MOKSLAS – LIETUVOS ATEITIS
SCIENCE – FUTURE OF LITHUANIA
ISSN 2029-2341 / eISSN 2029-2252
http://www.mla.vgtu.lt

STATYBA, TRANSPORTAS, AVIACINĖS TECHNOLOGIJOS
CIVIL AND TRANSPORT ENGINEERING, AVIATION TECHNOLOGIES

2014 6(5): 499–503

Statyba
Civil Engineering

http://dx.doi.org/10.3846/mla.2014.692

DIRECT SHEAR TESTS WITH EVALUATION OF VARIABLE SHEARING AREA

Šarūnas SKUODIS[1], Tadas TAMOŠIŪNAS[2]

Vilnius Gediminas Technical University
E-mails: [1]sarunas.skuodis@vgtu.lt; [1]t.tamosiunas@stud.vgtu.lt

Abstract. Investigations of soil shear strength properties for Baltic Sea shore sand along Klaipėda city are presented. Investigated sand angle of internal friction (φ) and cohesion (*c*) is determined via two different direct shear tests procedures. First procedure is standard and ordinary in geotechnical practice, when direct shear test is provided using constant shearing area A_0. Second test procedure is different because shearing area according to horizontal displacement each test second is recalculated. This recalculated shearing area author's call corrected shearing area *A*. Obtained normal and tangential stresses' difference via two different testing procedures was 10%.

Keywords: shear area, corrected shear area, direct shear, stress path, shearing strength of soil.

Introduction

During the determination of soil shear strength in direct shear tests soil shearing area and position is well known due to the apparatus construction (see Fig. 1). As shown in Figure 1, shearing area appears between top and bottom shearing rings during the shearing test procedure in a soil sample.

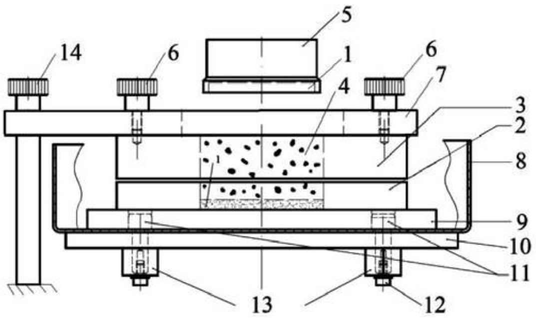

Fig. 1. Direct shear device principal constructional scheme. 1 – porous stone; 2 – bottom shearing ring; 3 – upper shearing ring; 4 – soil sample; 5 – load piston; 6 – gap position screws; 7 – rigid plate; 8 – water bath; 9 – lower shearing ring orientation plate; 10 – flexible base plate; 11 – orientation screws; 12 – flexible base plate fixing to the rails; 13 – rails; 14 – upper ring rigid support (Wille Geotec Group 2010)

Some of the devices are able to test square (Zhang *et al.* 2001; Lai 2004) or circular (Kang *et al.* 2013; Lai 2004; Amšiejus *et al.* 2014; Alikonis *et al.* 1999; Yuan *et al.* 2013) soil samples and in both cases there is a possibility to do a test with different testing device scale (Ohja, Trivedi 2013; Radu *et al.* 2014; Liu *et al.* 2009). Nevertheless, in all cases of soil shearing testing procedure which are mentioned above, a constant soil shearing A_0 is used.

The main purpose of this study is to implement corrected shearing area into testing procedure during soil shearing test. In this case due to the reduced shearing area at the different horizontal displacement shearing area is recalculated which is called corrected shearing area *A*.

Shearing area corrections

As the test progresses, the area of soil-to-soil contact reduces. If it is accepted to use a constant shearing area A_0 in testing procedure, vertical stress (σ_n) is calculated very simply – vertical force (F) is divided by constant area ($\sigma_n = F/A_0$). In the same way the shearing stress is calculated (τ) – horizontal force (H) is divided by constant area ($\tau = H/A_0$).

In this study circular soil sample and universal soil shearing device ADS 1/3 was used (Amšiejus *et al.* 2014; Skuodis *et al.* 2013). For a circular sample, displacement leads to soil-to-soil contact through the hatched area shown in Figure 2.

For a sample diameter d (see Fig. 2) the original area is calculated by (Lai 2004):

$$A_0 = \frac{\pi \cdot d^2}{4}, \tag{1}$$

where d is a sample diameter.

Assuming that soil shearing area during the testing procedure is variable, the corrected shearing area is calculated by:

$$A = 2 \cdot [\frac{(d \cdot 0.5)^2 \cdot \pi}{360^0} \cdot a\cos(\frac{h_{disp} \cdot 0.5}{d \cdot 0.5})] -$$
$$[(0.5 \cdot h_{disp} \cdot 0.5 \cdot \sin(a\cos(\frac{h_{disp} \cdot 0.5}{d \cdot 0.5})) \cdot d \cdot 0.5) \cdot 2] \cdot 2, \quad (2)$$

where d is a sample diameter and h_{disp} (see Fig. 3) is a horizontal displacement.

It is very important to use external horizontal displacement transducer (see Fig. 3) in order to avoid measuring errors. If a horizontal displacement is measured by internal horizontal displacement transducer which is inside device, an inaccurate measuring appears at test procedure's start and the end.

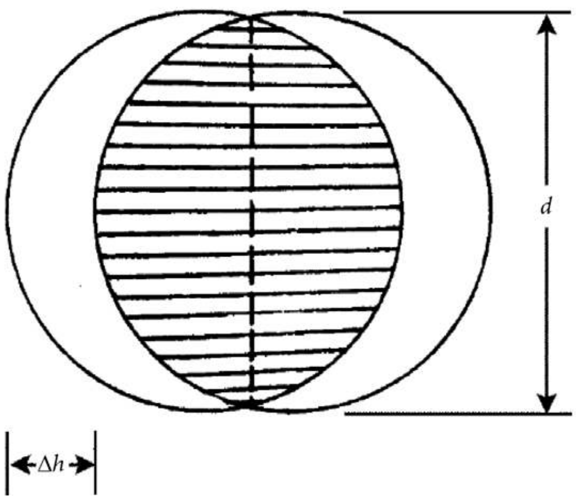

Fig. 2. Contact area of soil sample (Lai 2004)

Fig. 3. Direct shear apparatus. 1 – external horizontal displacement transducer

This measuring error is related with computer which controls testing procedure and with device operation principle. When computer gives a command for device to move horizontally, the movement of mechanical parts doesn't start immediately, because device engine is not able to be as fast as computer. Because of this engine delay it is not possible to reach desirable horizontal displacement velocity 0.5 mm/min at the start and end of testing procedure.

When implementing formulae (2) directly into testing procedure, corrected shearing area A is obtained which depends only from horizontal displacement. Than according to corrected area it is possible to recalculate normal and tangential stress. Corrected shearing area recalculation time step depends on the horizontal displacement values' recording interval. It is suggested to choose time interval about 0.5~1.0 s. In this investigations 1.0 s data recording interval was used, therefore vertical and horizontal load was recalculated after each second to keep desired vertical and tangential stress.

Experimental investigations

The investigated site occurs near the North part of Klaipėda city in Giruliai at the Baltic Sea coast. The Lithuanian coast (nearshore and coastal zone) character of the eastern shore of the Baltic Sea is ranging from erosional to the accumulative types (Grigelis 1996). In this area Holocene marine sand (m IV) occured (Skuodis *et al.* 2014). Investigated site has a flat surface of relief (Česnulevičius 1998). The average density of particles ($\boldsymbol{\rho}_s$) varies from 2.65 to 2.67 g/cm³ respectively and void ratio (*e*) changes from 0.474 to 0.778 (Dundulis *et al.* 2004, 2006). For this investigation loose air dry sand samples with initial void ratio e_0 = 0.784 were used. For investigated sand small admixture of organic dust (1.3~1.6 %) makes sand blackish brown (Gasiūnienė 1998) (see Fig. 4).

Before shearing stage a soil sample was loaded with 100, 200 and 300 kPa vertical stress. During shearing procedure on top of the sample constant vertical stress was kept and horizontal displacement velocity 0.5 mm/min was used (Amšiejus *et al.* 2002). Soil grading curve according to Paige-Green (1999) is given in Figure 5.

Analysis of obtained results

Investigations with soil direct shear apparatus ADS 1/3 were performed. Soil samples have been loaded with follo-

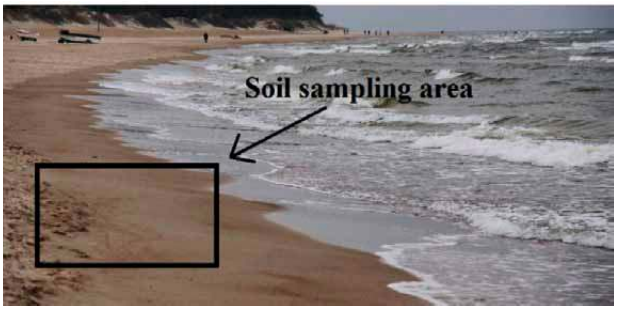

Fig. 4. Soil sampling area

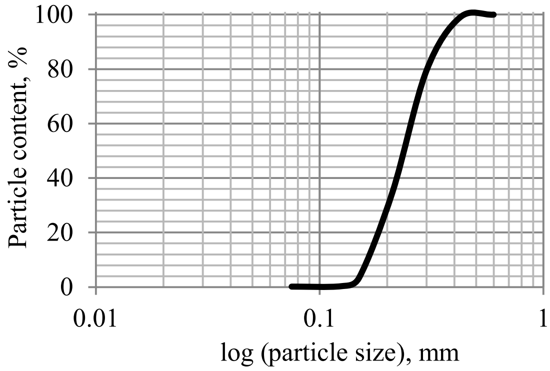

Fig. 5. Soil grading curve

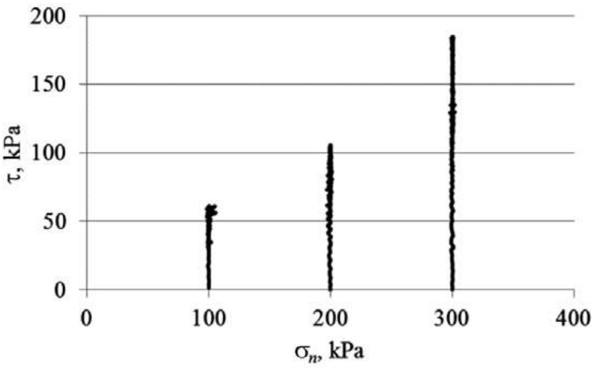

Fig. 6. Stress paths

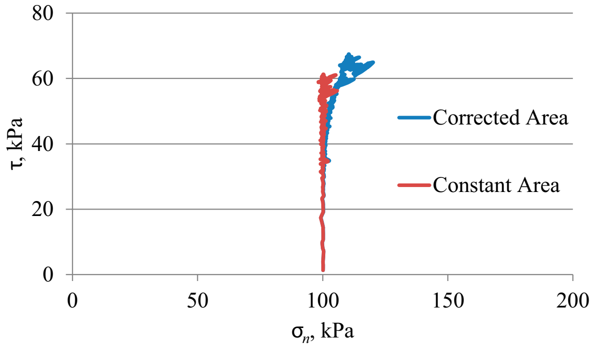

Fig. 7. Comparison of stress paths (test made according to constant area A_0)

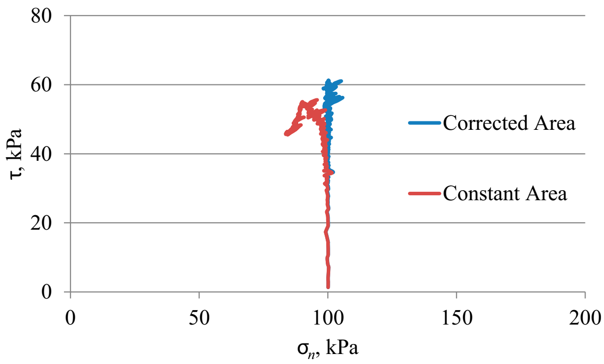

Fig. 8. Comparison of stress paths (test made according to corrected area A)

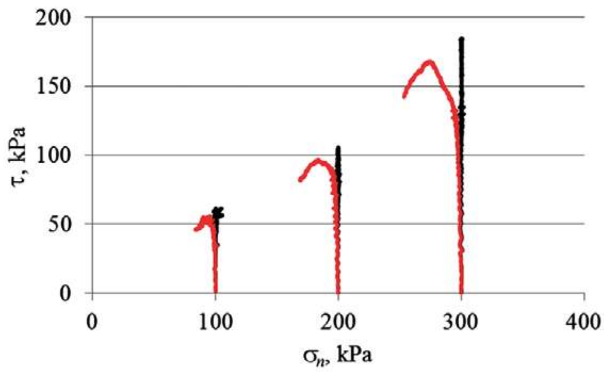

Fig. 9. Comparison of stress paths. Red curve is representing tests with constant area A and black curve is representing tests with corrected area A_0.

wing magnitudes of 100, 200 and 300 kPa. Shearing stress path which was obtained using constant shearing area (A_0) is presented in Figure 6.

Simple comparison of differences in stress paths which appear due to using different shearing area formulas is presented in Figure 7. In this case soil direct shear test was made controlling vertical stress according to A_0.

For direct shear test applying corrected shearing area A, vertical stress on top of the sample is recalculated each second according to horizontal displacement. The same recalculation of tangential stress is done during test procedure. In Figure 8 comparison of stress paths is shown from test which was made using corrected shearing area A.

In the two testing procedures, which are mentioned above (Figure 7 and 8), with evaluation of peak shearing strength parameters, obtained vertical and tangential stress difference at the peak shearing stress is 10%. This stress difference appears and with other vertical loading magnitudes (200 and 300 kPa). Comparison of stress differences when shearing test is made using corrected shearing area is given in Figure 9.

Analysis of peak shearing strength values revealed that the difference between two testing procedures is very small (see Fig. 10 and Table 1). But the difference of stress magnitudes (normal and tangential) for investigated sand was the same ~ 10% (see Table 2).

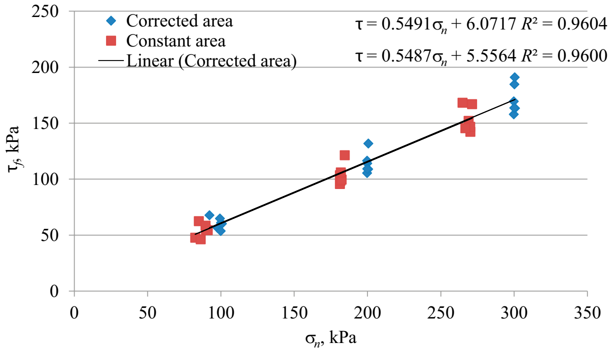

Fig. 10. Comparison of peak shearing strength parameters.

Table 1. Peak shearing strength values

	φ, °	*c*, kPa
A	28.77	6.07
A_0	28.75	5.56

Table 2. Stresses magnitudes at peak shearing strength

A		A_0		$\Delta\sigma_n$, %	$\Delta\tau_f$, %
σ_n, kPa	τ_f, kPa	σ_n, kPa	τ_f, kPa		
100.14	61.20	89.89	54.94	11.40	11.39
199.75	105.51	181.16	95.69	10.26	10.26
300.20	184.76	271.38	167.02	10.62	10.62

Analyzing shearing strength parameters which were obtained from different testing procedures it was found that the angle of internal friction has almost no changes (see Table 1). This effect is explained by Ghazavi (2008) and Bareither *et al.* (2008). Evaluating stress magnitudes, it is very important to know at what stress level it is necessary to make the test. This research work has showed that evaluating corrected shearing area during the direct shear test procedure it is possible to increase stress evaluation accuracy for 10 %. This stress accuracy magnitude was determined for investigated sand. For different soil types it is necessary to carry out additional experimental investigations, because stress difference which is obtained from two different testing procedures depends on horizontal displacement and peak shearing strength (see Fig. 11). Testing other soil types horizontal displacement magnitude at peak shearing strength can be different.

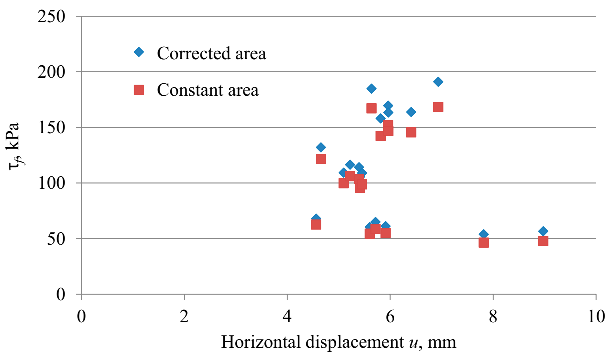

Fig. 11. Comparison of peak shearing strength versus horizontal displacement

Conclusions

1. The analysis of shearing strength parameters has shown that an angle of internal friction doesn't change (see Table 1), if a different testing procedure is used.
2. In the tests with corrected shearing area 10% stress difference was obtained comparing with tests which were made using a constant shearing area. This stress difference helps to increase initial stress selection more accurately.
3. Authors suggest to do the experimental tests with other soil types and with different soil density in order to determine stress differences in the two examined testing procedures.

Acknowledgements

The authors express their gratitude to Dr. Martin Tazl (Wille Geotec Group) and Dr. Marcus Freise (Wille Geotec Group) for useful remarks and valuable help with reprogramming testing device. The equipment and infrastructure of Civil Engineering Research Centre was employed for this investigation.

References

Alikonis, A.; Amšiejus, J.; Stragys, V. 1999. Improvement of shear box aparatus and methodology of test, in *Soil Mechanics and Geotechnical Engineering, The 12th European Conference*, 7–10 June 1999, Amsterdam, Austria, 1053–1057.

Amšiejus, J.; Mackevičius, R.; Medzvieckas, J.; Stragys, V. 2002. *Gruntų mechanika. Laboratoriniai darbai* [Soil mechanics. Laboratory practice]. Vilnius: Technika. 114 p. (in Lithuanian).

Amšiejus, J.; Dirgėlienė, N.; Norkus, A.; Skuodis, Š. 2014. Comparison of sandy soil shear strength parameters obtained by various construction direct shear apparatuses, *Archives of Civil and Mechanical Engineering* 14: 327–334. http://dx.doi.org/10.1016/j.acme.2013.11.004

Bareither, C. A.; Edil, T. B.; Benson, C. H.; Mickelson, D. M. 2008. Geological and physical factors affecting the friction angle of compacted soils, *Journal of Geotechnical and Environmental Engineering* 134(10): 1476–1489. http://dx.doi.org/10.1061/(ASCE)1090-0241(2008)134:10(1476)

Česnulevičius, A. 1998. Lietuvos reljefo morfolitogeninių klasifikacijų palyginimas [Comparison of morpholithogenetic classification of Lithuanian relief], *Litosfera* 2: 80–86. (in Lithuanian).

Dundulis, K.; Gadeikis, S.; Gadeikytė, S.; Račkauskas, V. 2006. Sand soils of Lithuanian coastal area and their geotechnical properties, *Geologija* 53: 47–51.

Dundulis, K.; Gadeikis, S.; Ignatavičius, V. 2004. Kvartero nuogulų inžinerinių geologinių sąlygų formavimasis [Engineering geological conditions formation of quaternary sediments], in *Lietuvos gelmių raida ir ištekliai*: *Spec. "Litosferos" leidinys.* Geologijos ir geografijos institutas, Vilniaus universitetas, Vilnius, 318–331. (in Lithuanian).

Gasiūnienė, V. R. 1998. *Lithuanian solid mineral resources*. Lietuvos geologijos tarnyba,Vilnius. 50 p.

Ghazavi, M.; Hosseini, M.; Mollanouri, M. 2008. A Comparison between Angle of Response and Friction Angle of Sand, in *The 12th International Conference for International Association for Computer Methods and Advances in Geomechanics (IACMAG)*, 1–6 October 2008, Goa, India.

Grigelis, A. 1996. Lithuanian marine geology and geophysics, *Geological mapping in Baltic States* 2: 10–12.

Kang, D.; Choo, J.; Yun, T. S. 2013. Evolution of pore characteristics in the 3D numerical direct shear test, *Computers and Geotechnics* 49: 53–61. http://dx.doi.org/10.1016/j.compgeo.2012.10.009

Lai, J. 2004. *Direct shear testing*. Chaoyang University of technology. 14 p.

Liu, C.; Ho, Y.; Huang, J. 2009. Large scale direct shear tests of soil/PET-yarn geogrid interfaces, *Geotextiles and Geomembranes* 27(1): 19–30. http://dx.doi.org/10.1016/j.geotexmem.2008.03.002

Ohja, S.; Trivedi, A. 2013. Shear strength parameters for silty-sand using relative compaction, *EJGE* 18: 81–99.

Paige-Green, P. 1999. A comparative study of the grading coefficient. A new particle size distribution parameter, *Bulletin of Engineering Geology and the Environment* 57(3): 215–223. http://dx.doi.org/10.1007/s100640050039

Radu, R.; Petru, C.; Loan, T. 2014. Assesment of a traction model for agricultural tires based on a variable shear area model and experimental data, *Advanced Materials Research* 837: 458–463.

Skuodis, Š.; Markauskas, D.; Norkus, A.; Žaržojus, G.; Dirgėlienė, N. 2014. Testing and numerical simulation of Holocene marine sand uniaxial compression at Lithuanian coast, *Baltica* 27(1): 33–44. http://dx.doi.org/10.5200/baltica.2014.27.04

Skuodis, Š.; Norkus, A.; Dirgėlienė, N.; Šlečkuvienė, A. 2013. Sand shearing peculiarities using direct shear device, *Proceedia Engineering* 57: 1052–1059. http://dx.doi.org/10.1016/j.proeng.2013.04.133

Yuan, J.; Fang, Y.; Gu, R.; Hu, G.; Peng, X. 2013. Experimental research on influence of granulometric composition on sandy soil strength and reological properties, *EJGE* 18: 4081–4091.

Wille Geotec Group. 2010. *Universal direct shear device* ADS 1/3. Göttingen, Germany. 36 p.

Zhang, B.; Zhao, Q. G.; Horn, R.; Baumgartl, T. 2001. Shear strength of surface soil as affected by soil bulk density and soil water content, *Soil and Tillage Research* 59(3–4): 97–106. http://dx.doi.org/10.1016/S0167-1987(01)00163-5

TIESIOGINIO KIRPIMO BANDYMAI ĮVERTINANT KINTAMĄ KERPAMĄJĮ PLOTĄ

Š. Skuodis, T. Tamošiūnas

Santrauka

Šiame straipsnyje yra pristatyta idėja, kaip įvertinti grunto kerpamojo stiprumo parametrus, t. y. vidinės trinties kampą (φ) ir sankibą (*c*). Eksperimentiniams bandymams atlikti buvo naudotas Baltijos jūros pakrantės smėlinis gruntas ties Klaipėda. Grunto tiesioginio kirpimo bandymai atlikti dviem skirtingomis kirpimo metodikomis. Pirmoji metodika yra standartizuota ir įprasta atliekant geotechninius tyrimus, kai kerpamasis plotas yra vertinamas kaip pastovus plotas *A*. Antroji kirpimo metodika skiriasi nuo pirmosios grunto kirpimo ploto įvertinimu. Antrojoje metodikoje grunto kerpamasis plotas yra perskaičiuojamas tiesiogiai pagal horizontalųjį poslinkį. Horizontaliojo poslinkio indikatoriaus rodmenys yra registruojami kiekvieną sekundę, todėl kas sekundę yra perskaičiuojamas vis naujas grunto kerpamasis plotas. Atliekant bandymus skirtingomis metodikomis, nustatytas vertikalaus normalinio ir tangentinio įtempių skirtumas, kuris apytiksliai lygus 10 %.

Reikšminiai žodžiai: kintamas kerpamasis plotas, tiesioginis kirpimas, įtempių kelias, grunto kerpamasis stipris.