly until fibre stretch and imprinting occur [17].

Figure 12 illustrates the impact of adding various percentages of cigarette butts using an unconfined compression test, the failure mechanism of unconfined compression tests for soil fibres comprises a mix of shear failure, fibre-related failure modes such as bulging or shearing, and the interactions between these failure modes. For successful engineering design, material selection, quality control, and performance prediction in a variety of geotechnical applications, it is essential to have a solid understanding of these processes.

Figure 13 shows the effect of adding different percentages of cigarette butt waste fibre on friction angle and the results demonstrated that as the percentages of cigarette butt waste fibre increases the angle of internal friction increases, the angle of internal friction (Ø)was calculated based on the angle formed by the plane with the horizontal (θ). Fibre bridging is the process by which reinforcing fibres inside a soil build a network of interlocking or overlapping structures that bridge over voids or gaps between soil particles. This process is referred to as fibre bridging.

During the physical process, the fibres that are included within the soil-fibre combination create bridges or linkages between the soil particles that are next to one another when they are exposed to external loads such as compressive stresses. Redistributing stresses, improving weight transmission systems, and preventing deformation are all characteristics of these bridges.

Table 3 shows the percentage of increase in stresses at a strain value equal to 0.1 and the main result can be drawn from this table that adding 4% waste causes an increase in stress at 0.1 strain approaches 100%. Table 4 revealed that adding 4 percent of cigarette butt waste causes an increase in undrained compressive strength up to 148%. Figure 14 displays the shear strength from the unconfined compression test with the addition.

Table 3. Results of stress-strain relation for untreated–treated soil.

Percentage of cigarette butt waste fibre dry weight of soil	Stress at strain equal to 0.1 kPa	% of increase in stress
Clay only	34	-
Clay with 2% cigarette waste	55	62
Clay with 3% cigarette waste	62	82
Clay with 4% cigarette waste	68	100

Table 4. Relation between unconfined compression strength for treated and untreated soil.

Percentage of cigarette butt waste fibre dry weight of soil	q_u (unconfined Compression) (kPa)	% Increase in unconfined compression strength
Clay only	21	-
Clay with 2% cigarette waste	34	62%
Clay with 3% cigarette waste	40	90%
Clay with 4% cigarette waste	52	148%

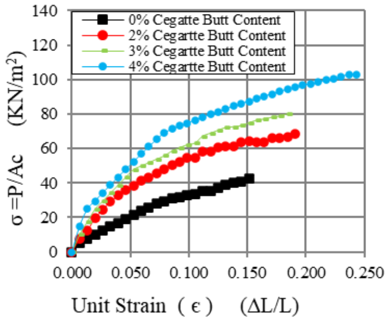

Fig. 11. Stress-strain relation for treated and untreated soils.

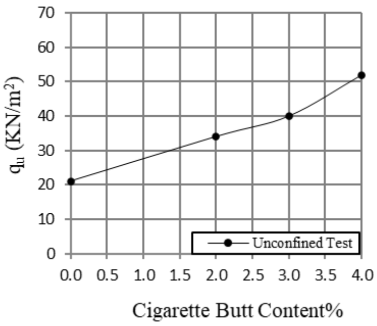

Fig. 12. The effect of cigarette butt waste fibre content addition on un-drained shear strength of soils.

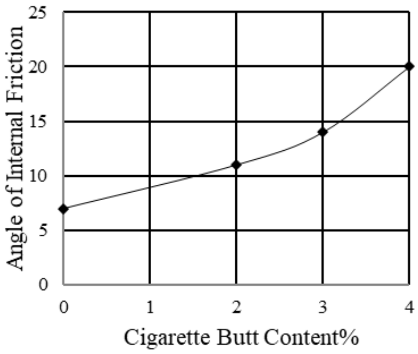

Fig. 13. The effect of cigarette butt waste fibre content addition on the angle of internal friction.

Fig. 14. Unconfined compression strength model during lab test.

4.5. Effect on California bearing ratio (CBR)

The California Bearing Ratio (CBR) is a measure of the strength and bearing capacity of the soil. The design of the pavement's lowest layers, such as the base layer and sub-base layer, is facilitated by the use of this sort of test. The moisture content of the soil sample is adjusted to the optimal moisture content prior to the process of compaction. The optimal moisture content is the moisture level at which the soil achieves its maximum density that can be achieved by the application of compaction efforts.

Five layers of compacted soil are applied, with 56 blows each layer, with a plunger of a standardized area, the test is conducted by determining the pressure necessary to penetrate a soil sample. The pressure of crushed rock for the same penetration is divided by the pressure of soil that is calculated from the test.

This study relies on AASHTO T193, which is specified in ASTM Standards D1883-05 (for laboratory-prepared samples) and D4429 (for soils in the field). This unsoaked, quick, easy, and accurate test has been used to confirm the stabilization of unstable soils by the addition of physical and chemical additives [18, 19].

The test results of CBR with each % of cigarette butt waste are given in Fig. 15. Figure 16 illustrates how the proportion of cigarette butt waste in the soil increases together with the soil's CBR value. The soil's CBR was raised by the addition of cigarette butt.

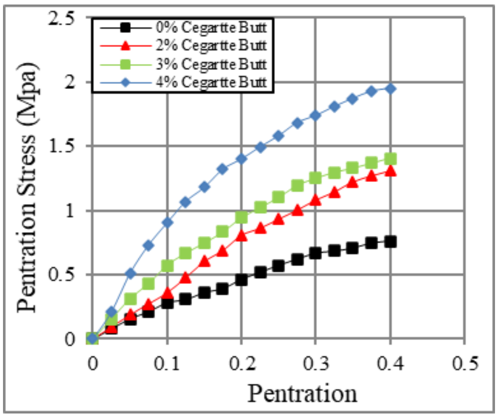

Fig. 15. CBR of cigarette butt mixed soil.

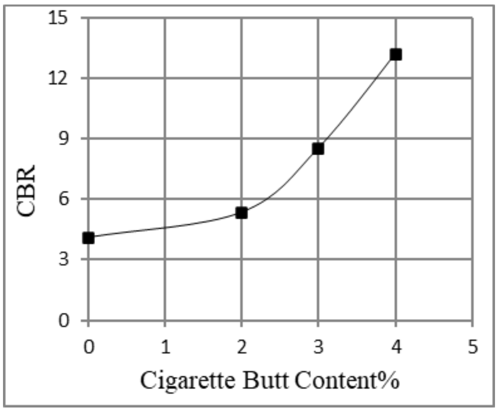

Fig. 16. CBR with cigarette butt percentages.

5. Conclusions

The inclusion of recycled fibre has a significant effect on the improvement of soft clay. This research investigates the impact of implication the of cigarette butt waste as a reinforcing material on the mechanical and physical characteristics of clayey soils. From the analysis of the results of soft clayey soil reinforced with different percentages of a cigarette butt, the following outcomes were made:

- The addition of cigarette butt waste fibre causes a lowering in specific gravity as the percentage of cigarette butt increases. The maximum reduction in specific gravity approaches 1.85% by adding 4 percent of cigarette butt waste fibre.
- The inclusion of cigarette butt waste fibre randomly in clayey soil causes a lowering in the max dry unit weight and an increase in optimum moisture content.
- The inclusion of cigarette butt waste fibre in soft clay causes an increase in unconfined compressive strength up to 164% by adding 4% of cigarette butt waste fibre.

- This type of improvement is mainly used for improving the subgrade layer which can reduce the thickness of the pavement layers and consequently reduces the initial and maintenance cost of the highway.

Greek Symbols

ϕ	Angle of internal friction
θ	Angle formed by the plane with the horizontal

Abbreviations

At	Activity of Clay
Calcium	Cao
CBR	California bearing ratio
CH	High plasticity
Clay	C
DS	Degree of Substitution
G	Gravel
Gs	Specific gravity
LL	liquid limits
M	Silt
MDD	Maximum Dry Density
O-M	Organic
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plastic Limit
S	Sand
SL	Shrinkage Limit
TDS	Total Dissolved Salt
TSS	Total Suspended Salt
UCS	Unconfined Compressive Strength

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