

MECHANICAL PROPERTIES OF CEMENT-STABILIZED CHLEF SAND REINFORCED WITH POLYPROPYLENE FIBER

PROPRIETES MECANIQUES D'UN SABLE DE CHLEF STABILISE AVEC DU CIMENT ET RENFORCE AVEC DES FIBRES DE POLYPROPYLENES

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Abstract - In recent years, stabilization and reinforcement techniques have been widely used in geotechnical engineering in order to improve soil's geotechnical properties, it can be achieved through the addition of a proper amount of cementitious agents (cement, fly ash... etc), or the inclusion of oriented or randomly distributed elements such as fibers. Adding fibers to stabilized sand reduces the risk of shrinkage cracks and promotes overall structural integrity. This paper investigated the addition of polypropylene fiber to cement-stabilized sand to enhance the mixture's mechanical properties. sand-cement specimens were prepared with different cement content ($C_c=2,5\%$; 5% ; 10%) and fiber content ($F_c=0,1\%$; $0,2\%$; $0,3\%$). Direct shear tests were carried out at a moisture content of 10% , a relative density of 80% , and normal stress (50 ; 100 ; and 200kPa), the specimens were cured for 7 days at room temperature. The main findings showed an increase in shear strength, cohesion, and internal friction angle with the increase in cement and fiber content, the maximum shear strength of the mixture sand-cement-fiber was attained at a fiber content of $0,2\%$ and then started decreasing with the augmentation of fiber content. in addition, the inclusion of fiber leads to an attenuation in the brittleness index and the dilative behavior of the fiber-reinforced cemented-sand.

Key-words: Stabilization; Reinforcement; Soil improvement; Shear strength; Sand

Résumé - Ces dernières années, les techniques de stabilisation et de renforcement ont été largement utilisées en ingénierie géotechnique afin d'améliorer les propriétés géotechniques des sols. Cela peut être réalisé par l'ajout d'une quantité adéquate d'agents cimentaires (ciment, cendre volante, etc.) ou par l'inclusion d'éléments orientés ou distribués de manière aléatoire, tels que des fibres. L'ajout de fibres au sable stabilisé réduit le risque de fissures de retrait et favorise l'intégrité structurelle globale. Cet article a étudié l'ajout de fibres de polypropylène au sable stabilisé au ciment pour améliorer les propriétés mécaniques du mélange. Des spécimens de sable-ciment ont été préparés avec différentes teneurs en ciment ($C_c=2,5\%$; 5% ; 10%) et teneurs en fibres ($F_c=0,1\%$; $0,2\%$; $0,3\%$). Des tests de cisaillement direct ont été effectués à une teneur en eau de 10% , une densité relative de 80% et une contrainte normale (50 ; 100 ; et 200 kPa). Les spécimens ont séjourné pendant 7 jours à température ambiante. Les principales conclusions ont montré une augmentation de la résistance au cisaillement, de la cohésion et de l'angle de frottement interne avec l'augmentation de la teneur en ciment et en fibres. La résistance au cisaillement maximale du mélange sable-ciment-fibres a été atteinte à une teneur en fibres de $0,2\%$, puis a commencé à diminuer avec l'augmentation de la teneur en fibres. De plus, l'inclusion de fibres entraîne une diminution de l'indice de fragilité et du comportement dilatant du sable cimenté renforcé de fibres.

Mots-clés : Stabilisation; Renforcement; Amélioration de sol ; Resistance au cisaillement ; Sable

1-Introduction

With the increase in population and urban sites, grounds with favourable geotechnical properties became occupied, while on the other hand, the demand for suitable construction sites has increased. Nowadays, geotechnical engineers are challenged to provide proper grounds for construction projects.[13,15,16]

Ground improvement is a technique that aims to improve soil's mechanical characteristics to match the desired performances for a project, it can be classified into three major categories physical, mechanical, and chemical improvement (treatment). hence, soil improvement can be achieved through both laboratory or in-situ tests such as vibro-compaction, fibers, and geosynthetics inclusion [5-8], soil stabilization with hydraulic binders [7,9], and bio-cementation using biopolymers [2,3]. In geotechnical engineering, chemical stabilization using cement is the most traditional method. Several researchers reported that the addition of cement to soils leads to an increase in resistance, a reduction of permeability as well as settlement reduction, and an improvement of bearing capacity [1,4,10,11,12,14,17,18].

However, the addition of cement to improve the mechanical properties of sand also increases the brittle behavior of the sand-cement mixture. Numerous studies investigated reinforcement techniques using different additives such as fibers to enhance the shear strength, reduce the brittleness of the sand-cement mix and improve its ductility in order to limit loss of post-peak strength. This paper investigates the influence of cement and polypropylene fibers on the mechanical properties of Chlef sand through direct shear tests [19-23].

2- Materials and Methods

2.1- Materials

2.1.1- Sand

The soil used in this study is sand collected from the Chlef river banks north of Chlef (Algeria). Once collected and transported to the laboratory, the sand was dried at 105° for 24 hours and then sieved to remove particles larger than 2mm. The particle size distribution curve of the sand used is illustrated in Figure 1 and its physical properties are presented in Table 1. It is classified as well-graded sand according to USCS.

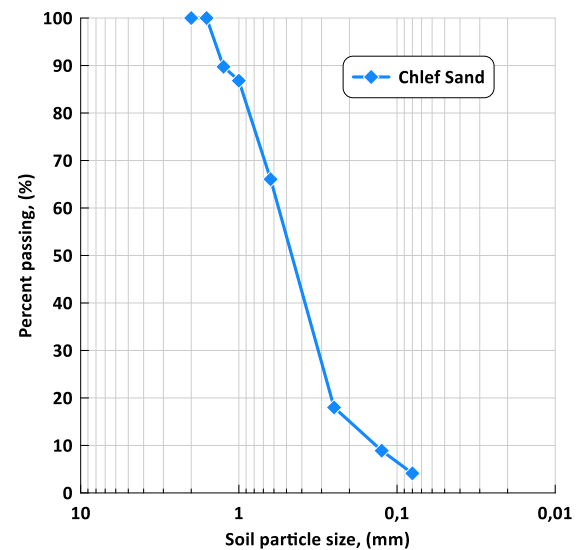


Figure 1: Particle size distribution of Chlef sand.

Figure 1 : Analyse granulométrique de sable de Chlef

Table 1: Physical properties of Chlef sand.

Tableau 1 : Propriétés physiques de sable de Chlef

Properties	Value
Uniformity coefficient, C_u (.)	4,1
Coefficient of curvature, C_c (.)	1,3
Medium size, D_{50} (mm)	0,46
Maximum diameter, D_{max} (mm)	2.00
Specific density, G_s (.)	2.69
Maximum void ratio, e_{max} (.)	1.05
Minimum void ratio, e_{min} (.)	0.64

2.1.2- Cement

The cement used in this study is Portland cement with limestone (CEM-II/B-L 32,5 N), manufactured by LAFARGE company following the Algerian standard (NA442-2013) and the European standard (EN 197-1). The physical properties of this cement are given in Table 2.

Table 2: Physical properties of cement

Tableau 2: Propriétés physiques de ciment

Properties	Value
Specific density, GS (.)	3,1
Average diameter (Microns)	1.258
Median diameter (Microns)	0,122
Specific surface (cm ² /cm ³)	4.9733E+5
D10 (Microns)	0.0787
D60 (Microns)	0.133

2.1.3- Polypropylene fiber

The fiber used in this study was a white monofilament polypropylene fiber with an average length of 12 mm and a diameter of 32 μm . Different fiber contents : $F_c = 0\%$, 0.1% , 0.2% and 0.3% were used.

2.2- Sample preparation and test procedure

To achieve the main objective of this study, a series of tests were carried out, on Chlef sand mixed with different contents of cement (2.5%; 5%; and 10%) and different fiber contents (0.1%; 0.2%; 0.3%), using a square shear box having plan dimensions of 60 mm on 60 mm. The initial height of the samples was 20 mm. The three sand-cement-fiber mixtures were prepared at a relative density of 80% and a moisture content of 10%.

The production of cement-treated sand with fiber samples was done first by mixing, sand, cement, Fiber, and water in specific amounts determined in advance. The cement, sand, Fiber, and water mixture were stirred until the materials were completely merged to form a uniform paste, then the mix was poured into a mold and left to be cured for 7 days at room temperature of $35^\circ \pm 3$. The mixture was then removed and placed directly into the direct shear testing apparatus.

The sample was then subjected to a vertical load using slotted steel weights. Each mixture was tested under three different normal stresses 50 kPa, 100 kPa, and 200 kPa.

The sample was left under the effect of normal load for a few moments until the vertical displacement stabilized, after which the sample was sheared at a constant rate of 1 mm/min until a horizontal displacement of about 8 mm was obtained. The shear rate was kept constant for all tests.

3-Results and discussion

3.1-Influence of cement content on the shear strength of Chlef sand

Figure2 represents the evolution of shear strength τ (kPa) as a function of the horizontal displacement δH (mm) of untreated and treated sand specimens with various cement content under three different normal stresses ($\sigma_N = 50, 100, \text{ and } 200 \text{ kPa}$) at dense state ($D_r = 80\%$), a moisture content of 10% and were cured for 7 days. It can be noticed that the shear stress (τ) of untreated sand increases until reaching its highest value, located between 1.5 and 5.5 mm of horizontal displacement (Δh), after which the variation in τ values becomes less significant with the evolution of Δh . The treated samples compared to sand show a sharp increase in shear stress at the beginning of the test and after reaching a maximum value a remarkable decrease in stress values is noticed. It can also be seen that the maximum shear strength values obtained for treated samples with cement are much higher than those obtained for untreated samples. These values are accentuated with an increase in cement percentage and normal stress. This higher strengthening effect is a result of resulting in an improvement in inter-particle cohesion.

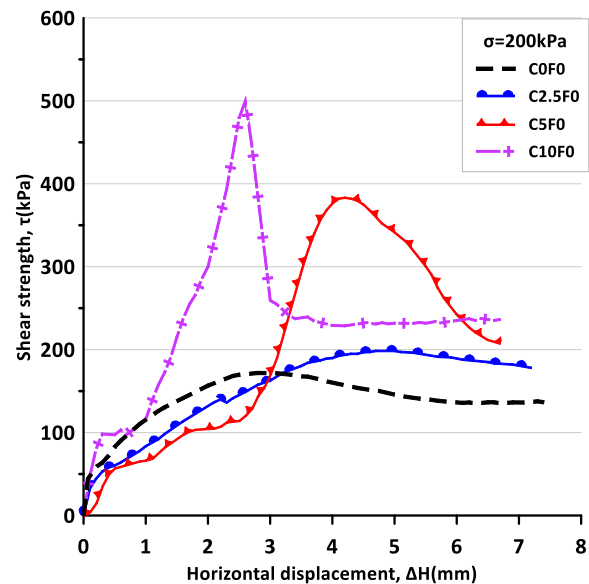
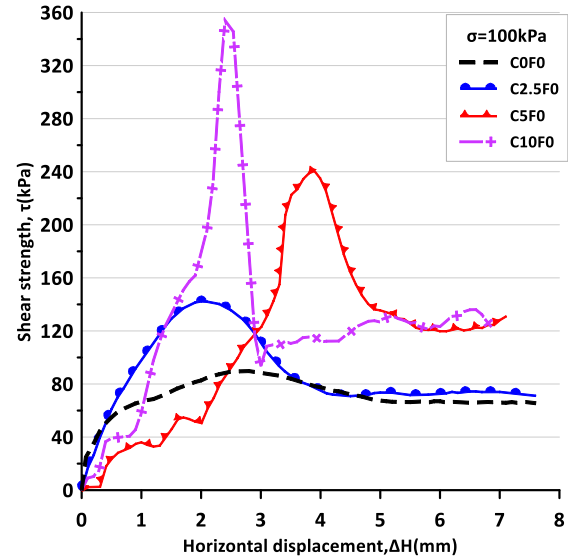
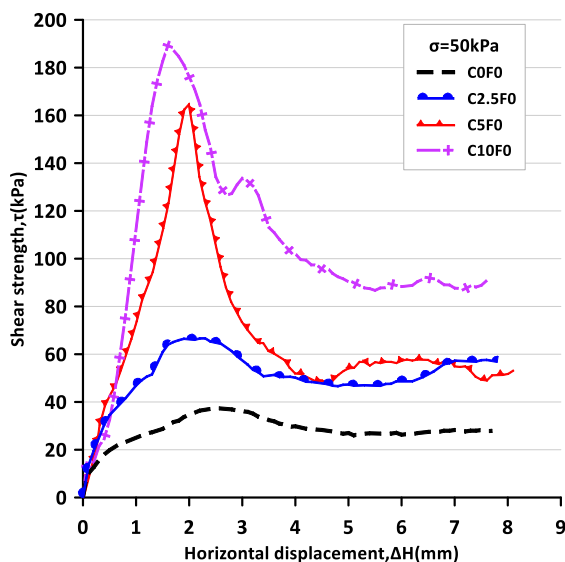


Figure2: Shear strength in terms of horizontal displacement

Figure2 : Résistance au cisaillement en fonction de déplacements horizontal

3.2- Influence of fiber content on the shear strength of cemented Chlef sand

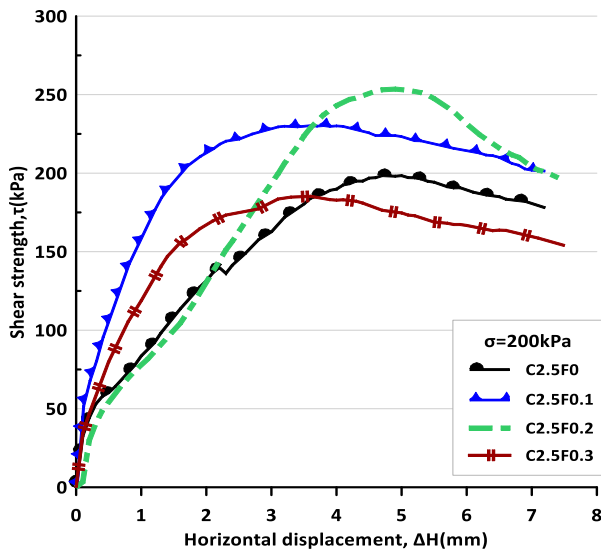


Figure3: Shear strength in terms of horizontal displacement

Figure3 : Résistance au cisaillement en fonction de déplacement horizontal

This figure exhibits the evolution of the shear strength as a function of the horizontal displacement of polypropylene fiber-reinforced cemented sand, it's clear to see from the graphics that the shear strength enhances with the increase of fiber content to reach its optimum value at fiber content of 0.2% then starts decreasing noticeably as the fiber content increases from 0.2% to 0.3% , this indicates that higher fiber contents have a negative impact on the mechanical properties of fiber-reinforced cemented sand. Fiber-reinforced cemented sand exhibits a ductile behavior compared to cemented sand before the inclusion of fiber which exhibits a brittle behaviour.

3.3 Influence of fiber and cement content on the cohesion and internal friction angle

Table3: Influence of cement content on the cohesion and internal friction angle

Tableau3 : L`influence de teneur and ciment sur la cohésion et l`angle de frottement interne

Cc(%)	C(kPa)	$\Phi(^{\circ})$
2.5%	22,431	45
5%	93,667	44,99
10%	116,49	43,53

Table 3 presents the evolution of the cohesion and the internal friction angle as a function of cement content, it's clear to see that with the increase of cement content, the cohesion increases significantly compared to the uncemented sand samples. This increase in cohesion could be associated with the hydration process of cement in which it fills the space between the sand particles and binds them together. It also appears from the table that with the increase of cement content, the internal friction angle slightly decreases.

Table4: influence of fiber content on the cohesion and the internal friction angle

Tableau4 : L`influence de teneur en fibre sur la cohésion et l`angle de frottement interne

Fc(%)	C(kPa)	$\Phi(^{\circ})$
0.1%	21,71	45,53
0.2%	53,219	44,25
0.3%	61,93	43,34

The evolvment of the shear parameters of cemented sand in terms of fiber content are displayed in table 4, it's clear to see from the results that the inclusion of polypropylene fibers enhanced the cohesion of the cemented sand, and was estimated at 21.17kPa; 53.219kPa; and 61.93kPa respectively for fiber content of 0.1%; 0.2%; and 0.3%. in addition to the previous findings, the internal friction angle decreased with the increase of the fiber content.

4-Conclusion

This paper investigated the influence of various proportions of cement and fiber on the mechanical properties of Chlef sand. The following conclusions can be drawn:

1. The maximum shear strength of Chlef natural sand treated with cement increases significantly with increasing cement content and normal stress. However, all cemented samples exhibited post-peak strength loss due to the increasing brittleness of the samples.
2. The addition of cement increased cohesion and decreased the internal friction angle, the inclusion of fiber also increased the cohesion and reduced the internal friction angle
3. the augmentation of cement content increased the brittleness of the cemented sand. However, with the addition of polypropylene fibers, the fiber-reinforced cemented sand exhibits a ductile behavior

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