



Impact of recycled waste red brick on the mechanical behaviour of sand-silt mixtures

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ABSTRACT

The waste generated by construction industries in many countries around the world is increasing significantly with the continued expansion of urbanization and industrialization, leading to numerous environmental and financial problems. Waste from brick production can be used as a stabilizing material for silty soil, which has caused damage to various roads and buildings. Utilizing waste bricks helps reduce environmental impact, minimize material waste, and conserve valuable resources. This study investigates the effect of waste brick grains on the stabilization of OUED RASS sand, which has low shear strength, thereby mitigating the environmental impact of waste bricks. The research involves processing a sand-silt mixture reinforced with 10% and 20% waste bricks of 1mm diameter. This mixture enhances shear strength up to 170 kPa in sand reinforced with 20% brick waste under a normal stress of 100 kPa, at a relative density of 90%, with fines contents of 10% and 20%, in a dry state with a water content of 0%. This reinforcement using brick waste increases soil cohesion but reduces the friction angle.

1 Introduction

The valorisation of demolition waste in soils is an essential approach to reducing the environmental impact of construction activities and promoting sustainable development. The land intended for construction must be reinforced using construction waste. This reinforcement technique increases the soil's resistance. Recycling construction waste has become a key solution for contributing to the construction process in civil engineering. Construction waste, particularly inert waste, can play a vital role in soil reinforcement and environmental preservation. Their use also reduces material waste and conserves valuable resources [1]. Silty soils have a fine texture and low cohesion, making them susceptible to erosion caused by wind or water, Lal R., (1991) [2]. These soils have poor drainage capacity. They can retain excess water, leading to waterlogging, or dry out rapidly in arid conditions, Brady N.C., & al., (2016) [3]. The Nature and Properties of Soils. Pearson. Silty soils compact easily under the pressure of agricultural machinery or trampling, reducing porosity and hindering root growth, Dexter A.R., (2004) [4]. In construction, silty soils pose stability issues due to their tendency to change consistency with humidity, causing swelling or shrinking. The presence of brick waste contributes to enhancing the tensile strength of concrete, particularly in elements such as beams and columns. Rizgar A.B. & al., (2020) [5], they conducted their research on a plastic loamy soil in Iraq. According to their findings, the strength of the soil increases with the proportion of waste powder added. They tested various brick waste powder contents

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(6%, 12%, 18%, 24%, and 30%) mixed with sand. This mixture demonstrated an improvement in the mechanical strength of the soil, ranging from 150 to 300 kPa. They also observed that the presence of brick waste reduces the soil's swelling potential. Saand A. & al., (2018) [6] they also observed an increase in the mechanical resistance of a clayey soil treated with brick waste. The percentages of brick waste used were 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%. The resistance increased from 377 kPa to 458 kPa due to the presence of the brick powder content. The work of Arifin Y.F. & al., (2020) [7] this illustrates an increase in compressive strength in clayey soil reinforced with 4% brick waste, where the strength reached 600 kPa in expansive soil. In organic soil, it reached approximately 300 kPa, while in lateritic soil, the compressive strength was around 350 kPa. Shriful I. & al., (2022) [8], they studied a clayey soil with low compressive strength over 28 days, using different rates of brick waste powder. For instance, with a rate of 25%, the resistance reached 300 kPa on the 7th day, 400 kPa on the 14th day, and 550 kPa on the 28th day. Additionally, concrete with low mechanical strength in the field of civil engineering can be reinforced with brick waste, as mentioned by researchers. Messaoudene I. & al., (2018) [9]. The latter observed a remarkable improvement in the strength of the concrete used. According to the same author, the concrete initially had a strength of 53.09 MPa, and with the addition of 10% brick waste, its strength increased to 55 MPa. Pardakhe P. & al., (2019) A study was conducted on the compressive strength of black cotton soil with 10%, 20%, and 30% brick waste. It was found that the unconfined compressive strength increased by 14.36%, 28.50%, and 44.83% for the 10%, 20%, and 30% samples, respectively, in black cotton soil [10].

In this work, we will study a soil to which another material will be added and then treated. This treatment aims to improve the mechanical properties of the soil as well as its in situ performance. For example, road surfaces and habitable areas with existing issues could be the focus of this study.

2 Materials and methods

2.1 Sand Oued Rass

The OUED RASS sand from the CHLEF region, taken from the edge of the OUED RASS bed, is the soil that was analyzed for this study. This beige-colored fine sand has a low proportion of lime (6.40% CaO), a high silica content (81.37% SiO₂), and 5.08% fines. This sand's grain size curve is depicted in (Fig.1). The median diameter of the medium-sized sand is $D_{50} = 0.37$ mm. With a plasticity index of $I_p = 5.07\%$, silt is not very flexible. 90% relative density was used during the tests.

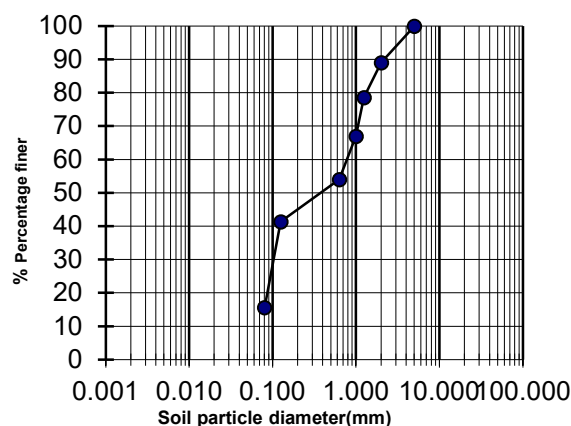


Fig. 1 – Grain size distribution of Sand OUED RASS (CHLEF).

2.2 Silt

The silt examined in this study is displayed in (Fig. 2). Using an 80 μ m sieve, the fines are separated from the OUED RASS sand. After the sand is put into the sieve, it is run through a sieving machine for ten minutes (Fig. 3).

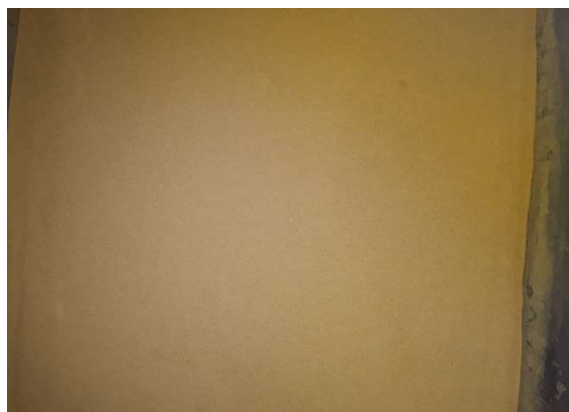


Fig. 2 – Silt extracted by sand



Fig. 3 – Extraction of fines.

2.3 Brick waste

The CHLEF region's red bricks are the source of the brick waste used in this investigation. They were first shown as pieces (Fig. 4), but the LOS ANGELES device was used to crush them until they were in the shape of grains (Fig. 5). (Fig. 6) shows the granulometric curve of the grains extracted from these brick wastes. The physical properties of the sand, silt, and brick waste from the CHLEF region are compiled in table 1.



Fig. 4 – Piece of brick.



Fig. 5 – 1mm brick grain.

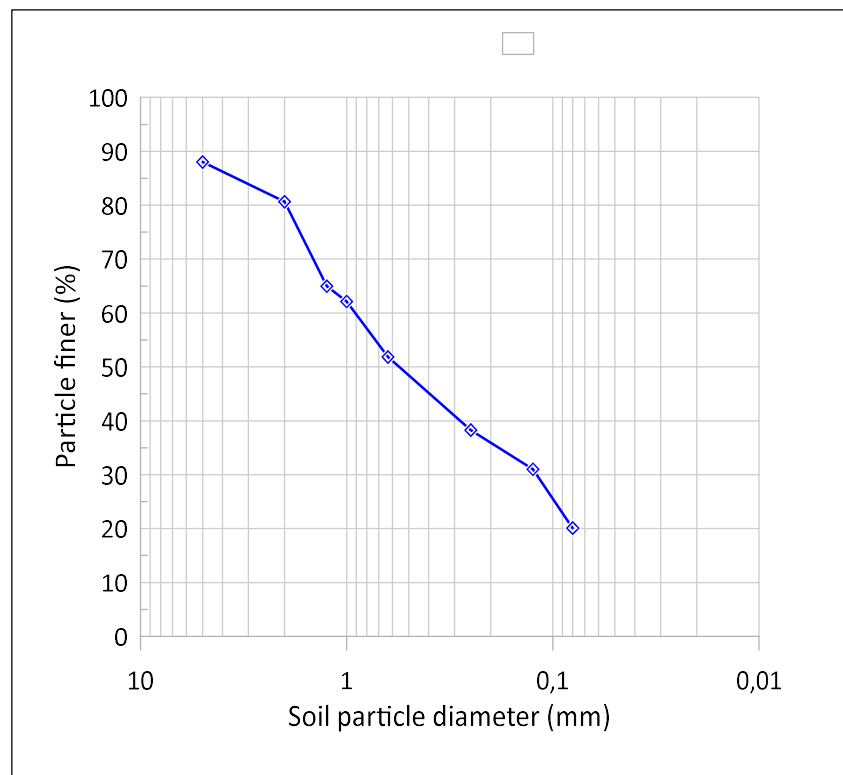


Fig. 6 – Grain size distribution of waste red bricks (CHLEF).

Table. 1. Physical properties of tested materials

Materials	G_s (Kg/m ³)	D_{50} (mm)	e_{min}	e_{max}
Sand OUED RASS	2.65	0.37	0,745	0,987
Silt		/	0,88	1,22
Waste Red bricks (CHLEF)	2.67	0,59	0,83	1,27

2.4 Clean sand

The clean sand used in this study is obtained from the extraction of sand from OUED RASS. First, the sand is washed to remove fine particles. To achieve this, the silty sand is placed in a sieve with an 80 μm opening and rinsed with water to eliminate all fine particles. Next, the sand is dried in an oven at 105°C for 24 hours. Once dry, it is sieved again to remove any remaining stones.

2.5 Operating mode

The experimental setup used in this study is based on the SHEARMATIC direct shear apparatus (Fig. 7). Before conducting any tests on the mechanical behavior of the soil, it is crucial to prepare the samples and weigh the mixtures to be tested, considering the nature of the soil to ensure reliable results. The soil sample is placed in half-boxes (Fig. 8), which can move horizontally relative to each other. A piston applies a constant normal stress to the soil throughout the test, while one of the half-boxes moves horizontally at a constant speed.

Once the CASAGRANDE box is filled, the screws are tightened, and the box is placed on the shear apparatus, where it is securely fixed using specific bolts. After proper installation, a sensor is positioned on top of the box. The parameters for speed and the desired normal stress are then entered into the software connected to the machine (Figs. 9 and 10). The test begins after the screws are removed from the box, allowing its horizontal movement without constraint.



Fig. 7 – Shearing machine (SHARMATIC).

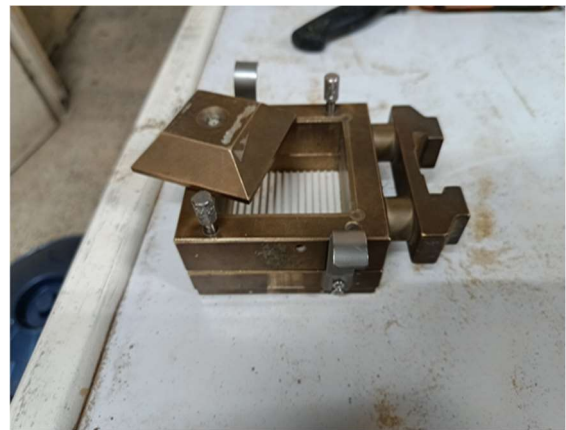


Fig. 8 – Overview of the CASAGRANDE box.

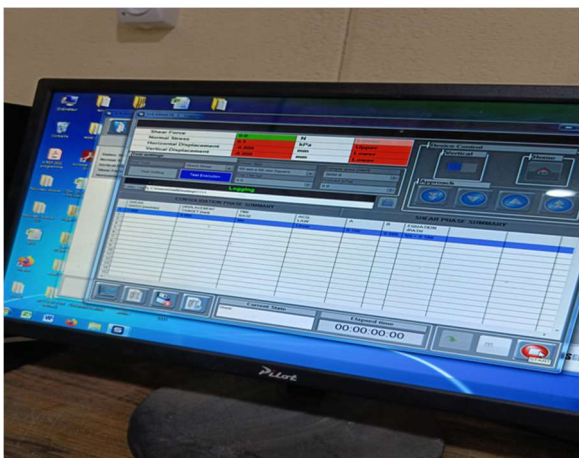


Fig. 9 – Machine software. Fig.



10 – The location of the box at the shearing device.

Before placing the box on the apparatus to begin the test, it is necessary to prepare the samples by calculating the masses based on the predefined contents. The tests were conducted with a relative density of 90%. They were performed in a dry state with a water content of $\omega=0\%$, under a stress of 100 kPa.

2.6 Sample preparation

2.6.1 Clean sand

The preparation of clean sand samples follows these steps:

- a) filling the box: the sample is placed in the testing box following a specific procedure;
- b) parameter calculation: the following parameters are determined:
 - Identifying characteristics: γ_{dmin} , γ_{dmax} , γ_s , e_{min} and e_{max}
 - Void index: e

2.6.2 Clean sand with silt

The procedure remains the same as for clean sand. However, the mass of the mixture is adjusted to achieve a medium-dense or dense state, while maintaining a normal stress of 100 kPa. The silt is introduced in specific proportions based on the previously calculated mass, forming the following mixtures:

- 10% silt + 90% clean sand
- 20% silt + 80% clean sand

All mixtures are tested in a dry state.

2.6.3 Clean sand with silt and brick waste

In this case, brick waste is sieved to retain grains passing through a 1 mm opening and sized up to 0.63 mm. After sieving, the same procedure as in the previous cases is applied. Different levels of brick waste are tested (see Fig. 11).



Fig. 11 – Filling the box with the sand-silt mixture + 1mm brick waste.

3 Results and discussions

Figure 12 illustrates the variation of shear stress as a function of horizontal displacement for a mixture composed of clean sand with 10% and 20% of its own fines. It is evident that the presence of fines affects the shear strength of the soil. Specifically, an increase in fines content results in a decrease in shear strength. These findings are consistent with the results obtained for a highly plastic silty soil [5].

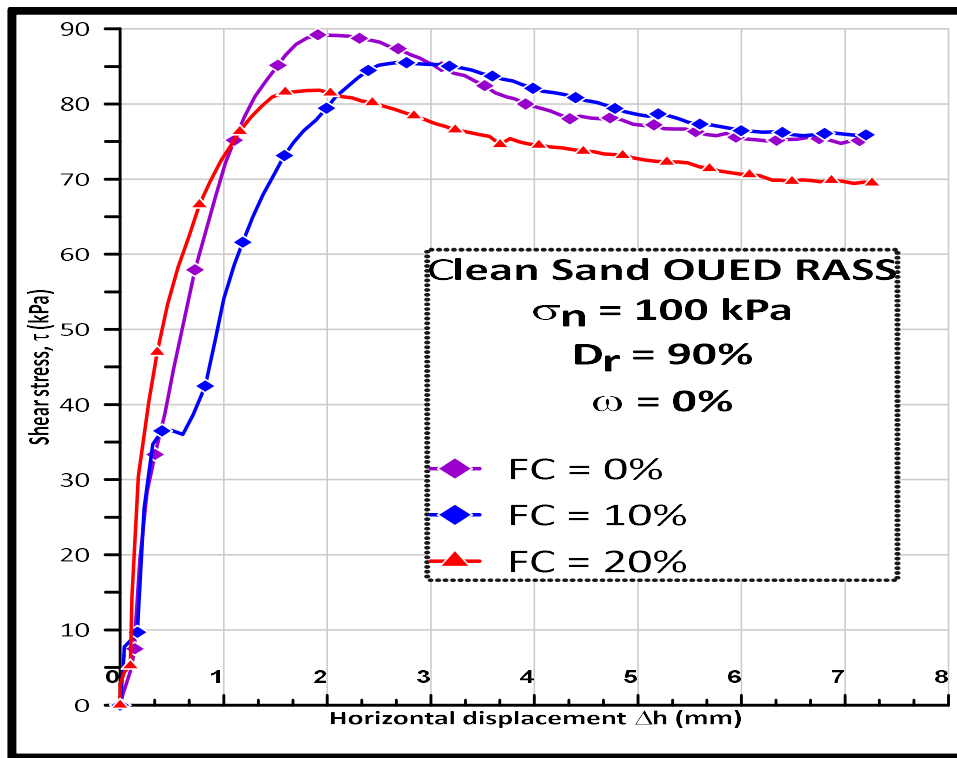


Fig. 12 – Shear stress as a function of horizontal displacement (sand-10% and silt-20%).

Figure 13 shows the evolution of the behavior of clean sand mixed with 10% and 20% of its own fines, reinforced with the addition of 10% and 20% brick waste. For the clean sand-10% fines mixture reinforced with 10% and 20% brick waste, an increase in the shear strength of the silty sand is observed as the brick content increases, reaching a maximum strength of 170 kPa (Fig. 13.a). Similarly, for the clean sand-20% fines mixture, an increase in shear strength is noted with higher brick waste content, achieving a maximum strength of 159.7 kPa. This difference in strength can be attributed to the fines content in the clean sand. These results align with those of [Missoum Benziane M. & al. \(2021\)](#) [11], who studied CHLEF sand reinforced with synthetic fibers (polypropylene and glass fiber) as well as natural sisal fibers, and with those of [10], concerning black cotton soil reinforced with brick dust.

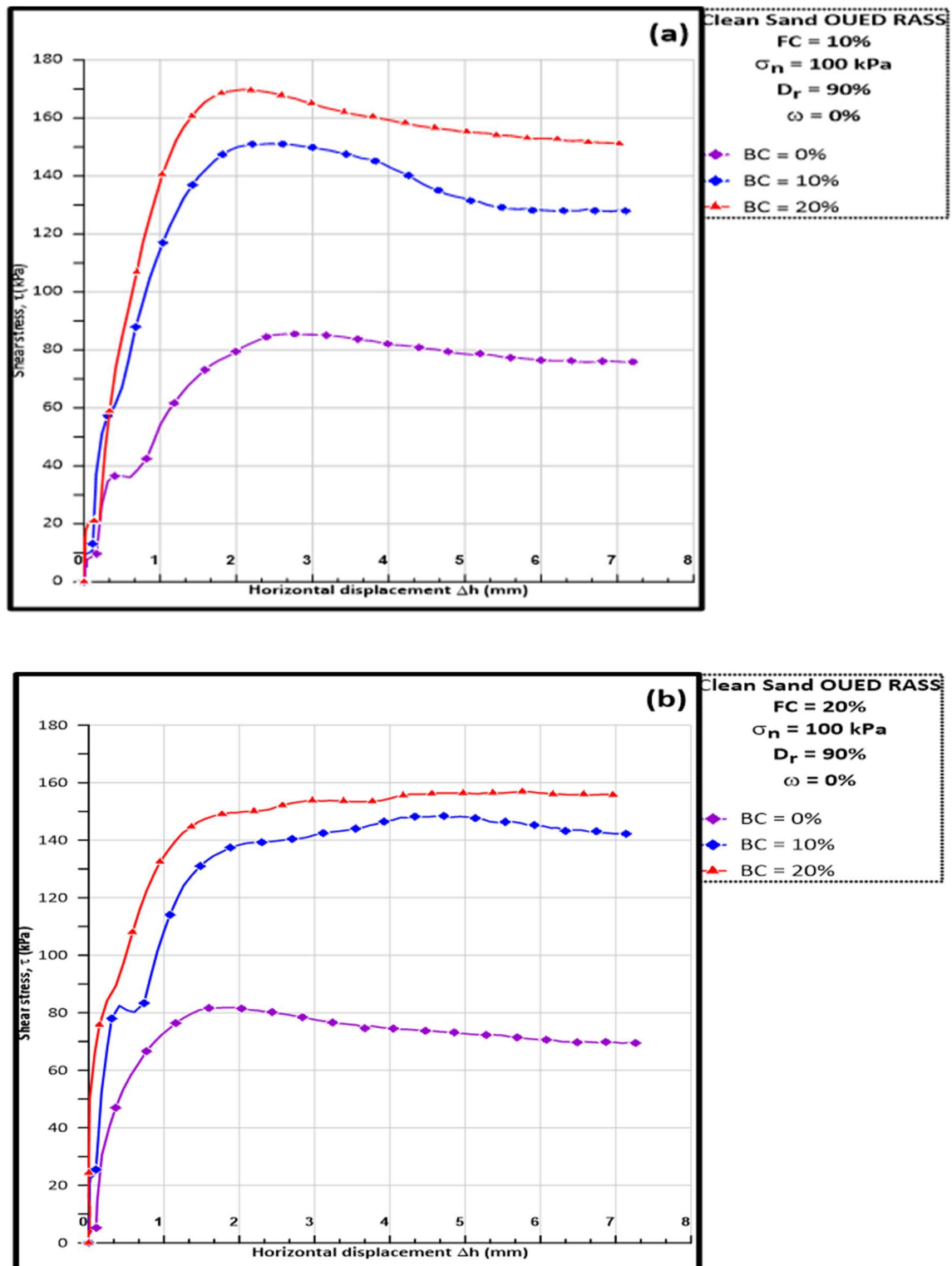


Fig. 13 – Shear stress function of horizontal displacement (a) sand-10% silt + 10% and 20% brick waste (b) sand-20% silt + 10% and 20% brick waste (1mm).

Figure 14 illustrates the variation of vertical displacement as a function of horizontal displacement for the clean sand-10% fines mixture reinforced with 10% and 20% brick waste. The unreinforced clean sand-10% fines mixture initially displays a contracting behavior, followed by progressive expansion, reaching a final vertical displacement of 0.5 mm. However, with the addition of brick waste, an improvement in the contracting behavior is observed, reducing the final vertical displacement to 0.2 mm due to the reinforcement.

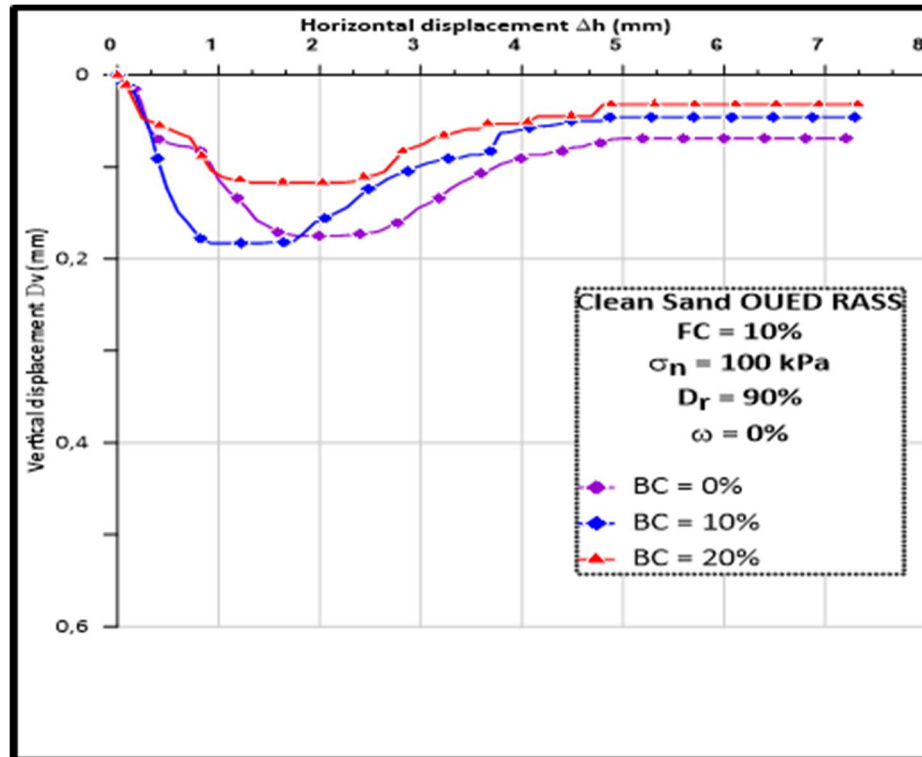


Fig. 14 – Curve of vertical displacement as a function of horizontal displacement (mixture of 10% and 20% 1mm brick waste).

Figures 15 and 16 present the intrinsic curves for sand mixed with 10% and 20% of its own fines, as well as for the same mixtures treated with 10% and 20% brick waste (particle size of 1 mm). The initial sand-10% fines mixture exhibits poor mechanical characteristics. However, the addition of brick waste progressively improves these characteristics, particularly in terms of cohesion, as the brick content increases. Table 2 summarizes the results for cohesion and friction angle, demonstrating a significant enhancement in the mechanical properties of the reinforced soil compared to the unreinforced soil. While cohesion shows considerable improvement, the friction angle is slightly reduced compared to the unreinforced sand.

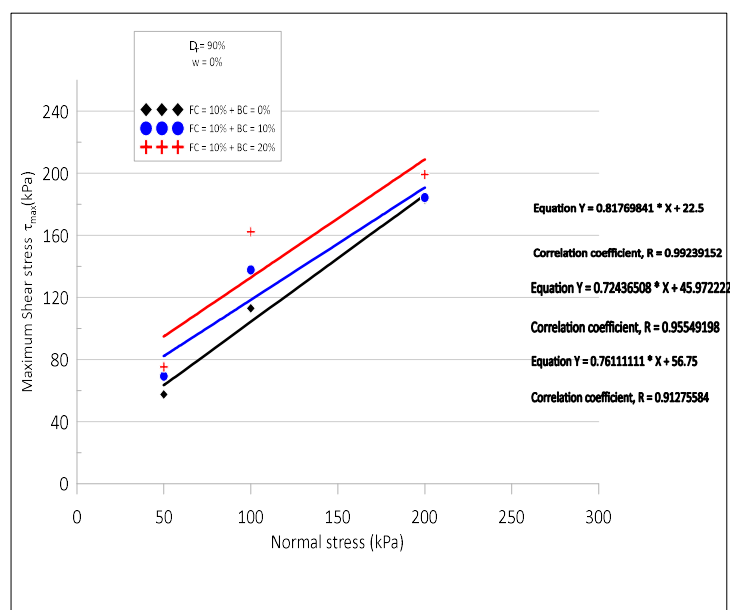


Fig. 15 – Intrinsic curve (10% silt).

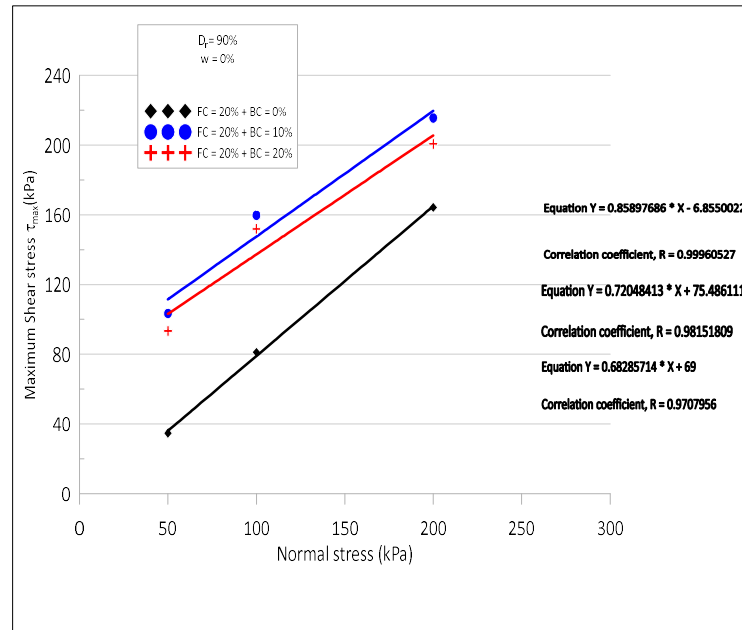


Fig. 16 – Intrinsic curve (20% silt).

Table. 2. Mechanical characteristics of reinforced soil compared to unreinforced soil

Mixtures	C (kPa)	ϕ (°)
Clean sand + 10% FC	22,50	39,35
Clean sand + 10% FC + 10% BC	45,97	35,75
Clean sand + 10% FC + 20% BC	56,75	37,23
Clean sand + 20% FC	6,86	40,70
Clean sand + 20% FC + 10% BC	75,49	35,75
Clean sand + 20% FC + 20% BC	69,00	34,21

4 Conclusion

This experimental soil stabilization work led to the following conclusions:

- Several factors must be considered before undertaking improvement work. First, engineers must understand the properties of the materials to be introduced, as well as the characteristics of the soil to be treated.
- **For the case of clean sand + silt:** The mixture exhibits low mechanical resistance.
- **For the case of clean sand + brick waste:** The mixture contributes to increasing the mechanical resistance of the soil to be treated. It can be concluded that brick waste plays a significant role in improving or even enhancing the mechanical resistance of silty soils.

In conclusion, fine soils are often the main contributors to settlement issues. To mitigate this phenomenon, the sand-silt mixture with brick waste proves effective in reducing soil and road surface settlement, while also contributing to the stability of structures.

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