

Mechanical behavior of silty sand reinforced with natural discrete elements: effect of silt content, fiber content and other parameters

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Abstract:

Introduction/purpose: Many studies have reported a notable reduction in the shear strength of sandy soils when fine fractions are present, resulting in soils with poor geotechnical properties. With the lack of suitable soils for construction, it is now imperative to alter the properties of soil to make it suitable for engineering purposes. Numerous methods and techniques exist to enhance soil stability. The inclusion of discrete elements as reinforcement is particularly effective due to its contribution to a variety of desirable results.

Methods: This paper investigates the impact of natural discrete elements on the shear strength behavior of silty sand at medium relative density prepared with different dispositional methods using different moisture contents. The study focuses on different parameters, namely, silt, fiber and water contents.

Results: The experimental results indicate a reduction of strength with an increase in silt content and water content. Furthermore, the strength, volumetric change, and mechanical properties of the mixtures greatly improved with the addition of sisal fibers at low moisture contents. However, no significant improvement was recorded at high moisture contents, indicating the negative influence of moisture content on the fiber reinforcement mechanism.

Conclusion: Following a rigorous analysis of the obtained results, it was determined that Sisal fibers can be judiciously used for improving soil characteristics.

Key words: sand, silt, natural fiber, moisture content, shear strength, mechanical characteristics.

Introduction

Post-earthquake field investigations have revealed that sand samples extracted from liquefaction-induced sand boils often contain a significant percentage of fines. In geotechnical engineering, soils are frequently encountered as mixtures of sand-clay or sand-silt, with plastic or non-plastic fines, necessitating a thorough understanding of their mechanical behavior to ensure safe infrastructure design. The role of low-plasticity fines in altering the liquefaction resistance of sand-fines mixtures has been a focal point of research over the past two decades. Despite extensive studies, the geotechnical community remains divided on how fines content (FC) influences liquefaction potential, highlighting the complexity of these soil systems. For instance, Amini and Qi (2000) argued that increasing fines content enhances liquefaction resistance, attributing this to the filling of void spaces between sand particles, which reduces pore pressure

buildup. Conversely, Lade and Yamamuro (1997), Belkhatir et al. (2010), Monkul et al. (2016), and Bouri et al. (2019) reported that higher fines content diminishes resistance by disrupting intergranular contacts, leading to weaker soil matrices. A third perspective, proposed by Xenaki and Athanasopoulos (2003), Bouferra and Shahrour (2004), and Benghalia et al. (2015), suggests a nonlinear relationship: liquefaction resistance initially decreases with fines addition until a threshold FC is reached, beyond which resistance improves. Another trend was reported by Feknous et al. (2024), who found that adding 10% silt to clean Chlef sand resulted in an increase in shear strength, whereas a further increase in silt content beyond this value led to a reduction in strength. These discrepancies underscore the influence of factors such as fines plasticity, particle gradation, and testing conditions on outcomes. The undrained shear strength, or liquefaction resistance, of sandy soils is governed by a multitude of interrelated factors. Laboratory studies have highlighted the role of fines content (FC), particle size, shape, and packing density in dictating mechanical behavior under static and cyclic loads. For instance, Georgiannou et al. (1991), Belkhatir et al. (2012, 2014), and Yazdani et al. (2022) demonstrated that increasing fines content can alter soil fabric, reducing permeability and promoting pore pressure buildup. These discrepancies suggest that fines content alone is insufficient to predict liquefaction; microstructure, particle arrangement, initial water content, and testing methods must also be considered.

Soil reinforcement has been a pivotal innovation in geotechnical engineering, offering solutions to enhance the mechanical properties of weak or unstable soils. Among the various techniques, the use of randomly distributed fibers has emerged as a superior alternative to conventional geosynthetics due to its cost-effectiveness, ease of application, and environmental benefits. The concept of fiber reinforcement draws inspiration from plant root systems, which naturally stabilize soil by creating a cohesive network that resists erosion and displacement. Similarly, flexible, discrete, and randomly distributed fibers replicate this biological mechanism, reinforcing near-surface soils where low effective stress often leads to failure (Wu et al., 1988; Greenwood et al., 2004). Soil reinforcement using synthetic materials has gained significant interest in geotechnical engineering, offering innovative solutions to enhance soil strength and stability. In addition to these materials, natural plant fibers such as coconut, jute, palm, and sisal offer a compelling alternative. These materials are cost-effective, biodegradable, and recyclable, aligning with global demands for eco-friendly engineering practices (Zakikhani et al., 2014; Bordoloi et al., 2017; Rangappa et al., 2022; Reis et al., 2023).

Incorporation of randomly distributed fibers stands out as a method that bolsters the stability of soil masses by increasing resistance near the surface, where low effective strength often poses challenges (Noorzad and Zarinkolaie, 2015), and reducing post-peak strength loss (Al-Refeai, 1991; Ahmad et al., 2010; Diambra et al., 2010; Anagnostopoulos et al., 2013; Zhang et al., 2022). When integrated into soil, fibers act as a composite material, where high-tensile-strength fibers interact with the soil matrix to enhance mechanical properties. During shear stress, the fibers mobilize their tensile resistance, transferring loads and limiting soil particle displacement (Ghiassian et al., 2008; Jamshidi et al., 2010). This interaction forms a three-dimensional network that interlocks soil grains, creating a unified matrix with improved cohesion and reduced deformation. Such behavior is critical in liquefaction-prone areas, as the fiber network redistributes stresses and mitigates sudden strength loss during dynamic loading. Extensive studies by researchers such as Maher and Woods (1990), Edinçliler and Ayhan (2010), and Ali et al. (2020) have demonstrated that fiber reinforcement significantly enhances key geotechnical properties, including shear strength, stiffness, compaction characteristics, and bearing capacity (Sridhar, 2017). Fiber reinforcement is dependent on different parameters related to both fibers (fiber aspect ratio, fiber length and fiber content) and soil characteristics (relative density, normal stress, particle size and gradation). Additionally, fiber-reinforcement efficiency is highly dependent on spatial configuration, including matrix packing and orientation (Abtahi et al., 2008; Ghiassian et al., 2008). The behavior of fiber-reinforced soil also varies according to the type and structure of the fibers, whether natural or synthetic. Benziane et al. (2022) investigated the shear behavior of natural Chlef sand reinforced with three types of randomly distributed fibers, namely polypropylene, glass, and sisal fibers. They found that adding sisal fibers to sand improved its strength parameters more than the incorporation of glass or polypropylene fibers did, and that the optimum sisal fiber content was 0.75%.

The behavior of sand-fines mixtures has been largely documented; however, the influence of fibers on the mechanical behavior of sand-fines mixtures remains understudied. This experimental study aims to investigate the shear behavior of silty sand reinforced with natural discrete elements, focusing on the effect of fiber content, silt content, water content and sample preparation method.

Materials and methods

Soil

The soil used in this study was sand collected from the Chlef river banks in the north of Chlef (Algeria). During the last earthquake of October 1980, this region experienced a case of soil liquefaction (Krim et al., 2024) mainly attributed to the presence of silt in the soil mass. The silty sand mixtures used in this study (Figure 1) are classified as poorly graded sand (SP). Figure 2 presents the grain size distribution curve of the mixtures and their engineering properties are given in Table 1.

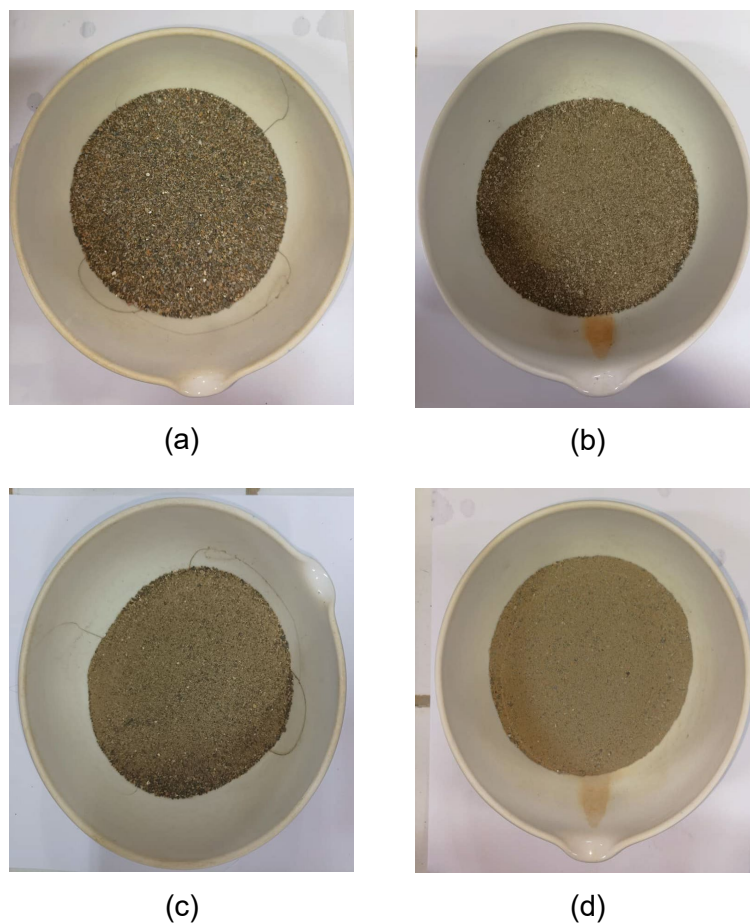


Figure 1 - Silty sand: (a) $Sc=0\%$, (b) $Sc=10\%$, (c) $Sc=20\%$, (d) $Sc=30\%$

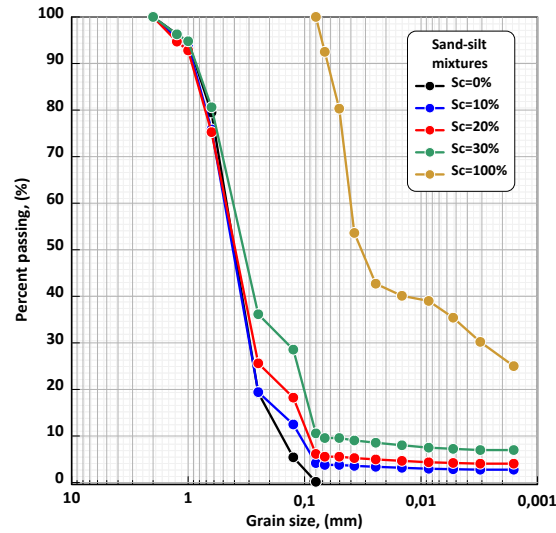


Figure 2 - Grain size distribution curve of Chlef sand-silt mixtures

Table 1 - Properties of Chlef sand-silt mixtures

Parameter	Sand-silt mixtures			
Silt content, S_c (%)	0	10	20	30
Maximum grain size, D_{max} (mm)	2.00			
Mean grain size, D_{50} (mm)	0.43	0.41	0.39	0.35
Coefficient of uniformity, C_u (.)	3.28	4.64	5.44	5.86
Coefficient of curvature, C_c (.)	0.85	1.5	1.65	0.6
Minimum void index, e_{min} (.)	0.59	0.485	0.446	0.437
Maximum void index, e_{max} (.)	0.885	0.823	0.747	0.724
Mean specific gravity, G_s (.)	2.74	2.733	2.726	2.718

Reinforcement

The fibers used in this study are sisal fibers with similar length ($l_f = 12\text{mm}$) and different fiber contents, $F_c = 0\%$, 0.3% , 0.5% , and 0.8% by dry soil mass (Figure 3). Sisal is a leaf fiber with high tensile strength and is commercialized and used in different engineering applications. The physical and mechanical characteristics of fibers are presented in Table 2.



Figure 3 - Sisal fiber

Table 2 - Physical and mechanical characteristics of sisal fibers

Specific gravity	Length (mm)	Diameter (μm)	Tensile strength (MPa)	Young Modulus (MPa)
0.91	12	35	550	19

Experimental program and sample preparation method

The experimental program consists of a series of direct shear tests carried out on a medium dense Chlef sand ($D_r = 50\%$) with varying silt contents and different fiber percentages prepared with different initial water contents using two different sample preparation methods sheared under normal stresses of 50, 100 and 200 kPa. The horizontal shearing was performed at a constant displacement rate of 1.00 mm/min. Horizontal load, and horizontal and vertical displacements were acquired automatically via the apparatus load unit. All the parameters considered in the testing program are listed in Table 3.

Table 3 - Experimental program

Sample preparation method	Normal stress σ_n (kPa)	Silt content S_c (%)	Fiber content F_c (%)	Water content w (%)
Dry disposition	50, 100 and 200	0, 10, 20 and 30	0, 0.3, 0.5 and 0.8	0
Wet disposition		10	0, 0.3, 0.5 and 0.8	1.5, 3 and 5

The experimental program was divided into two sets. The first set of samples was prepared using the dry disposition method in order to

investigate the influence of silt and natural fibers on the behavior of Chlef sand. The test specimens were prepared by mixing clean sand with different silt fractions and fiber percentages by dry soil mass until a homogeneous mixture was obtained (Figure 4). The second set was carried out on unreinforced and reinforced silty sand at 10% silt content prepared using the wet disposition method in order to study the influence of moisture content and sample preparation methods on the behavior of unreinforced and reinforced silty sand. Test specimens were obtained by mixing sand, silt and fibers with different contents of distilled water (Figure 5). Test specimens obtained through the different preparation methods were then placed into the shear box cavity ($60 \times 60 \times 25 \text{ mm}^3$) in three layers and gently leveled off to achieve a medium-dense state.

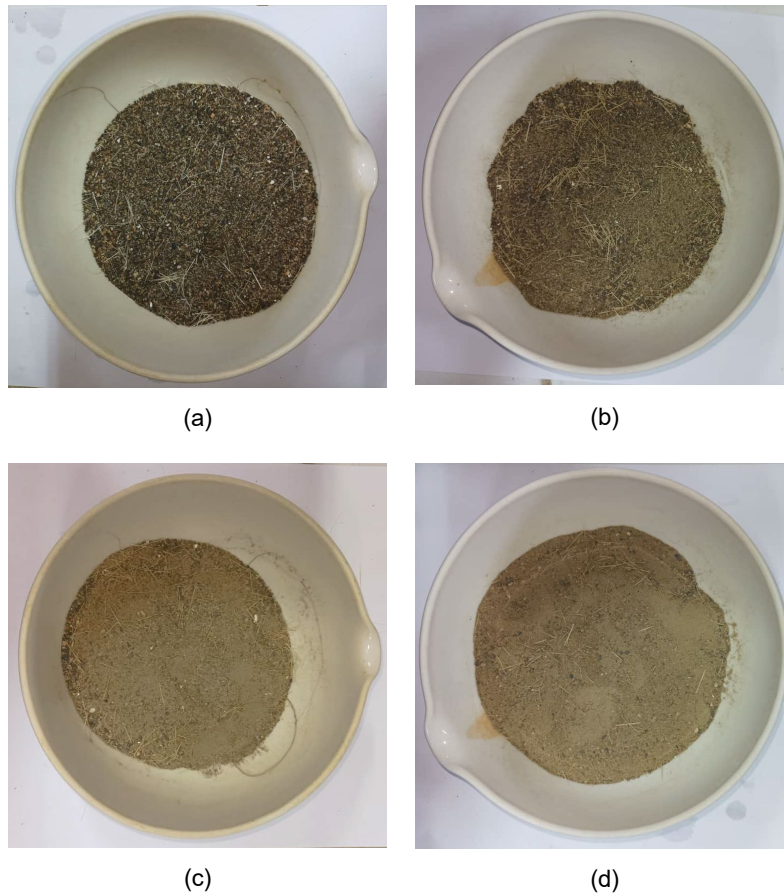


Figure 4 - Reinforced silty sand prepared with the dry disposition method: (a) $Sc=0\%$, (b) $Sc=10\%$, (c) $Sc=20\%$, (d) $Sc=30\%$

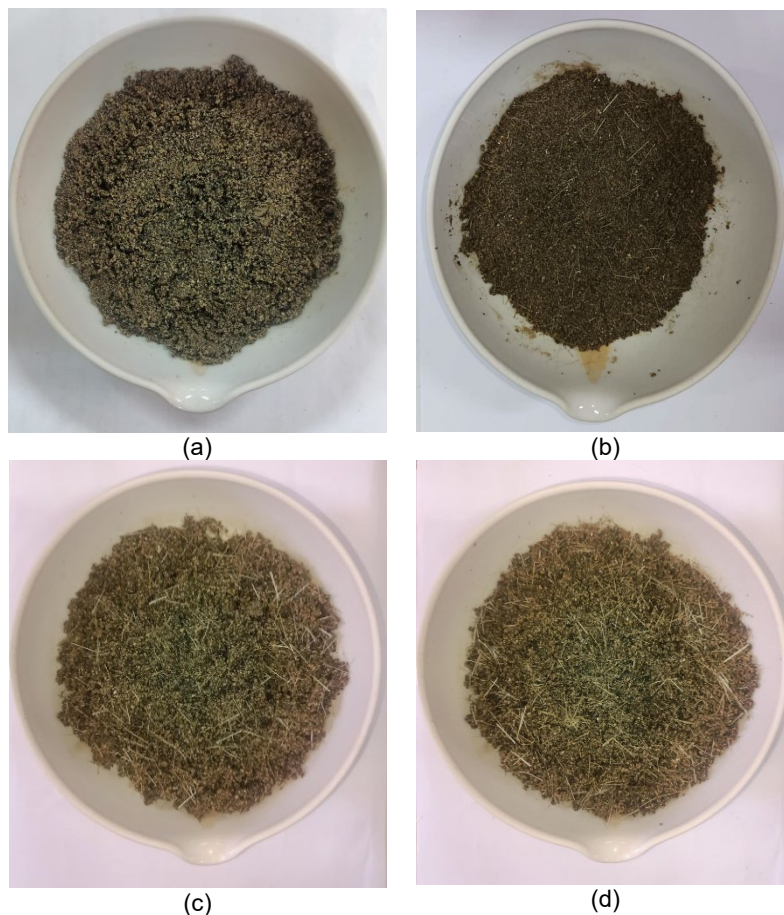


Figure 5 - Unreinforced and reinforced silty sand ($Sc=10\%$) prepared with the wet disposition method: (a) $F_c=0\%$, (b) $F_c=0.3\%$, (c) $F_c=0.5\%$, (d) $F_c=0.8\%$

Results analysis and discussion

Influence of silt content

Figure 6 presents the results of direct shear tests conducted on untreated Chlef sand-fines mixtures prepared at a medium relative density $Dr = 50\%$ using the dry pluviation preparation method. The data show that the maximum shear stress decreases proportionally with an increase in fines content (Fig. 6a). Sand-fines mixtures can be considered as binary systems constituted of two submatrices a coarser grain matrix and a finer grain matrix. At lower fines content the fines occupy the voids between the sand grains and the overall strength of the mixture is governed by the

coarser grain matrix. With further addition of fines, the coarse grains become separated from each other and the coarse particles interaction dissipates (Yazdani et al., 2022). Beyond a specific threshold, the mechanical behavior of the mixtures is then ruled by the finer grain matrix. Similar results were observed by Georgiannou et al. (1991), Belkhatir et al. (2013), Arab and Belkhatir (2012), and Benghalia et al. (2015).

Figure 6b illustrates the evolution of vertical displacement as a function of horizontal displacement for sand-fines mixtures with varying fines contents ($F_c = 0\%$, 10% , 20% and 30%). The results show an intensified contraction phase, with the contractive behavior becoming more pronounced as the fines content increases. Yamamuro and Lade (1997) attribute this behavior to the formation of a highly compressible structure between the smaller and larger particles in the soil. This phenomenon is explained by the tendency of fines to initially accumulate at the points of contact between larger grains. Upon shearing, these fines are displaced to fill voids within the structure, generating a contractive response. This process can lead to static liquefaction under undrained conditions.

Figure 6c indicates that the maximum shear strength of sand-silt mixtures is very dependent on the fines content and normal stress where it was found that an increase in normal stress tends to increase maximum shear strength values. However, an increase in fines content leads to a decrease in the mixtures' strength for every normal stress studied. In addition, the effect of fines on cohesion and friction angle values of Chlef sand-fines mixtures was determined through the intrinsic curves and plotted in Figure 7. From the figure, it is noted that the cohesion of sand-silt mixtures slightly increased with an increase of fines content. The obtained cohesion values were 0, 5.5, 7.5 and 11.03 for fines content of 0, 10, 20 and 30%, respectively (Figure 7a). This is due to silt particles penetrating into the voids between the larger sand particles, creating more contact points and enhancing the interaction between the particles leading to an increase in the overall cohesion of the sand-silt mixture. Regarding the internal friction angle, it was found that the inclusion of silt fines results in a decrease in the internal friction angle of sand-fine mixtures (Figure 7b). This result is attributed to the smooth surface of silt reducing the effective inter-particle friction. This reduction of friction is enhanced at higher percentages of silt.

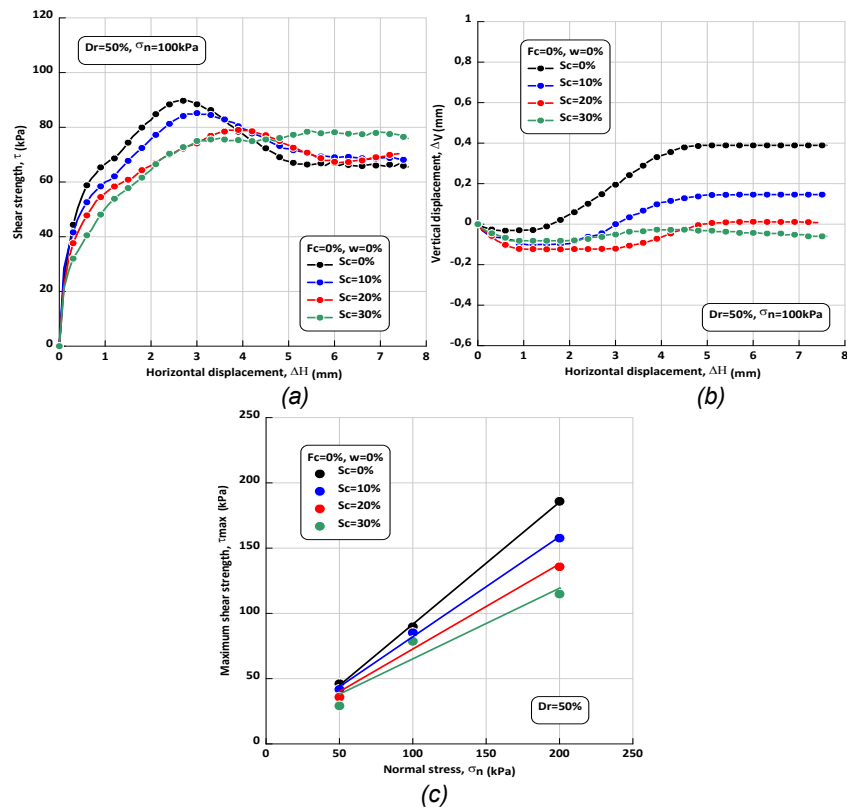


Figure 6 - Influence of silt content on the mechanical behavior of clean Chlef sand in the dry state under a normal stress of 100 kPa: (a) variation of shear strength as a function of horizontal displacement, (b) variation of vertical displacement as a function of horizontal displacement, (c) variation of maximum shear strength as a function of normal stress

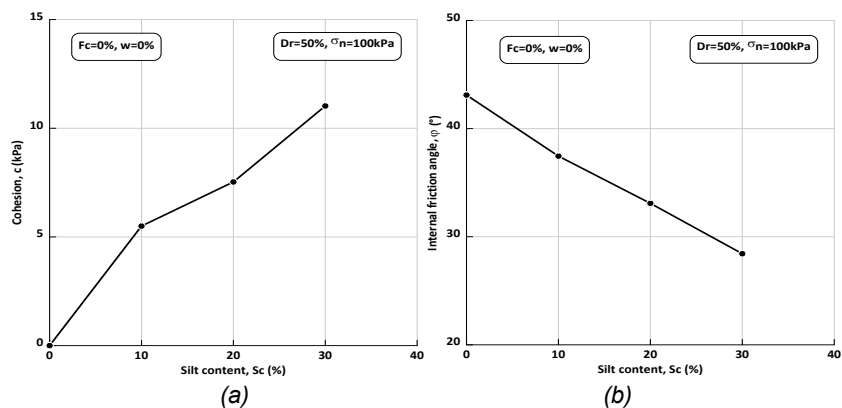
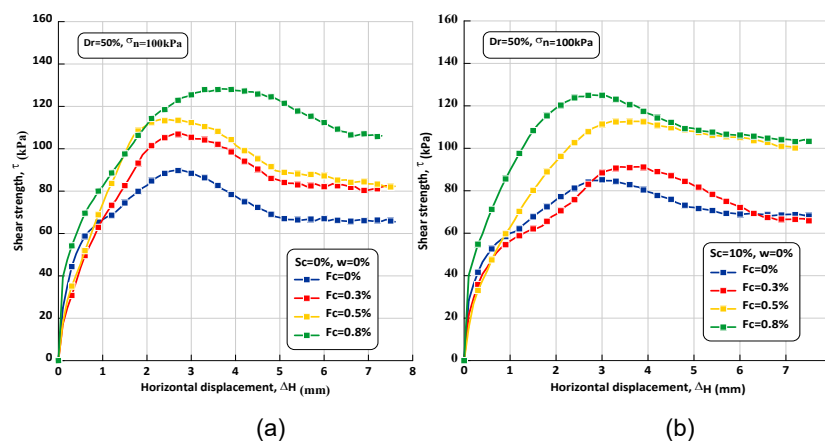


Figure 7 - Evolution of the cohesion and internal friction angle of Chlef clean sand as a function of silt content

Influence of fiber content

Figure 8 shows the influence of fiber reinforcement on the shear behavior of sand-fines mixtures prepared at a medium relative density $D_r = 50\%$ using the dry pluviation preparation method. From the figure, it is apparent that the inclusion of fibers greatly influences the stress-dilatancy behavior of the sand-silt composites, where it was found that the resistance of silty sand, characterized by the shear stress, increases significantly with an increase in fiber content for all silt contents studied (Figure 8a). Wei et al. (2018) postulated that an increase in fiber content results in a greater contact area between the fibers and soil particles, which in turn enhances the frictional resistance at the fiber-soil interface. Additionally, the presence of fibers facilitates the formation of multiple intersecting points, contributing to the development of fiber networks within the soil matrix. These networks improve the spatial confinement effect, thereby leading to an increase in the overall cohesion of the mixture. However, it is noticeable from the figures that an increase in silt content decreases the sand-silt-fiber composites' strength. These results indicate that the mechanism of fiber reinforcement operates in contrast to the influence of silt on sandy soil. Fiber reinforcement enhances the contact between sand particles, leading to an increase in the composite strength. This is due to the fibers improving particle interlocking and friction at the particle interfaces. In contrast, the addition of silt reduces the contact between sand particles, as the fine silt particles tend to occupy void spaces and reduce the inter-particle friction, resulting in a decrease in the composite strength. The values of maximum shear strength obtained for unreinforced and reinforced sand-silt mixtures are summarized in Table 4.



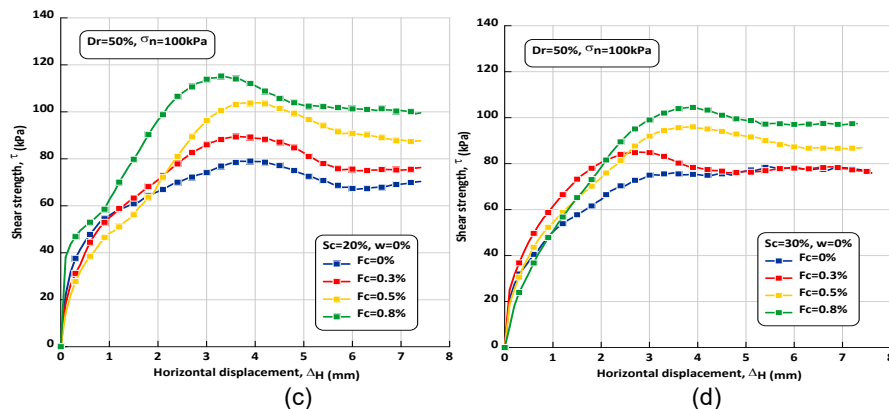


Figure 8 - Influence of fiber content on the variation of shear strength of Chlef silty sand in the dry state under a normal stress of 100 kPa: (a) $Sc=0\%$, (b) $Sc=10\%$, (c) $Sc=20\%$, (d) $Sc=30\%$

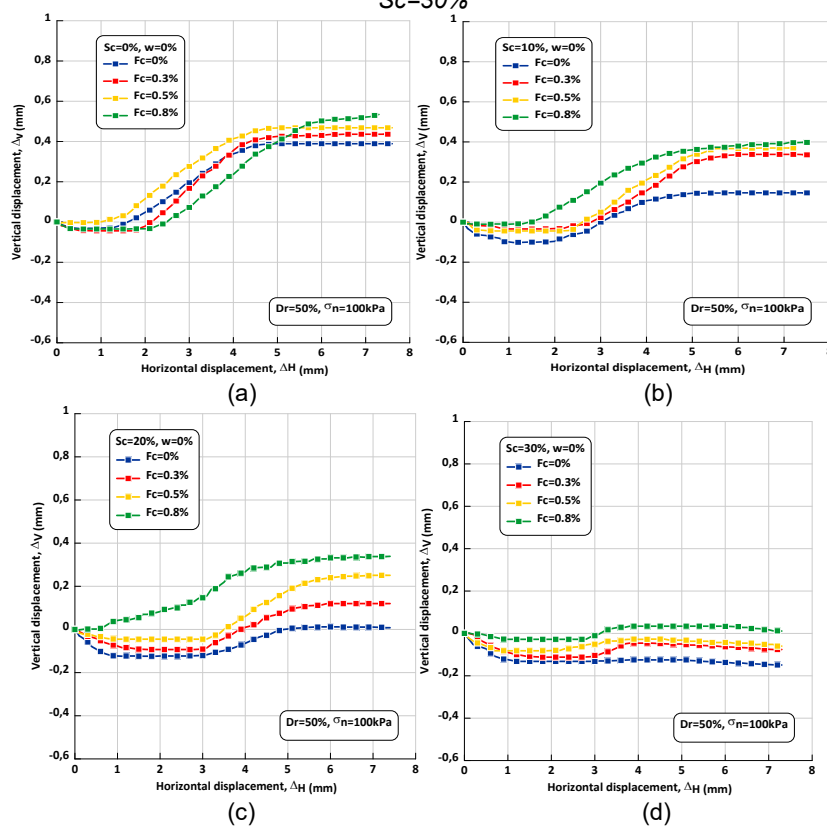
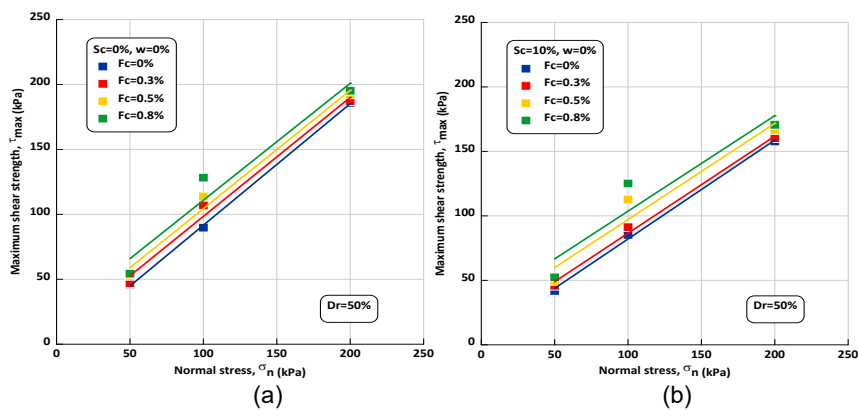


Figure 9 - Influence of fiber content on the variation of volumetric deformation of Chlef silty sand in the dry state under a normal stress of 100 kPa: (a) $Sc=0\%$, (b) $Sc=10\%$, (c) $Sc=20\%$, (d) $Sc=30\%$

Figure 9 presents the vertical displacement curves of unreinforced and reinforced sand-silt specimens. It has been noted that the introduction of fiber inclusions counteracts the detrimental effects of silt on the soil dilatancy, where it was observed that an increase in fiber content results in the accentuation of the soil dilative behavior. These results are in good agreement with those of Ibrim and Fourmont (2007), Diambra et al. (2010), and Eldesouky et al. (2016), who reported that fiber-reinforced sand exhibited a higher dilation tendency than unreinforced sand.

Figure 10 illustrates the evolution of maximum shear strength as a function of silt content (Sc), fiber content (Fc) and normal stress (σ_n) for samples prepared at medium density in a dry state. From the figures, it can be seen that the maximum shear strength decreases with increasing silt content. Inversely, the maximum shear strength values increased proportionally with an increase in fiber content and normal stress. Furthermore, the shear strength parameters (internal friction angle and cohesion) obtained from the linear regression analysis for different contents of silt and fibers are presented in Figure 11 and summarized in Table 4. It is noted from Figure 11a that the cohesion of fiber-reinforced sand-silt specimens increased with an increase in silt content. This increase is accentuated with an increase of fiber content. However, no significant influence was observed regarding the effect of fiber reinforcement on the variation of the internal friction angle of sand-silt mixtures (Figure 11b).



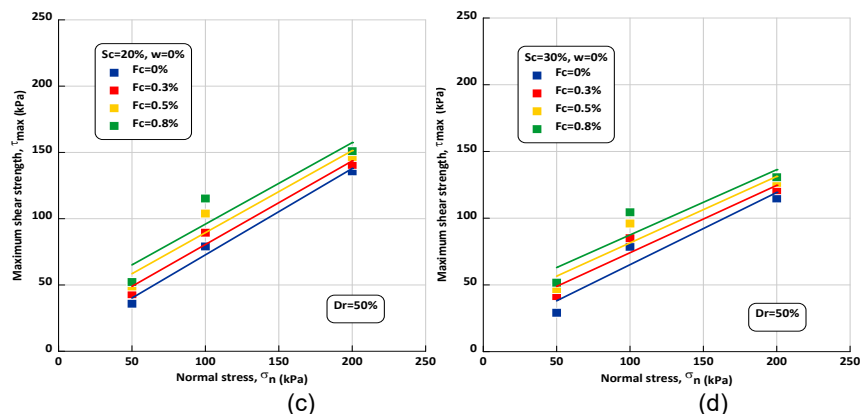


Figure 10 - Influence of fiber content on the variation of maximum shear strength of Chlef silty sand in the dry state under a normal stress: (a) $Sc=0\%$, (b) $Sc=10\%$, (c) $Sc=20\%$, (d) $Sc=30\%$

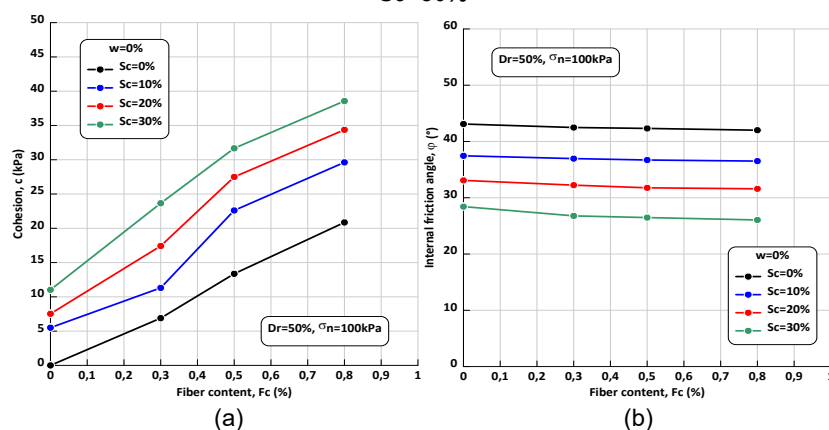


Figure 11 - Evolution of cohesion and internal friction angle of silty sand as a function of fiber content

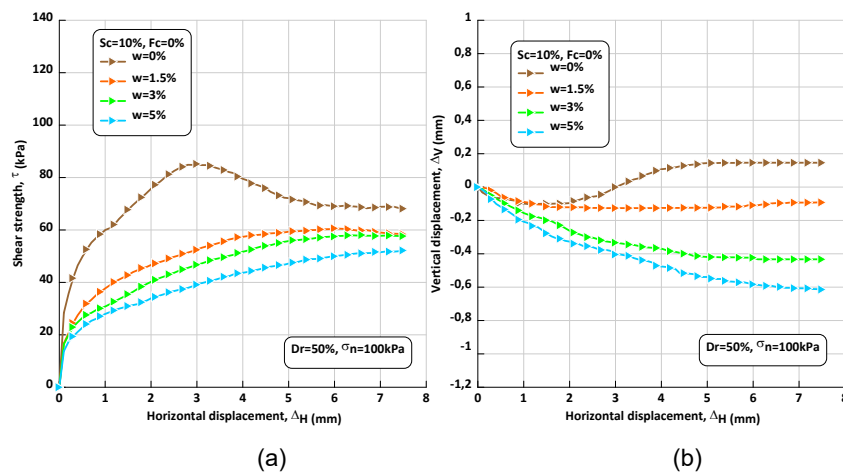
Table 4 - Mechanical characteristics of fiber-reinforced silty sand

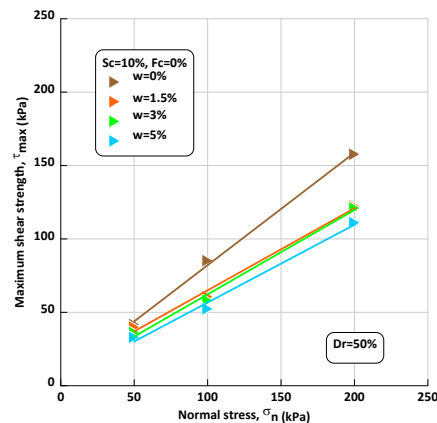
	Sc=0%		Sc=10%		Sc=20%		Sc=30%	
	c (kPa)	ϕ (°)	c (kPa)	ϕ (°)	c (kPa)	ϕ (°)	c (kPa)	ϕ (°)
Fc=0%	0	43,10	5,50	37,46	7,53	33,09	11,03	28,43
Fc=0.3%	6,89	42,48	11,31	36,96	17,42	32,24	23,66	26,78
Fc=0.5%	13,37	42,32	22,61	36,71	27,50	31,77	31,67	26,48
Fc=0.8%	20,86	42,00	29,62	36,51	34,37	31,59	38,57	26,05

Influence of water content

Unreinforced sand

Figure 12 presents the effect of water content on the mechanical properties of silty sand for silt content $Sc = 10\%$ at a medium relative density $Dr = 50\%$. An increase in the shear strength with horizontal displacement has been observed in Figure 12a up to its peak at around 3 mm of horizontal displacement, followed by a slight decrease, resulting in a residual strength for the dry specimens ($w = 0\%$). However, the strength shift phase and residual shear strength were not found for the wet specimens ($w = 1.5, 3$ and 5%). Furthermore, it is noted that the shear strength of sand-silt mixtures decreased with increasing water contents. The maximum shear strength values recorded were: 85.19, 60.61, 58.08 and 52.36 kPa for water contents of 0, 1.5, 3 and 5%, respectively. Figure 12b represents the variation of vertical displacement versus horizontal displacement of sand-silt mixtures at different water contents. Dry specimens have shown initially a contractive phase until a horizontal displacement of around 3 mm, followed by a dilative phase until the end of the test. On the other hand, all wet specimens have shown a pure contractive behavior. This contractancy is accentuated with increasing water content. These results are in good agreement with those of Benessalah et al. (2016) and Ali et al. (2020). Figure 12c illustrates the variation of the maximum shear strength as a function of water content and normal stress for silty sand samples prepared at a medium-density state. It appears from the figure that the maximum shear strength increased with an increase in normal stress and decreased proportionally with an increase in moisture content.





(c)

Figure 12 - Influence of water content on the mechanical behavior of fiber reinforced silty sand ($Sc = 10\%$) under a normal stress of 100 kPa: (a) variation of shear strength as a function of horizontal displacement, (b) variation of vertical displacement as a function of horizontal displacement, (c) variation of maximum shear strength as a function of normal stress

Reinforced sand

Figure 13 shows the influence of moisture content and sample preparation method on the shear behavior of fiber-reinforced sand-fines mixtures prepared at a medium relative density $Dr = 50\%$ using the dry deposition preparation method ($w = 0\%$ by mass of dry sand) and the wet deposition method ($w = 1.5, 3$ and 5% by mass of dry sand). From the figure, it is apparent that an increase in moisture content greatly influences the stress-dilatancy behavior of reinforced sand-silt composites, where it was found that the shear strength of reinforced silty sand decreases proportionally with an increase in moisture content. In addition, it is noted that the inclusion of fiber reinforcements increased the shear strength of silty sand at low moisture contents ($w = 0$ and 1.5%); however, the reinforcing effect of fibers gradually diminished at higher moisture contents until no substantial amelioration was recorded ($w = 5\%$). This result is due to the lubricating effect of water. Since the fiber reinforcement mechanism is purely frictional, the surface roughness of fibers influences their strength mobilization with the interacting soil particles (Benziane et al., 2022). However, the added water forms a thin film between sand particles and the fiber surface, reducing the matrix inter-friction during shearing, resulting in a loss of strength. This loss of strength is more pronounced at higher moisture contents.

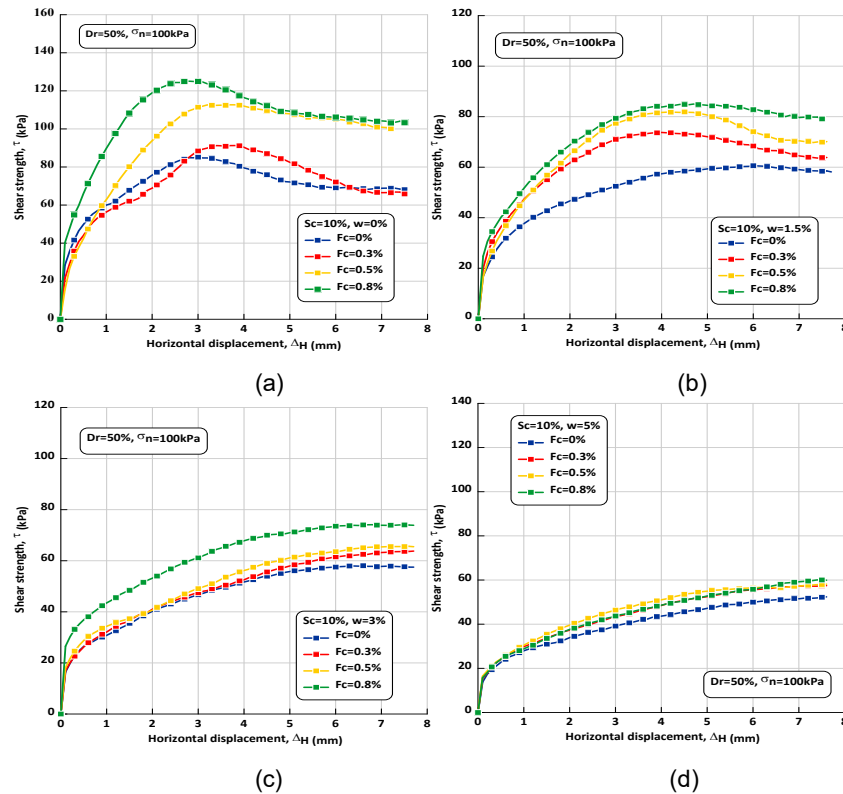


Figure 13 - Influence of water content on the variation of shear stress of fiber reinforced silty sand under a normal stress of 100 kPa: (a) $w=0\%$, (b) $w=1.5\%$, (c) $w=3\%$, (d) $w=5\%$

Figure 14 illustrates the variation of vertical displacement versus horizontal displacement of fiber-reinforced sand-silt mixtures at different water contents. From the figure, it is noted that specimens prepared at low moisture contents ($w = 0$ and 1.5% by dry mass of sand) have shown initially a contractive behavior until a horizontal displacement of around 3 mm for dry reinforced silty sand and around 4 mm for wet reinforced silty sand; both were followed by a dilative phase until the end of the shearing process. However, reinforced specimens prepared at higher water contents ($w = 3$ and 5% by dry mass of sand) have shown a purely contractive response. Nonetheless, it is noted from the figure that fiber inclusions have positively impacted the composites' deformation. It is apparent that fiber reinforcement prompted a more dilative behavior at all moisture contents studied.

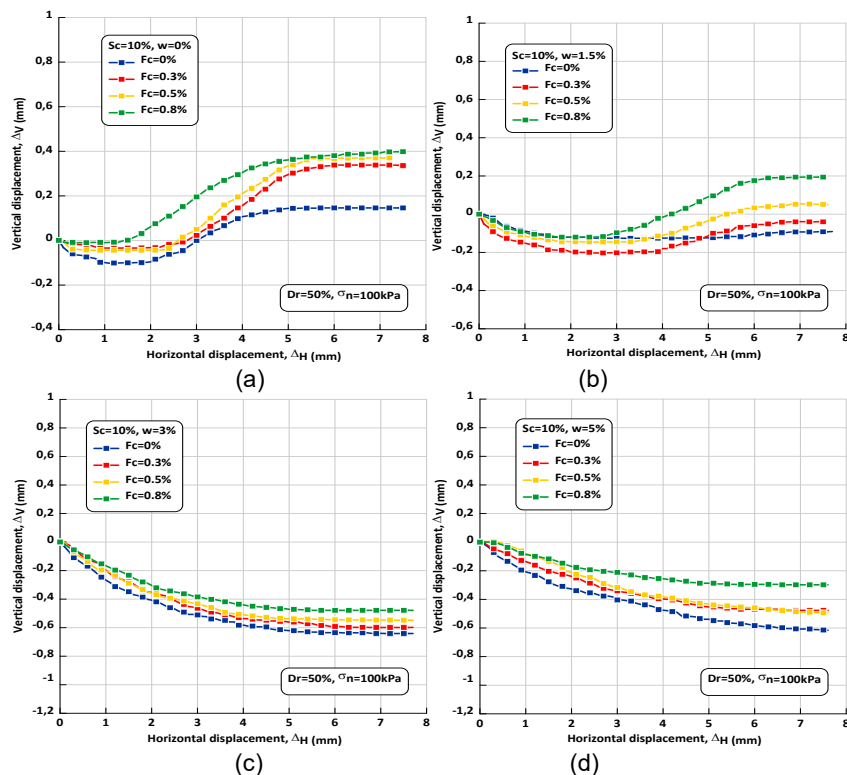


Figure 14 - Influence of water content on the variation of volumetric deformation of fiber reinforced silty sand under a normal stress of 100 kPa: (a) $w=0\%$, (b) $w=1.5\%$, (c) $w=3\%$, (d) $w=5\%$

Figure 15 presents the variation of the maximum shear strength as a function of water content and normal stress of fiber-reinforced silty sand. From the figures, it is observed that the maximum shear strength increased with an increase in fiber content and normal stress and inversely decreased with an increase in moisture content. Moreover, the mechanical characteristics (internal friction angle and cohesion) obtained from the linear regression analysis for different contents of fiber and water are presented in Figure 16 and summarized in Table 5. The results indicate that the values of the internal friction angle decreased with an increase in fiber content and moisture content (Figure 16a). With regard to the influence of moisture content on the cohesion of fiber reinforced silty sand, it was noted that there is a significant increase in cohesion with increasing fiber content and water content up to $w = 1.5\%$, followed by an important decrease in the matrix cohesion past that moisture content. However, it is clear that the cohesion values obtained for fiber reinforced samples

prepared at low moisture contents ($w = 0$ and 1.5%) are much higher than those obtained for reinforced samples prepared at high moisture contents ($w = 3$ and 5%) (Figure 16b).

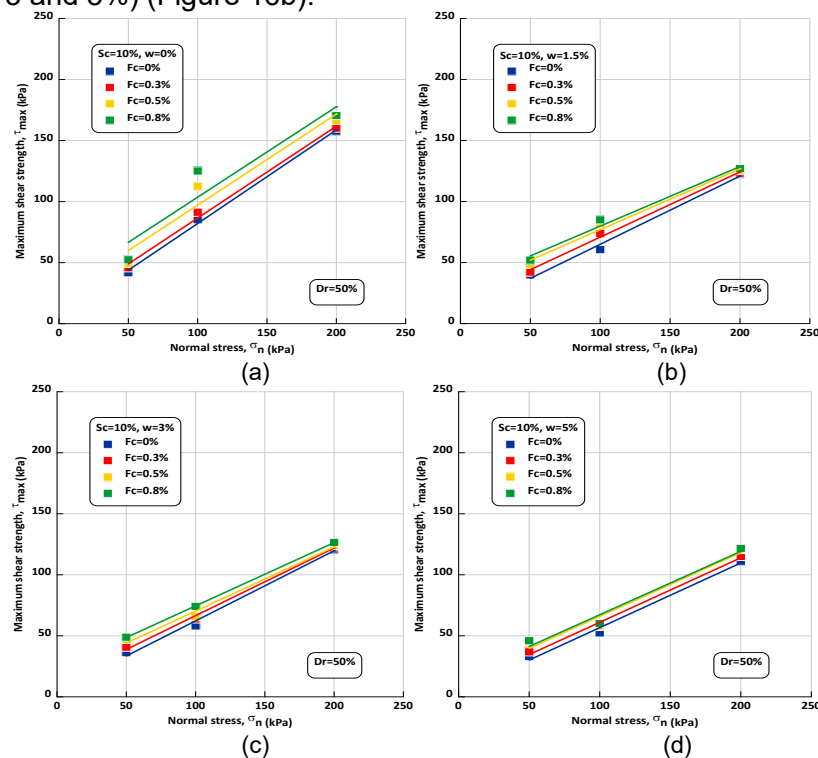


Figure 15 - Influence of water content on the variation of maximum shear strength of fiber reinforced silty sand under a normal stress of 100 kPa: (a) $w=0\%$, (b) $w=1.5\%$, (c) $w=3\%$, (d) $w=5\%$

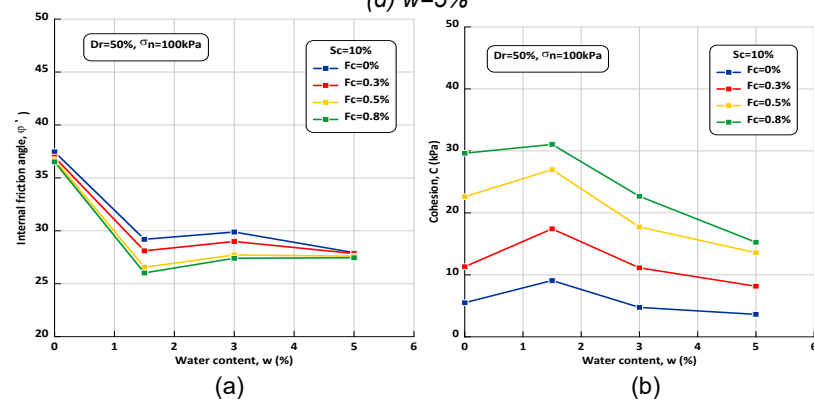


Figure 16 - Evolution of cohesion and friction angle of fiber reinforced silty sand as function of water content

Table 5 - Influence of molding water content on the mechanical characteristics of fiber-reinforced silty sand

	Fc=0%		Fc=0.3%		Fc=0.5%		Fc=0.8%	
	c (kPa)	ϕ (°)	c (kPa)	ϕ (°)	c (kPa)	ϕ (°)	c (kPa)	ϕ (°)
w=0%	5,50	37,46	11,31	36,96	22,61	36,71	29,62	36,51
w=1.5%	9,09	29,20	17,43	28,11	26,98	26,56	31,05	26,02
w=3%	4,75	29,89	11,13	28,99	17,72	27,72	22,67	27,41
w=5%	3,63	27,94	8,17	27,86	13,58	27,60	15,26	27,46

Conclusion

A laboratory experimentation was conducted on unreinforced and fiber-reinforced sand-fines mixtures with different silt, natural fiber and moisture contents in order to study the effect of fiber reinforcement on the mechanical behavior of Chlef silty sand prepared with different dispositional methods. Taking into account the results obtained in this study, the following conclusions can be drawn:

- Silt fractions negatively affect the mechanical behavior of sand, as it was found that an increase in silt content reduced the shear strength and the dilative behavior of sand-silt mixtures. However, an increase in silt content slightly increased the cohesion of the composites.
- The efficiency of fiber inclusions is highly dependent on the fiber concentration, since the shear strength of the reinforced specimens increased relatively with the increase in fiber content.
- Test results show that the maximum values of cohesion increased with the increase of fiber content. However, no significant influence was found regarding the internal friction angle.
- The discrete element reinforcement is a promising technique to counter the influence of silt content on the mechanical behavior of sand.
- The initial moisture content has a significant impact on the shear behavior of fiber-reinforced silty sand, as an increase in water content caused less effective interfacial contact between the fiber-soil matrix, resulting in a decrease in strength. Therefore, special consideration must be given to the initial moisture content in practical applications.

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Mehaničko ponašanje muljevitog peska ojačanog prirodnim vlaknima: uticaj sadržaja mulja, vlakana i drugih parametara

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OBLAST: građevinarstvo

KATEGORIJA (TIP) ČLANKA: originalni naučni rad

Sažetak:

Uvod/cilj: Brojna istraživanja ukazuju na značajno smanjenje čvrstoće na smicanje peskovitih tla prilikom sitnih frakcija, što posledično dovodi do zemljišta sa nepovoljnim geotehničkim svojstvima. Usled nedostatka odgovarajućeg tla za građenje, danas je neophodno modifikovati svojstva zemljišta kako bi ona bila pogodna za inženjersku primenu. Postoje brojne metode i tehnike za poboljšanje stabilnosti zemljišta, a naročito efikasnu metodu predstavlja uključivanje pojedinačnih elemenata za jačanje u sastav tla, jer se na taj način doprinosi različitim povoljnim efektima.

Metode: U radu se ispituje uticaj prirodnih vlakana na ponašanje muljevitog peska pri smicanju, pri srednjoj relativnoj zbijenosti, različitim metodama pripreme uzoraka i različitim udelima vlage. Istraživanje je usmereno na različite parametre, odnosno sadržaj mulja, sadržaj vlakana i sadržaj vode.

Rezultati: Eksperimentalni rezultati ukazuju na smanjenje čvrstoće pri povećanju sadržaja mulja i sadržaja vode. Pored toga, čvrstoća mešavina, promene u pogledu zapremine i mehanička svojstva značajno se poboljšavaju dodatkom sisal vlakana pri niskim udelima vode. Međutim, pri visokim sadržajima vode nije zabeleženo značajno poboljšanje, što ukazuje na negativan uticaj vlage na mehanizam ojačanja vlaknima.

Zaključak: Nakon detaljne analize dobijenih rezultata, utvrđeno je da se sila vlakna mogu opravdano koristiti za poboljšanje svojstava zemljišta.

Ključne reči: pesak, mulj, prirodna vlakna, sadržaj vode, čvrstoća na smicanje, mehanička svojstva.

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