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Unconfined Compressive Strength Characteristics of Treated Peat Soil with Cement and Basalt Fibre

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ABSTRACT

So far many studies have focused on the mechanical behavior of fibre reinforced soils and stabilized soils with conventional chemical stabilizers such as cement and lime; however, very limited researches were conducted on the unconfined compressive strength characteristics of fibre reinforced cement stabilized peat soils. Fibre-reinforcement of a stabilized soil resulted in a significant improvement in the ductility and strength characteristics of weak or soft soils. The main objective of the current study is considering the effects of cement content, fibre content, fibre length and curing time on the unconfined compressive strength (UCS) of peat soil. The study finds that adding basalt fibre or cement causes a remarkable increase in the UCS values of peat soil. The UCS value of the cement-stabilized sample is observed significantly more than basalt fibre-reinforced ones. However, the sample reinforced with basalt fibers showed more ductile behavior compared to the stabilized sample with cement. The results showed that the increase in UCS values of combined basalt fibre and cement inclusions was more than the increase caused by each of them, individually.

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1. INTRODUCTION

The geotechnical properties of soils can be improved through material modification in civil projects. However, design and the construction of civil projects over soft and weak soil such as peat deposits have remained a major challenge. The replacement of such soil is expensive and not economically feasible; therefore, it has been necessary to improve soil properties. Peat soils are considered as extremely soft, wet, unconsolidated materials which are generally composed of fibrous organic matters. These soils are an extreme form of soft soils which are generally associated with high compressibility, medium to low permeability, low strength and large settlements and hold serious problems in civil engineering constructions [1-3]. Previous researchers investigate on any possible techniques or practices to enhance strength properties of peat soils. Various soil improvement techniques such as utilize mechanical energy and/or man-made materials have been used to improve the mechanical characteristics of weak or soft soils in practice for many years [4-6]. The problems of structures situated on weak or soft deposits are represented by significant settlement, low shear and compressive strength parameters [7-11]. Similar to conventional additive such as cement or lime, natural or synthetic fibres such as cotton, coir, sisal, polypropylene, basalt and polyester may be used to enhance the mechanical characteristics of weak or soft soils [12-15]. The effectiveness of soil improvement method is mainly dependent on the soil characteristics. Cement or lime stabilization have been used for many years which has been reported in the literature as a popular soil improvement technique. Previous studies indicated that cementation bonds among soil particles become stronger and pore spaces between soil particles could be occupied by cementing materials when various cementing materials were mixed with weak soils which could be

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resulted in an increase in the strength [16-19]. In previous studies reported in the literature, cement stabilization have been suggested as an effective method to improve the mechanical characteristics of weak soils [20-22]. Kalantari et al. [23] studied the mechanical behavior of silica fume and cement stabilized peat soils using unconfined compressive strength (UCS) and California bearing ratio (CBR) under soaked and unsoaked conditions. The results showed that the strength of peat soil layer increased when cement and silica fume have been used to stabilize and improve the mechanical properties of the peat soil.

Boobathiraja et al. [24] investigated the mechanical behavior of stabilized peat soil. They reported that the addition of lime and cement improved the mechanical characteristics of soil. A comparison of the results of cement and lime stabilized the specimens indicated that cement appeared to perform better than the lime. On the other hand, a lot of studies proved the beneficial effects of various types of fibres on the mechanical characteristics of reinforced soils [25-32]. Among various types of fibres, Basalt fibre (BF) is a new kind of inorganic, biologically inactive, environmentally friendly fibre which has better physical and mechanical characteristics with more cost-effective than other fibres [9, 33]. BF has been a popular material in civil engineering constructions such as soil reinforcement, concrete and asphalt [33-41]. Ndepete and Sert [42] indicated that the shear strength parameters of soil under undrained condition have been improved with the inclusion of BF with an optimum fibre content of 1.5%, when compared to the natural soil. Wang et al. [38] investigated the mechanical behavior and microstructure of BF reinforced cemented kaolinite. They found that the inclusion of BF resulted in enhancement of strength and ductility of specimens. Saberian and Rahgozar [43] studied the mechanical behavior of stabilized sand with gypsum, lime or cement along with waste tyre chips. The results showed that cement stabilized specimens exhibited the greatest improvement in UCS as well as improvements in the shear strength parameters (c and ϕ). Kalantari et al. [2] investigated the CBR and UCS values of treated peat soil with cement, polypropylene and steel fibres. The results showed that the UCS and CBR values of specimens containing 5% of cement, 0.15% of polypropylene fibres and 2% of steel fibres increased by as high as 748.8% and 122.7%, respectively.

Even though, many studies have been conducted to investigate the mechanical behavior of treated soils with various materials such as cementation materials and fibres, limited studies have been performed to study mechanical behavior of treated peat soils. Due to the low strength of peat soils, in the current study, the BF and cement were used to enhance the UCS value of peat soil specimens.

2. TEST APPARATUS, MATERIALS AND TESTING PROCEDURE

The unconfined compression test is widely used to determine the compressive strength value of cohesive or treated soils because of simple experimental process, and low requirement for the equipment. In this study, a series of UCS tests was carried out on treated peat soil specimens with cement and BF under a constant strain rate of 1% per minute according to ASTM D2166.

First stage of present study is collection of the peat soil from the south of Isfahan. The physical and chemical properties of peat soil are presented in Table 1. Field visits show that this soil is weak and needs to be improved for construction purposes.

The peat samples were brown in color and they were hemic (37 % fibre), high ash (22 %) and moderately acidic condition (pH 5.5) according to ASTM 4427-92.

In this work, basalt fibre was used for the reinforcement of peat samples, as shown in Figure 1. As shown in this figure, the effects of fibre lengths of 6, 12 and 18 mm were studied. The effect of fibre content varied from 0% to 5% and cement content varied from 0% to 5% has been investigated. Table 2 shows the physical and mechanical properties of basalt fibre. Type II Portland cement was used to stabilize peat samples. The physical and chemical characteristics of cement are shown in Table 3. The compressive and tensile strength values of cured cement samples in 28-day were equal to 44 and 2.8 MPa, respectively. The compressive and tensile strength tests were conducted according to ASTM 109 and ASTM 190, respectively.

TABLE 1. Physical and chemical properties of Chaghakhor peat

Characteristics	Values and descriptions
Fibre content (%)	37
Organic content (%)	55
Liquid limit (%)	307
Density of solids (g/cm^3)	1.66
Dry density (Mg/m^3)	0.31

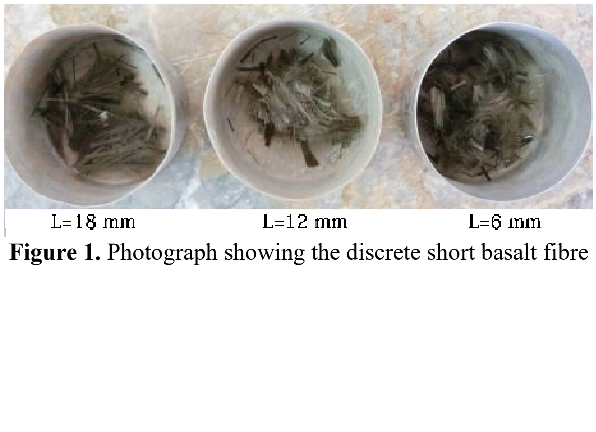

Figure 1. Photograph showing the discrete short basalt fibre

TABLE 2. Physical and mechanical properties of basalt fibers

Property	Value
Cut length (mm)	12
Filament diameter (μm)	17
Density (g/cm^3)	2.61
Elastic modulus (GPa)	95
Tensile strength (MPa)	3000

TABLE 3. Physical and chemical properties of cement

Property/composition	Value
Specific gravity	3.14
Specific surface area (m^2/kg)	320
CaO (%)	60.4
SiO_2 (%)	15.9
Al_2O_3 (%)	9.5
SO_3 (%)	6.4
Fe_2O_3 (%)	4.1
MgO (%)	0.9
K_2O (%)	0.7
TiO_2 (%)	0.1

The peat was first oven dried for at least 24 h at 110°C, and then addatives (i.e. basalt fiber or cement, if any) were mixed in dry state with dry peat. The required amount of distilled water was sprayed onto the mixture and the constituents were mixed until a homogeneous mixture was obtained. The treated samples with a natural moisture content were placed in three layers in a mold with height and diameter of 100 mm and 50 mm, respectively. Each layer of samples was given 25 blows by using the tamping. After sample preparation, the samples were then taken out of the mold and wrapped with a plastic film. Afterwards, the samples were stored in the humidity controlled chamber (temperature= 20°C, and relative humidity= 95%) until testing at 14, 28 or 60 days of curing. Finally, after all the tests, all the stress-strain diagrams in Excel were plotted and compared to find a suitable combination selection for improvement.

3. TESTS RESULTS AND DISCUSSION

The effects of fibre length on the stress-strain curve of the reinforced samples at basalt contents (BC) of 0.5% and 1% are shown in Figures 2 and 3, respectively. As shown from the results, the UCS values of reinforced samples are always greater than that of peat sample regardless of fibre content and fiber length (L). The reinforced samples exhibited a more ductile behavior with a larger strain corresponding to the peak stress than that of peat sample which is good agreement with the reported data in the literature [9, 47-49]. The UCS value of reinforced samples with basalt content of 0.5% is almost independent of fibre length; however, the UCS value of reinforced samples with basalt content of 1% increases slightly with an increase in fibre length. In general, the sample containing longest fibres (18 mm) showed the highest UVS value. A comparison of Figures 2 and 3 shows that the UCS values of reinforced samples increases about 10% with an increase in fibre content from 0.5% to 1% which also reported in previous studies [41, 42, 48, 50]. Figure 4 shows the effect of fibre content on the stress-strain curve of the reinforced samples for a given fibre length of 18 mm. The results reveal the improvement of the UCS for reinforced samples with an increase in fibre content. An increase in the fibre content from 0.5% to 2% results in an increase in the UCS value from 133 kPa to 205 kPa. The basalt fibre-reinforced samples indicate a more ductile behavior than the peat sample.

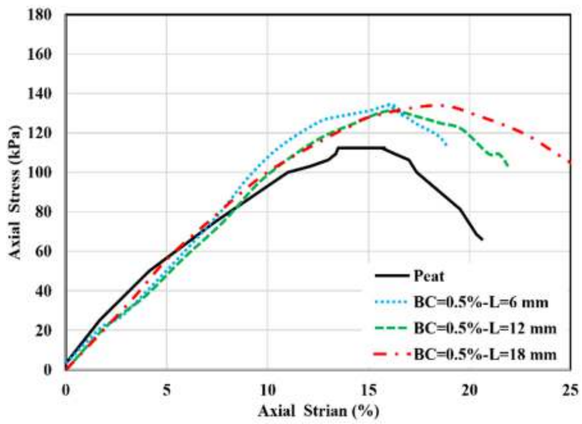

Figure 2. Stress–strain curves of the basalt fibre-reinforced samples with BC=0.5% and varied fibre length

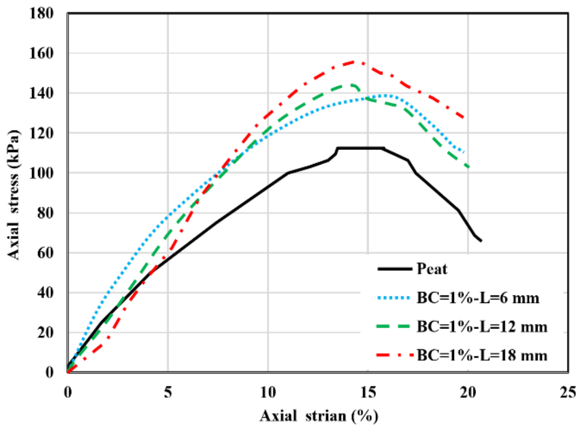

Figure 3. Stress–strain curves of the basalt fibre-reinforced samples with BC=1% and varied fibre length

The effects of cement content on the stress-strain curve of the stabilized samples at cement contents (CC) of 2% and 5% at various curing times are shown in Figures 5 and 6, respectively. Addition of cement has important effect on the behaviors of peat samples and increases the UCS values and decreases the strain corresponding to the peak stress. The cement-stabilized peat samples with cement exhibits brittle behavior and the most improvement in UCS value is observed within the first 7 days. The UCS increases gradually with an increase in curing time which good agreement with previous studies [10, 51-54]. Comparison of the fibre -renforced samples with cement-stabilized samples showed that for a given additive content, the cement stabilized samples exhibited higher UCS values than those reinforced with fibre. As shown, the UCS increases with increasing the curing time from 7 to 60 days. From Figure 5, it could be seen that by an increase in the curing time from 7 to 60 days the UCS value of cement-stabilized samples containing 2% cement increased from 220 kPa to 415 kPa. As shown from Figure 6, for the samples containing 5% cement, the UCS value increased from 520 kPa to 880 kPa with an increase in the curing time from 7 to 60 days. Figures 7 and 8 show the stress-strain curve of the fibre -reinforced cement-stabilized samples at various curing times with fibre content of 1% and cement contents of 2% and 5%, respectively.

The results indicate the treated samples behaved as a brittle material with higher axial stress values than that of peat sample regardless of cement content and curing time. There is a general slightly increase in UCS value for treated samples as curing time increased. The axial strain corresponding to the peak stress for treated samples decreased with increasing curing time. A comparison of Figures 7 and 8 indicate that the UCS values of treated samples increases about 10% with the increase about two times as cement content increases from 2% to 5% for a given curing time. A comparison between cement-stabilized samples and treated samples with basalt fibre and cement shows that the addition of 1% of basalt fibre in the stabilized samples with 2% cement content resulted in an increase of 15% to 40% of UCS values depending on curing time. On the other hand, curing time has less influence on the UCS values of the treated samples with basalt fibre and cement than in treated samples without basalt fibre.

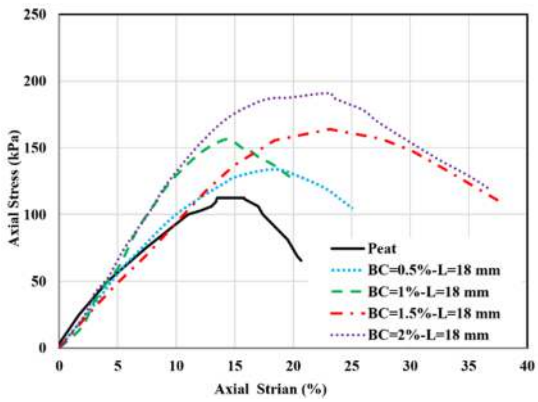

Figure 4. Stress–strain curves of the basalt fibre-reinforced samples with varied fibre content and fibre length of 18 mm

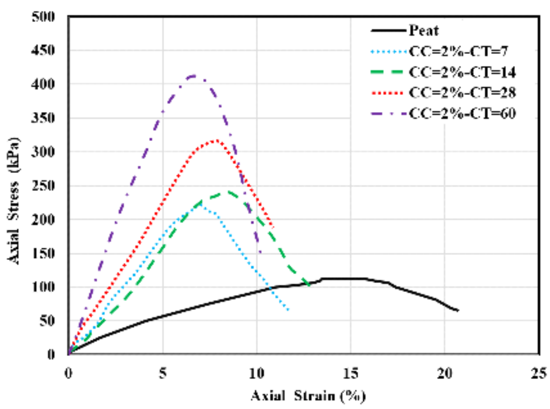

Figure 5. Stress–strain curves of the cement-stabilized samples with cement content of 2% at various curing times

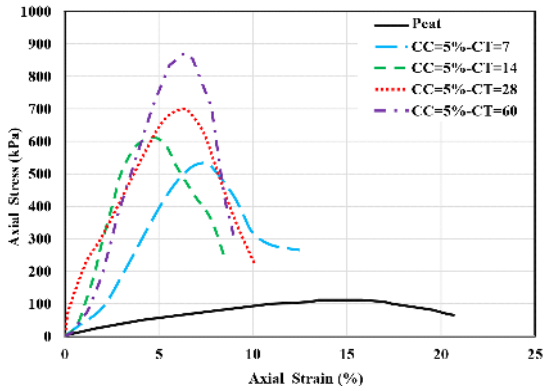

Figure 6. Stress–strain curves of the cement-stabilized samples with cement content of 5% at various curing times

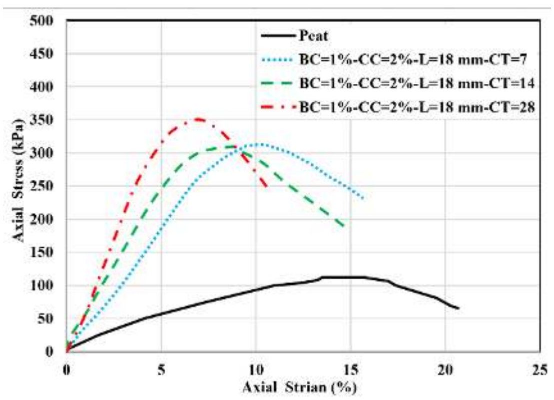

Figure 7. Stress–strain curves of the treated samples with fibre content of 1% and cement content of 2% at various curing times

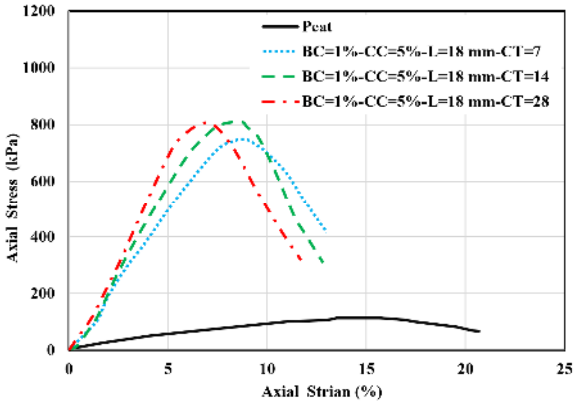

Figure 8. Stress–strain curves of the treated samples with fibre content of 1% and cement content of 5% at various curing times

4. CONCLUSIONS

Peats are an extreme form of soft soils which are generally associated with high compressibility, medium to low permeability, low strength and large settlements and hold serious problems in civil engineering constructions. In the current study, a series of UCS tests were conducted on the peat samples to study the influences of basalt fibre content, fiber length, cement content and curing time. Based on the results, the following conclusions are reached.

The addition of basalt fiber or cement significantly enhanced the UCS values of peat soil. Increasing basalt fiber content or cement content leads to a significant increase of UCS values. The UCS value was more with the addition of cement than the same content of basalt fibre especially for high curing time. For example, the UCS value of stabilized sample with 2% cement content at curing time 60 days was almost twice that of reinforced sample with 2% basalt fibre. In other words, the strength of cement-stabilized samples was very much greater than that of the fibre-reinforced samples for long-term performance. However, the sample reinforced with basalt fibers showed more ductile behavior compared to the stabilized sample with cement. Furthermore, the axial strain at failure for cement-stabilized sample decreased with increasing cement content or curing time. In general, the results show that a combination of fiber and cement could be suitable for peat improvement.

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Persian Abstract

چکیده

تاکنون مطالعات زیادی بر روی رفتار مکانیکی خاک‌های تقویت‌شده با الیاف و خاک‌های تثبیت‌شده با تثبیت‌کننده‌های شیمیایی معمولی مانند سیمان و آهک انجام شده است، با این حال تحقیقات بسیار محدودی بر روی ویژگی‌های مقاومت فشاری محصور نشده خاک‌های peat تثبیت‌شده با سیمان به همراه الیاف انجام شده است. اضافه شدن الیاف به خاک تثبیت شده با سیمان منجر به بهبود قابل توجهی در ویژگی های رفتاری همچون شکل پذیری و مقاومت خاک های ضعیف یا نرم می‌شود. هدف اصلی مطالعه حاضر در نظر گرفتن اثرات مقدار سیمان، مقدار الیاف، طول الیاف و زمان عمل‌آوری بر روی مقاومت فشاری محصور نشده خاک peat است. این مطالعه نشان می‌دهد که افزودن الیاف بازالت یا سیمان باعث افزایش قابل توجهی در مقادیر UCS می‌شود. مقدار UCS نمونه تثبیت شده با سیمان به طور قابل توجهی بیشتر از نمونه‌های تقویت شده با الیاف بازالت است. با این حال، نمونه تقویت‌شده با الیاف بازالت، رفتار نرمتری نسبت به نمونه تثبیت شده با سیمان نشان دادند. نتایج نشان داد که افزایش مقادیر UCS در ترکیبی از الیاف بازالت و سیمان بیشتر از افزایش ایجاد شده توسط هر یک از آنها به صورت جداگانه است.