American Journal of Mechanical and Industrial Engineering
2021; 6(3): 34-38
http://www.sciencepublishinggroup.com/j/ajmie
doi: 10.11648/j.ajmie.20210603.11
ISSN: 2575-6079 (Print); ISSN: 2575-6060 (Online)

Soil Structure Interaction Using Silt Clay by Direct Shear Test: A Review Paper

Shah Alam

Design Alliance Ltd., Dhaka, Bangladesh

Email address:
shahalamruet4@gmail.com

To cite this article:
Shah Alam. Soil Structure Interaction Using Silt Clay by Direct Shear Test: A Review Paper. *American Journal of Mechanical and Industrial Engineering*. Vol. 6, No. 3, 2021, pp. 34-38. doi: 10.11648/j.ajmie.20210603.11

Received: August 1, 2021; **Accepted**: August 10, 2021; **Published**: August 18, 2021

Abstract: Direct shear test is a type of laboratory test which is used to determine shear strength parameters such as cohesion c (kPa) and angle of internal friction φ (°). For performing this test various conditions should be considered. The conditions are such that there must have constant vertical pressure at the top of the sample and the volume of the sample must be constant to estimate shear strength parameters of loose and dense soils. A constant horizontal displacement rate is utilized to determine shear strength parameters. The researchers also found some factors which control these shear strength parameters. These controlling factors are surface roughness, soil composition, the magnitude of normal loading, and moisture content. In the direct shear test, the surface thickness of the sample influences shear strength parameters. The researchers have given a different report based on their analysis. They showed the different modes of shear strength parameters in different conditions of sand, clay, soil, etc. for the interaction of soil structure. By mixing geo-membrane, geotextile, etc. with soil, sand, clay greatly affects shear strength parameters. When horizontal displacement is applied, vertical deformation of the shear plane of soil increases up to the yielding point of sand. The direct shear box contains a gap between the upper and lower ring but it is not constant. But, there are some drawbacks to their research. They did not show how shear strength parameters behave in silty clay. In this paper, a relative review of soil-structure interaction using silty clay is shown. In the direct shear test, cohesion is increased due to an increase in moisture content. To determine shear strength parameters, the conditions of silty clay are unsaturated. For this investigation, a shear box is used. Different loading is applied to see the deflection in a specific time interval.

Keywords: Silty Clay, Cohesion, Angle of Internal Friction, Shear Box, Direct Shear Test, Mohr-coulomb Criterion

1. Introduction

Direct shear test is one of the oldest and most economical shear strength test methods. The direct shear test is a standard testing method that is mainly used to calculate the shear strength parameters. It is widely used to test large sizes of samples. Normally, two types of direct shear tests such as single-stage and multistage are considered. The multistage direct shear test is used to estimate shear strength parameters not only for the saturated condition but also for unsaturated conditions. In a direct shear test, it is easy to set up the instrument. It is also used to predict shear strength parameters quickly. These parameters are required for the design of slopes and to estimate bearing capacity. Many researchers try to investigate their research to find out shear strength parameters for sand, soil, clay, etc. Darvishi and Erken [1] stated that the mixtures of fiber also can develop the shear strength of sand. For their experiment, they kept the type of sand and fiber constant. They used various percentages of polypropylene fiber for their experiment in the laboratory. Shear strength parameters of the unreinforced and reinforced sand specimen can be determined by using the direct shear test. From their experiment, the shear strength parameters of dry, dense, and poorly graded quartz sand were resolved when the effect of homopolymer polypropylene fiber was considered. Skuodis, et. al. [2] stated that some factors influencing the characteristics of shear strength parameters. They used three different approaches to evaluate the behavior of shear strength parameters. For their research, they followed the Mohr-Coulomb strength criterion. Ilori, Udoh, and Umenge [3] used a direct shear test to find the interaction between a predominantly cohesion-less soil and in-situ concrete. They set different fictional angles between soil to soil and soil to concrete. From their experiment, a particular range of stress values should be maintained to get a suitable fictional value for the design structure. Liu, Ho, and Huang [4] used a series of large-scale shear to determine the interface shear strength of different types of soil. They used a lower shearing box to justify its suitability. For their research, the higher shear box is more appropriate. From their experiment, different shear strengths for different soil were found. Abdelmagied [5] observed that fiberglass of different ratios can influence the fiberglass's shear strength of the soil. It was found that the fiber ratio can be increased by the peak shear strength parameters. Noorzad and Zarinkolaei [6] stated that the addition of fiber has an important effect on the behavior of sand. They also showed that the addition of fiber can promote the shear strength parameters. It is helped to increment the peak shear strength. Vlcek and Valaskova [7] established a relation between laboratory experiments and numerical modeling by geosynthetic reinforcement and soil. For their experiment, they used a coefficient. They found that there was a strong interaction between reinforcement with the grid structure and rigid joints with the soil environment. Moayed, Alibolandi, and Alizadeh [8] used different silt contents to evaluate the effect of the scale factor on shear strength parameters by using the direct shear test. They found that with the increase of shear box size shear strength parameters decrease. Abdi and Gonbad [9] examined the different factors which are responsible for affecting the soil-geogrids interaction. These factors are contact surface roughness and geogrid aperture size which was used in the direct shear test. From their experiment, it was found that the increasing amount of these factors are greatly responsible to increase shear strength at the soil-geogrid interface. Yetimoglu and Salbas [10] examined by using randomly distributed discrete fiber. These discrete fibers were not affected the peak shear strength and initial stiffness. For their research, normal stress was applied on the direct shear box constantly and continuously. This fiber reinforcement was helped to lessen the soil brittleness. Mohapatra et. al. [11], Jewell and Wroth [12] estimated the shear strength parameters by using a direct shear box. It consists of two parts. The upper part was restrained and the lower part was moving. For their experimental study, they used fine poorly graded sand. In their experimental results, a numerical model was considered and FLAC3D (Itasca) software was utilized. Tallah and Khemissa [13] performed a direct shear test under monotonous loading conditions. They used both loose and dense sand with a rigid steel plate. In the analysis, they decided that the rough surface of the steel plate was more suitable than the smooth surface. They applied a modified Casagrande shear box to carry out their experiment. There have some drawbacks and limitations in their research. They did not show any interaction between soil structure when silty clay is used. In this paper, a relative overview of soil-structure interaction is shown when silty clay is used. The shear strength parameters of this experiment are reviewed in this paper. After completing the experiment, we can compare shear strength parameters of soil, sand, clay with other structural materials.

2. Materials and Methods

In this review paper the problematic analysis is reviewing according to the reference of researchers. Different researchers analyzed direct shear tests using different components of soil, sand, clay, etc. by mixing with a different component of steel properties. The goal of the researchers had to determine shear strength properties. For their experiment, they used a direct shear instrument.

Figure 1. *Figure shows a direct shear test equipment.*

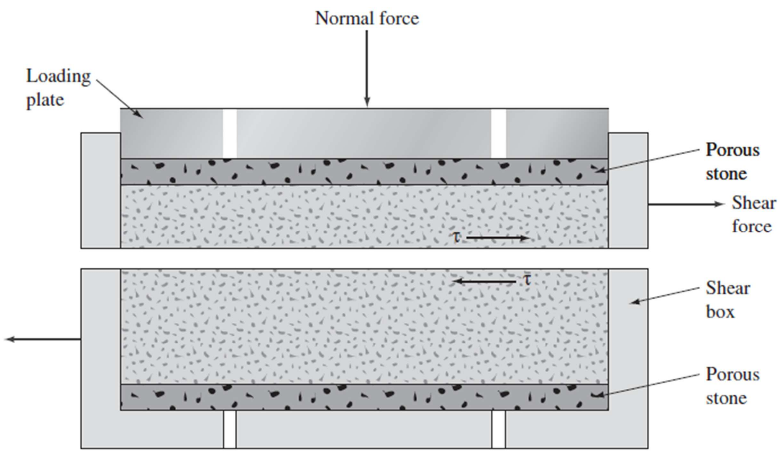

Figure 2. *The arrangement of direct shear test diagram.*

Abdelmagied [5] took an undisturbed soil sample to investigate his research. By hammering, he produced a homogeneous media. For the experiment, he tested different parameters such as Waterberg limit, specific gravity, sieve analysis, water content. He used vinyl ester resin as fiberglass and covered it with saline-based sizing. For experimental analysis, he used a square-size direct shear box. The samples were prepared by mixing fiberglass of different ratios and added a small amount of water. For the direct shear test, the sample was divided into three-layer and each layer had constant compression energy. He tested two types of samples. At first, sample was tested with mixing fiber and another without mixing fiber. These two parameters were compared. Hamidi et al. [14] considered the amount of moisture content present in the soil properties. They tested saturated and unsaturated soil to determine shear strength parameters. Senatore and Iagnemma [15] tested by direct shear test to determine shear strength properties of soil. In this test, the Mohr-Coulomb failure criterion did not give any report about shear vs. displacement. They took different references of different researchers regarding shear vs. displacement. The main objective of the researchers was to determine shear modulus and shear strength properties. The researchers used different types of curves to determine different shear stress and displacement value. For these, a different value of density was taken. By adopting this procedure, they were able to determine cohesion and the angle of internal friction. Nakao and Fityus [16] examined different sizes of a sample using different sizes of shear boxes and obtained shear strength parameters. Multi-speed direct shear equipment was utilized for their experiment and the values were presented digitally. They used particles of different sizes according to the Unified Soil Classification System (USCS). Sieve analysis was used to fine different grain-size samples. Then, the grading size of the sample was determined according to AS Code. By doing these procedures the shear strength parameters were determined. Dolzyk-Szypcio [17] carried out his experiment by using coarse granular material. For this experiment, a vertical force was applied and then the sample was consolidated. He continued his experiment using different components of different properties. He divided the sample into three-layer placed it into the shear box. For experimental analysis, he applied a hammer. The hammer was dropped up to a constant height. The number of hammer drops was different for each layer. Ahmad et. al. [18] used 6 groups of FRP specimens considering surface roughness and normal stress to carry out the direct shear test. All the specimens were unidirectional fiberglass fabric covered by epoxy resin. Three types of sandy soils were utilized and different properties such as uniformity coefficient, coefficient of curvature, and different plastic limit were determined. For preparing the specimen a wax paper was used underneath each sheet. A roller was used at the top. The process of fabrication was done at room temperature and then the specimen was cut in squares sizes. The sample was placed into the direct shear box and the vertical and horizontal displacement was determined by using a dial gauge. Ilori, Udoh, and Umenge [3] collected an undisturbed soil sample that was cohesionless and that sample poured into a square size block. Different properties of soil which were needed to estimate shear strength parameters were determined. The test was continued according to ASTM standards. For experimental analysis, they used soil and concrete. This soil and concrete were poured into the shear box and by adding cement, a normal load was applied. A digital shear machine device was used to determine the vertical and the horizontal deformations. Amsiejus et al. [19] tested by using a modified standard direct shear apparatus. A constant vertical load was applied on the shear plane. They kept the volume of the specimen constant. A constant shearing velocity was applied at the lower part of the ring. They estimated different soil properties from the graph. They prepared the sample and placed it into the shear ring. They kept the velocity of the specimen constant. By adopting that procedure, they determined shear strength parameters. Abdi and Gonbad [9] tested the experiment by using the direct shear test. They used two types of sand. For experimental analysis, they used the trial and error method to determine the particle grading. They followed the ASTM code to carry out the analysis. They prepared the sample by mixing reinforcement and placed it into the direct shear box. A hammer was used and compacted the specimen. The number of blows was placed at the top of the specimen. Tallah and Khemissa [13] examined the experiment by using monotonous loading using a modified Casagrande shear box which consists of two-part. They used different properties of soil to experiment and used a table that was given the material properties. By using the procedure, they estimated the shear strength parameters.

3. Results and Discussions

The experimental result obtained from the research is presented in this section. Abdelmagied [5] presented the experimental result through different curves. From these curves, he showed that by mixing fiber with soil, normal shear strength increases with increasing of normal stress. Dolzyk-Szypcio [17] developed a formula. By using that formula, he estimated the $\tau/\sigma n$ value. $\tau/\sigma n$ value was plotted in the graph. He mixed water content and using graph values, the parameters α and β were determined. Palmeira and Milligan, [20] estimated the shear strength parameters from the graph which was plotted by using the direct shear test. In mid-section, increasing the thickness of the sample, the frictional angle also increases. Hamidi et. al. [14] tested the sample by applying different vertical loads. By suctioning, shear strength parameters increase. To determine shear strength parameters, they used the bishop [21] formula and Mohr-Coulomb failure criteria for unsaturated soil. Ahmad et. al. [18] determined the frictional characteristics of the soil. They plotted different graphs. From that graph, they estimated ultimate shear strength. The values obtained from the direct shear test were plotted in the graph and the angle of internal friction and cohesion were determined. Ilori et. al. [3] presented a table which was given the sieve analysis results. The different values of peak shear stress were determined. They estimated the angle of internal friction by using the direct shear box. From the analysis, it is found that some factors affect interfacial friction. They were able to estimate the friction ratio from different curves. They found cohesion and angle of internal friction from different mix ratios and curves. Amsiejus et. al. [19] showed that displacement was occurred due to loading conditions. For that condition, the SPE-2 apparatus was successfully used. They kept the volume constant. They showed that friction force influenced the upper and lower rings. They used the least-squares method to find shear strength parameters. They also showed that there was a clear difference between the value of shear strength parameters obtained from ADS 1/3 and SPE-2. Abdi and Gonbad [9] showed that shear strength parameters value was different both for reinforced and unreinforced sand. From the experiment, it is known that roughness is influenced by normal pressures. That roughness affects the shear resistance. Tallah and Khemissa [13] plotted different curves for loose and dense sand. From that curves, they estimated shear strength parameters. They showed that the shear rate decreases due to an increase of normal stress.

4. Conclusions

The review paper is tried to give a basic idea about determining shear strength parameters by using the direct shear test. This research will further help to measure the strength of the foundation, dam, etc. In this paper, researchers used different components. All the researchers mainly determined the shear strength parameters. The density of soil has a major impact in determining shear strength parameters. The value of cohesion is decreased due to a decrease of moisture content and the angle of internal friction is increased. The value of the angle of internal friction is decreased due to an increase in moisture content and cohesion is increased. When soil properties mix with other materials, shear strength parameters are changed. For avoiding similarity, some of them mixed fiberglass with soil (e.g. Abdelmagied, [5]). Many researchers considered influencing factors. Many of them used mixing ratios. (Skuodis et. al. [2]) proved that the shear strength parameter depended on the magnitude of vertical load applied onto the top of the soil sample. In the direct shear test, friction angle does not dependent on the scale of the test (e.g. Palmeira and Milligan [20]). Ultimately, they used direct shear apparatus to estimate the shear strength parameters. These shear strength parameters are further used for determining the bearing capacity of strata, for the design of slopes, and calculation of consolidation parameters.

References

[1] Darvishi, A. and Erken, A., “Effect of Polypropylene Fiber on Shear Strength Parameters of Sand.” Proceedings of the 3rd World Congress on Civil, Structural, and Environmental Engineering (CSEE’18), 2018. [DOI: 10.11159/icgre18.123].

[2] Skuodis, S.; Norkus, A., “Dirgeliene, N. and Rimkus, L., “Determining characteristic sand shear parameters of strength via a direct shear test.” Journal of Civil Engineering and Mnagement, Vol. 22, No. 2, 271-278, 2016.

[3] Ilori, A. O.; Udoh, N. E., and Umenge, J. I., “Determination of soil shear properties on a soil to concrete interface using a direct shear box apparatus.” International Journal of Geo-Engineering, 2017. (http://creativecommons.org/licenses/by/4.0/), [DOI 10.1186/s40703-017-0055-x].

[4] Liu, C.; Ho, Y. and Huang, J., “Large scale direct shear tests of soil/PET-yarn geogrid interfaces.” Geotextiles and Geomembranes 27, 19–30. 2009. [doi: 10.1016/j.geotexmem.2008.03.002].

[5] Abdelmagied, M. F., “Experimental study on shear strength parameters of soil mixed with glass fiber.” EJERS, European Journal of Engineering Research and Science Vol. 4, No. 6, June 2019.

[6] Noorzad, R. and Zarinkolaei, S. T. G., “Comparison of Mechanical Properties of Fiber-Reinforced Sand under Triaxial Compression and Direct Shear.” 1: 547–558, 2015. [DOI 10.1515/geo-2015-0041].

[7] Vlcek, J. and Valaskova, V., “Investigation of the Soil-Geosynthetic Interaction Using Direct Shear Testing and FEM Method.” Materials Science and Engineering 603, 052052, 2019. [doi: 10.1088/1757-899X/603/5/052052].

[8] Moayed, R. Z.; Alibolandi, M. and Alizadeh, A., “Specimen size effects on direct shear test of silty sands.” ISSN: 1938-6362 (Print) 1939-7879 (Online) Journal homepage: http://www.tandfonline.com/loi/yjge20, 2016.

[9] Abdi, M. R. and Gonbad, M. S. S., “Effect of roughness on soil-geogrid interaction in direct shear mode.” 11th National Congress on Civil Engineering, Iran, 2019.

[10] Yetimoglu, T. and Salbas, O., “A study on shear strength of sands reinforced with randomly distributed discrete fibers.” Geotextiles and Geomembranes 21, 103–110, 2003. [doi: 10.1016/S0266-1144(03)00003-7].

[11] Mohapatra, S. R.; Mishra, S. R.; Nithin, S. and Rajagopal, K., “Effect of box size on dilative behaviour of sand in direct shear test” Indian Geotechnical Conference IGC 2016, IIT Madras. Chennai, India, 15-17 December 2016.

[12] Jewell, R. A., and Wroth, C. P., “Direct Shear Tests on Reinforced Sand,” Geotectonics, Vol. 37, pp. 53–68, 1987.

[13] Tallah, N. and Khemissa, M., “Modelling of the Soil-Structure Interface Behavior by Direct Shear Tests under Monotonous Loading.”12th international congress on advances in civil engineering, Turkey, 2016.

[14] Hamidi, A.; Habibagahi, G. and Ajdari, M., “Shear behavior of shiraz silty clay determined using osmotic direct shear box” Kasetsart University, Thailand, ISBN 978-616-7522-77-7, 2011.

[15] Senatore, C. and Iagnemma, K. D., "Direct shear behaviour of dry, granular soils for low normal stress with application to lightweight robotic vehicle modelling." Proceedings of the 17th ISTVS International Conference. Blacksburg, VA, USA. September 18-22, 2011.

[16] Nakao, T. and Fityus, S., "Direct Shear Testing of a Marginal Material Using a Large Shear Box." Geotechnical Testing Journal, Vol. 31, No. 5, 2009.

[17] Dolzyk-Szypcio, K., "Direct Shear Test for Coarse Granular Soil." International Journal of Civil Engineering, https://doi.org/10.1007/s40999-019-00417-2, 2019.

[18] Ahmad, A.; Hany, E. N. and Pedram, S., "Direct shear test of sandy soils interfaced with FRP sheets." 2018.

[19] Amšiejus, J.; Dirgėlienė, N.; Norkus, A., "Analysis of methods for evaluation of soil shear strength parameters." In The 10th International Conference "Modern Building Materials, Structures and Techniques", 19–21 May 2010, Vilnius, Lithuania, 1077–1082, 2010.

[20] Palmeira, E. M., and Milligan, G. W. E., "Scale effects in direct shear tests on sand." In Proceedings of the 12th international conference on soil mechanics and foundation engineering (Vol. 1, No. 1, pp. 739-742), (1989, August).

[21] Bishop, A. W., "The Principle of Effective Stress," Teknisk Ukeblad, Vol. 106, No. 39: 859–863, 1959.