Global Journal of Environmental Research 16 (1): 01-06, 2022
ISSN 1990-925X

DOI: 10.5829/idosi.gjer.2022.01.06

Oevaluation of the Silt Contenteffect on the Shear Strength Parameters of Unsaturated Sand

[1]Kempena Adolphe, [1]Mbilou Gampio Urbain, [2]Rafael Guardado Lacaba, [3]Antonio Olimpio Gonçalves and [1]Boudzoumou Florent

[1]Department of Geology, Faculty of Sciences and Technics,
Marien Ngouabi University, Brazzaville-Congo
[2]Department of Geology, Faculty of Mines and Geology,
Higher Institute of Mines and Metallurgy, Moa-CUBA
[3]Department of Geology, Faculty of Sciences, Agostinho Neto University, Luanda-Angola

Abstract: The current study is focused on determining the shear strength parameters of the silty sand from direct shear tests. Tests are performed on the soil samples of Ignie's sand, Congo Republic, with 10, 25 and 40% of silt content and constant relative density, Dr = 65% applying vertical stress of 50, 100 and 150 kPa. The test results were expressed asgraphs of shear stress against shear deformation and changes of soil sample height versus shear deformation. Hence, soil shear parameters such as internal friction and dilation angles were determined and compared. From results obtained, it is noticed that once the soil sample has a silt content superior to 10%, one can observe that peak shear strength and peak angle of internal friction have tendency to increase. But, whenthe soil sample coversa silt content variation from 10% to 40% the peak shear strength and internal friction angle have tendency todecrease.

Key words: Friction angle · Dilation angle · Direct shear test · Silt · Sand · Fines content

INTRODUCTION

The soil deposits cover a certain content of silt and clay. Due to increasing of clean sands near project areas, the use of mixed sand including clayey sand and sandy silt, will remain a practical alternative in renovationresearches. The presence of fines in sandy soilscan be a concern in geotechnical engineering. It is sometimes supposed that the soil strength decreases with the increase of fines content [1]. Therefore, the maximum content of fines is commonly limited to 10% in the majority of geotechnical projects [2]. However, the accessibilityto soils with small fines content is very occasional. But, soil with maximum fines contentup to 10% is found [3]. The form of soil grains also affects the behaviour of engineering properties of soils [4].

Until recent years, rare researches have been focused on the effect of fines content variation on the behavior of sandy soils. Data on the properties of sandy soil such as the relationship between stress and strain and the behavior of shear strength called attention of the earlier studies. The vanayagam [5] focused his researches on the non-plastic silt effects on the un-drained shear strength. Results obtained from this study showed that sand-silt covering silt content up to 30% revealed the behaviorof silt. Thian and Lee [6] showed that the un-drained shear strengthand pore pressure decreased with the increase of the clay content. Triaxial compression tests performed by Kim *et al*. [7] on soil-slit mixingindicated that the critical friction reducedwhen fines aggregate content increased.

In spite of all the experience gained over the pastyears, direct shear tests are commonly used in geotechnical engineering. This type of test is used to determine the shear strength parameters for constructions design. All over the last 50 years, the direct shear test has been used in geotechnical industry due to its easiness and results obtained. Strength properties of Sandy soil is often determined by using the direct shear test to

Corresponding Author: Kempena Adolphe, Department of Geology, Faculty of Sciences and Technics, Marien Ngouabi University, Brazzaville-Congo.

determine the internal friction angle, dilation angle or the sand shear strength. Many researchers have investigated the shear strength and dilation behavior of sands. Evaluation of triaxial test results led to reach the critical and maximum values of friction angle of sand and silty sand. Theses researchers found that, the silt content in sandincreases significantly the shear strength parameter and the soil dilation. Changes were observed as well in small strains once the decrease of stiffness causes the increase incritical strength and maximum strength [8]. Studies related to the silt content effect on un-drainedstrength of sand using a triaxial cyclic test performed by Gupta [9] showed the decrease of internal friction angle with the addition of fine in the sand due to the fine grains compressibility. Relationship for the silt content effect on the strength and dilation properties was proposed by Xiao *et al*. [10]. This model presented by Xiao *et al*. from existing data agrees with the Salgado *et al.* [8]. Fine content effect on the shear strength and dilation properties of sand was also reached by Yusufpour [11]. In this study, using a direct shear test in saturated condition, it was noticed that the soil behavior depends on itssand grains arrangement. So, the current work carried out different direct shear tests on Ignie's sand mixtures with different silt contents (0, 10, 25 and 40) considering a 65% relative densitywith vertical stress of 50, 100, 150kPa. The aim of this research work is to evaluate the silt content effect on the shear strength parameters and the dilation angle under unsaturated conditions for silty sand applying static loading.

MATERIALS AND METHODS

Soil Material: In the current study, sand and silt were used as soil samples taken away from Ignie Department, Congo Republic. The material selection is founded on its accessibility or easy location and classified as silty sand [12] from studies carried out by Kempena [13]. Then, the selected material are classified as sand (SP) and silt (ML) according to the Unified soil classification [12].

Sample Preparation: In spite of many methods for soil sample preparation for sandy soil, in this study we used the soil sample under wet conditions due to its initial water content which is 6% [14]. The laboratory tests techniquewas founded on existing literature. So, manyexisting works were based on the soil strength evaluation from direct shear test under various conditions, considering different fine contents by mixing with sand, silt [15, 16].

Experimental study is founded on taking an intact soil sample for different laboratory tests such as waterberg limit, specific gravity, Particlesize, water content and soil strength.

Direct Shear Test: The automatic direct shear apparatus used is shown in Figure 3. Each test consists of the consolidation phase and the shear test phase. The tests used normal stresses (σ_n) of 50, 100 and 150 kPa. The strain rate of 15% was used for all experiments where in the high stresses, the soil behavior can be noticed.

RESULTS AND DISCUSSION

From 9 tests performed by using the direct shear apparatus, the results determined the effect of different silt percentage on the behavior of soils parameters and the dilatation for sand soil. The shear stress variations can be seen in Fig. 1 with its corresponding shear deformation in different silt content for a density of 65% applying vertical stress of 50, 100 and 150 kPa.

From Fig. 2, one can notice the increase of shear strength for the sand mixingfor the silt contentinferior to 10% and then the shear strength decrease is observed for silty content superior to 10%.

The sample volumetric behavior can be seen in Figure 5. In this figure, the behaviour of soil depends on the dilatation process showing by the sand structure.

Figure 4 shows the variations of the friction angle in silty sand samples. From this Figure, it is noticed the increase of friction angle in silty sand samples for the silt content inferior to 10% and then the decrease of friction angle is observed for silt content superior to 10%.

The results of the experimental studyrevealed that the increase of the silt content up to 10%, causes the increase and decrease of the friction angle. Similar results have been found by Yosefpour [11] and Vu To-Anh Phan *et al*. [17]. These results obtained by authors before mentioned areclose to those found in the current study using the Figure 5. However, in the results of Xiao *et al*. [10] despite the low fines content from 7% to 20% considered, but the soil behavior is the same comparing with the current study. The difference remains just in the peak friction angle. Then in the current study, the peak friction angle is found once the soil sample holds 10% of

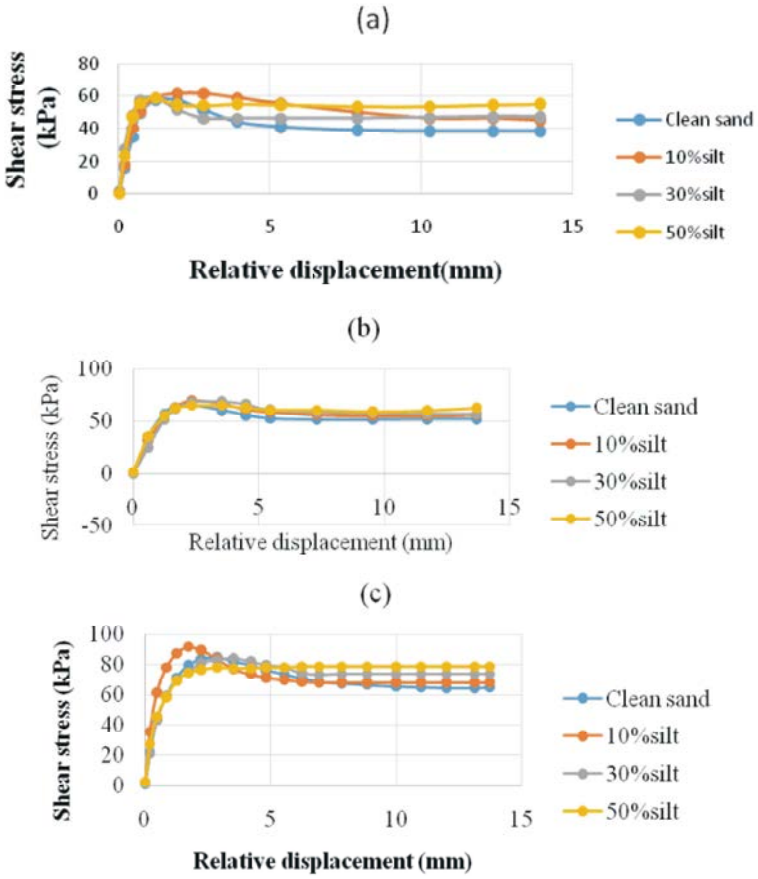

Fig. 1: Shear Stress against relative displacement

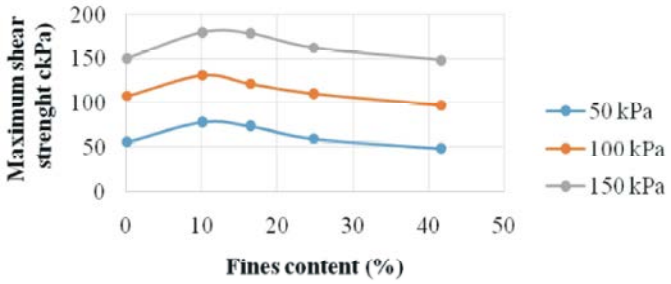

Fig. 2: Shear strength versus the fine content

silt content and 7% represents the peak friction angle [10]. This peaks locations difference is due to the difference among soils properties such as particle grain distribution, particle form and density. So, it can be conclude that both studies have an agreement among the resultsobtained.

The variation of dilation against the silt content applying vertical stresses of 50, 100 and 150 kPa is shown in Fig. 5. From this Figure, one can observe the increase of dilation in the mixture with the increase of the silt content and the decrease observed once the silt content is superior to 10%. Due to the 6% of water content used in the experiment the soil was considered unsaturated in the current study. Comparing the results obtained with those obtained by Vu To-Anh*et al.* [17], using drained triaxial tests on sand, all results obtained have some similarity. Then it can be deduced that the incremental limited water content used in the current study did not affect significantly the variation of dilation angle inthe silty sand, while more analysis on this topic will perform tests in drained condition.

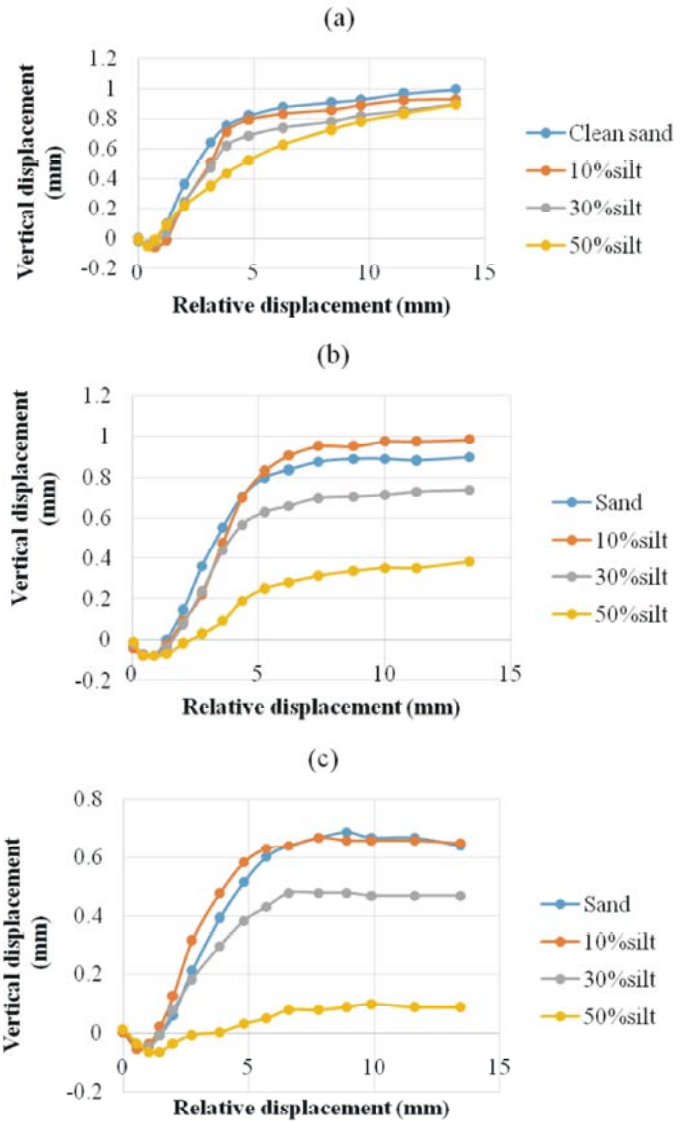

Fig. 3: Vertical displacement against displacement

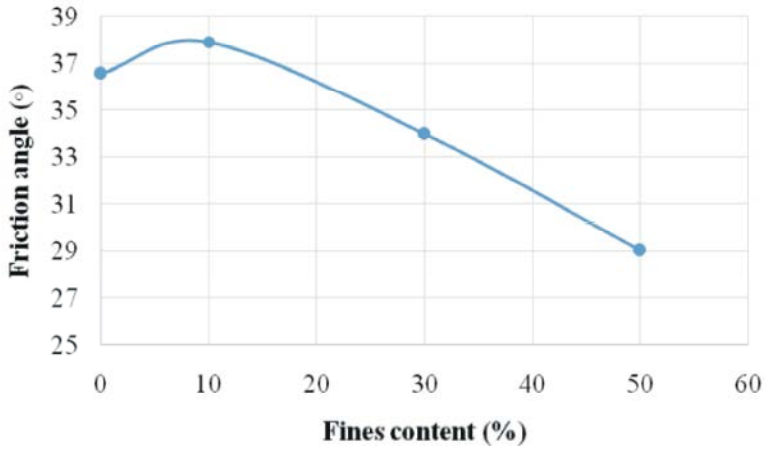

Fig. 4: Variations of friction angle versus fines content

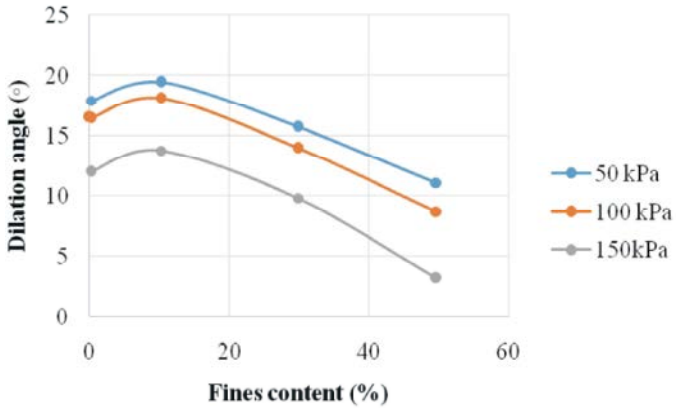

Fig. 5: Variations of dilation angle versus fines content

CONCLUSION

Fromthe current study, 9 different direct shear tests were carried out to evaluate the effect of silt percentage on the shear strength properties of sand applying different values of vertical stress. The samples were prepared with silt contents of 10, 25 and 40 and compacted at 65% of relative density. The samples of sandy soil were analysed under vertical stresses of 50, 100, 150kPa and, giving the following results:

- The samples behavior depends on the sand grains arrangement.
- An increase in the silt content in mixtures withsilt 10% increases the dilation. But, next, with an increase in silt content in mixtures covering from 25% to 40%, the dilatation decreases andwith the decrease of the vertical stress, anincrease is observed in the angle of dilation as well.
- The peak shear strength and friction angle of samples of sandy-soil increasesonce the silt content isup to 10% and then the decreaseis observed with an increase of silt content.

REFERENCES

1. Koester, J.P., 1994. The influence of fine type and content on cyclic resistance. Ground failures under seismic conditions. Geotech Spec Publ No 44, ASCE, New York, pp: 17-33.
2. Maleki, M., A. Ezzatkhah, M. Bayat and M. Mousivand, 2011. Effect of physical parameters on static un-drained resistance of sandy soil with low silt content. Soil Dynamics and Earthquake Engineering, 31(10): 1324-31.
3. Youssef , M., Moghaddas, M. Rahim, S. Rahim and N. Adel, 2022. Facies analysis, depositional environment and sequence stratigraphy of the Permian Ruteh Formation in north of Mahabad (NW Iran). Iranian Journal of Earth Sciences, 14(1): 58-77.
4. Mair, K., K.M. Fryeand C. Maronez, 2002. Influence of grain characteristics on the friction of granular shear zones. Journal of Geophysical Research, 107(10): 41-49.
5. Thevanayagam, S., 1998. Effect of fines and confining stress on un-drained shear strength of silty sands. Journal of Geotechnical and Geo-environmental Engineering, 124(6): 479-91.
6. Thian, S.Y. and C.Y. Lee, 2011. Un-drained response of mining sand and fines contents. Journal of Civil and Structure Engineering, 1(4): 844-51.
7. Kim, D., M. Sagong and Y. Lee, 2005. Effects of fine aggregate content on the mechanical properties of the compacted decomposed granitic soils. Construction and Building Materials, 19(3): 189-96.
8. Salgado, R., P. Bandini and A. Karim, 2000. Shear strength and stiffness of silty sand. Journal of Geotechnical and Geo-environmental Engineering, 126(5): 451-462.
9. Gupta, R. and A. Trivedi, 2009. Effects of Non-Plastic Fines on the Behavior of Loose Sand- An Experimental Study. Electronic Journal of Geotechnical Engineering, 14: 1-14.
10. Xiao, Y., H. Liu, Y. Chen and J. Chu, 2014. Strength and dilatancy of silty sand. Journal of Geotechnical and Geo-environmental Engineering, 140(7): 0601-4007.

11. Yosefpour, V. and A. Hamidi, 2015. Comparison of clay and Silty Finite content on Shear Strength parameters and Sands dilation. The First National Conference on Soil Mechanics and Foundation Engineering, Faculty of Civil Engineering, Shahid Rajaee University, Tehran, Iran.
12. ASTM Committee D-18 on Soil and Rock, 2017. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
13. Kempena, A., 2017. Assessment of water erosion risk in Brazzaville City. Ph.D. Thesis, pp: 100, Higher Institute of Mines and Metallurgy of Moa, Cuba.
14. Ladd, R.S., 1974. Specimen preparation and liquefaction of sands. Journal of Geotechnical and Geo-environmental Engineering, 100 (Proc. Paper 10857 Proceeding).
15. Nakao, T. and S. Fityus, 2009. Direct Shear Testing of a Marginal Material Using a Large Shear Box. Geotechnical Testing Journal, 31(5): 18-27.
16. Dolzyk-Szypcio, K., 2019. Direct Shear Test for Coarse Granular Soil. International Journal of Civil Engineering. https://doi.org/10.1007/s40999-019-00417-2.
17. Vu To-Anh, P., H. Darn-Horng and T.L.N. Phuong, 2016. Effects of Fines Contents on Engineering Properties of Sand-Fines Mixtures. Procedia Engineering, 142: 212-219.