Journal of Advances in Science and Technology

Vol. IV, No. VIII, February-2013, ISSN 2230-9659

A COMPARATIVE STUDY OF DIFFERENT MECHANISM AND EQUIPMENTS USABLE IN SHEAR TESTING OF SOILS

Journal of Advances in Science and Technology
Vol. IV, No. VIII, February-2013, ISSN 2230-9659

A Comparative Study of Different Mechanism and Equipments Usable In Shear Testing Of Soils

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Abstract – In order to put subsequent discussions into proper perspective, it is convenient to list the various kinds of apparatus that have been used to measure the shearing strength and associated stress-strain properties of soils. More detailed attention will then be directed at the few types of tests that have achieved general usage by consulting and testing firms.

Based on a detailed analysis of DEM simulation data, this paper provides new insights into the effects of boundary surface topography on the mobilized stress ratio and stress-displacement behavior in the interface shear test and the direct shear test. The soil mechanics observed in the two types of tests are unified under a novel perspective of boundary-induced soil behavior. It is shown that the principal direction of the contact force anisotropy developed at the soil-surface boundary has an exclusive control over the peak stress ratio measured both at the boundary and inside the sampling window. However, a subtle change in the roles of the principal direction and the magnitude of contact force anisotropy is found as the contact force chains extend from the surface into the interphase soil.

ABSTRACT: A review and evaluation of the advantages and limitations of laboratory equipment for measuring the shear strength of soils arc presented. Equipment evaluated include direct shear, torsional shear, simple shear, triaxial. multiaxial (true triaxial), plane strain, hollow cylinder triaxial, and directional shear devices. The evaluation indicates that the impetus to obtain parameters for constitutive equations and modeling has resulted in the development of improved equipment and testing techniques; specifically, the development of multiaxial (true triaxial) and hollow cylinder triaxial test equipment. Although these devices are more versatile, the conventional solid cylinder triaxial test is still the most popular. The evaluation suggests that direct shear and simple shear devices are best utilized by designers who have gained experience applying the results from such tests to structures that have behaved satisfactorily.

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INTRODUCTION

The object of laboratory testing is to study the behavior of a given soil under conditions similar to those encountered in the field and to obtain those parameters which describe this behavior in a set of constitutive equations. In a laboratory test the specimen is intended and generally assumed to represent a single point in a soil medium. The validity of this assumption depends on the uniformity of stress and strain distributions within the soil samples. The uniformity will depend on the configuration of the specimen and the control and measurement of stress and strain on its surface. Separate measurements are often made for the soil phase, the water phase, and sometimes the air phase of the specimen in order to relate its contribution to the strength of the mass. While the data needed in design may be less extensive than those required for the development of constitutive equations, the present trend is to obtain as complete a record as possible. Constitutive equations arc an indispensable ingredient in the application of the finite-element method to geotechnical problems; and the increased availability of computers has resulted in increased pressure for the development of testing equipment capable of covering the whole stress and strain spectra.

Consequently, the last ten years have seen an explosion in the number of tools aimed at better measurements, better recording, and better processing of data obtained during laboratory testing. Testing units conceived many years ago but whose implementation was quite difficult are being used nearly on a routine basis. Automation, both electronic and fluidic, has taken most of the drudgery out of the stressing or straining systems.

TYPES OF EQUIPMENT FOR SHEAR TESTING OF SOIL

The laboratory is equipped with tools for testing of soil properties to determine all relevant charactersitics neccessary for civil engineering projects. All tests described below are conducted in accordance with appropriate British Standards Method of Test for Soil for Civil Engineering Purposes. The types of tests that can be conducted in this laboratory facility include the following:

1. DOUBLE RING SHEAR: Probably the first type of laboratory apparatus used to measure the shearing strength of clays was one we will call the "double ring shear" apparatus. In its most common form it consists of a set of three metal rings containing clay and mounted in an apparatus such that the outer two rings can be supported and the middle ring can be sheared out from between the outer rings thus leading to a soil failure on two surfaces. One of the first apparatuses of this general type was used by Alexandre Collin (1846) who used samples 4cm x 4cm x 35cm long without any rings, but with the outer l5 cm ends of the clay prism supported and the center 5 cm sheared off by simply placing a plate on the top and applying dead 1oads.

2. DIRET SHEAR: In the "direct shear apparatus," the soil is contained in two rings. The rings may be circular or, more commonly, square. The inside dimensions are typically 2" x 2" to 4" x 4" but sizes up to more than 12" have been used. A normal force N is applied through a mechanical loading system and failure is achieved by applying a force F to either the upper or lower halves of the shear box so that the soil is forced to fail on a single shear plane.

The soil sample in the direct shear devices is normally trimmed from the original soil sample but it is possible to use a shear box with the same inside diameter as the soil sample so the soil can be extruded directly into the ring. The soil samples for direct shear tests are usually fairly thin (of the order of 0.5 inch thick) to facilitate rapid drainage and direct shear tests are almost always fully drained tests.

3. SIMPLE SHEAR: In the simple shear apparatus, a rectangular or cylindrical sample of clay is mounted in a special cell and then subjected to an axial stress and to shear as indicated in, in such a manner that the entire sample distorts without the formation of a single shearing surface. In the original apparatus developed at Cambridge University (Roscoe, 1953) the leading and trailing vertical surfaces of the soil were constrained by metal plates which were hinged in such a way that they forced the sample to deform in the desired manner.

4. TRIAXIAL SHEAR: The triaxial shear apparatus has become established as the main means of determining the shear strength of soils when it is considered necessary to have a confining pressure. The soil sample is a solid cylinder with a height to diameter ratio of 2 which is subjected to confining pressure through a rubber membrane and loaded axially through a rigid top cap. The apparatus can be made reasonably inexpensive. Samples of a wide range of sizes can be tested in a single apparatus by simply altering the diameter of the base pedestal and the top cap so that either trimmed or untrimmed samples can be used without the necessity of building completely different apparatus for each sample size.

5. REAL TRIAXIAL SHEAR: The apparatus normally termed the "triaxial shear apparatus" is in fact a biaxial apparatus only two principal stresses can be controlled independently. In a true triaxial shear apparatus, all three principal stresses are subject to independent control. The details of the many true triaxial shear devices are beyond the scope of this discussion. The devices are all characterised by considerable complexity and expense and none have been used for commercial type testing.

LABORATORY INDEX TESTS FOR SOILS

General: Data generated from laboratory index tests provide an inexpensive way to assess soil consistency and variability among samples collected from a site. Information obtained from index tests is used to select samples for engineering property testing as well as to provide an indicator of general engineering behavior. For example, a soil with a high plasticity index (PI) can be expected to have high compressibility, low hydraulic conductivity, and high swell potential. Common index tests discussed in this section include moisture content, unit weight (wet density), Atterberg limits, particle size distribution, visual classification, specific gravity, and organic content. Index testing should be conducted on each type of soil material on every project. Information from index tests should be assessed prior to a final decision regarding the specimens selected for subsequent performance testing.

Moisture Content: The moisture (or water) content test is one of the simplest and least expensive laboratory tests to perform. Moisture content is defined as the ratio of the weight of the water in a soil specimen to the dry weight of the specimen.

Unit Weight: The terms density (ρ) and unit weight (γ) are often incorrectly used interchangeably. The correct usage is that density implies mass while unit weight implies weight measurements.

Density and unit weight are related through the gravitational constant (g) as follows: $\gamma = \rho g$. In this document they will be referenced as “density (unit weight)" if the usage is independent of the specific definition.

Particle Size Distribution: Particle size distributions by mechanical sieve and hydrometer analyses are useful for soil classification purposes. Procedures for grain size analyses are contained in ASTM D 422 and AASHTO T88. Testing is accomplished by shaking air-dried material through a stack of sieves having decreasing opening sizes.

Atterberg Limits: The Atterberg limits of a fine grained soil represent the moisture content at which the physical state of the soil changes. The tests for the Atterberg limits are referred to as index tests because they serve as an indication of several physical properties of the soil, including strength, permeability, compressibility, and shrink/swell potential.

Organic Content: A visual assessment of organic materials may be very misleading in terms of engineering analysis. Laboratory test method AASHTO T194 or ASTM D 2974 should be used to evaluate the percentage of organic material in a specimen where the presence of organic material is suspected based on field information or from previous experience at a site. The test involves weighing and heating a previously dried sample to a temperature of 824°F (440°C) and holding this temperature until no further change in weight occurs.

Electro Chemical Classification Tests: Electro chemical classification tests provide the geotechnical specialist with quantitative information related to the aggressiveness of the soil conditions with respect to corrosion and the potential for deterioration of typical foundation materials. Electro chemical tests include determination of pH, resistivity, sulfate ion content, sulfides, and chloride ion content.

PRACTICAL ASPECTS FOR LABORATORY TESTING

A poor understanding sometimes exists among geologists, structural engineers, and some foundation engineers about the type and amount of laboratory testing required for design of geotechnical features whether they happen to be structural foundations or earthwork. This weakness may render subsequent analyses useless. Organizations that have neither the proper testing facilities nor trained soils laboratory personnel should contract testing to competent AASHTO/ASTM certified private testing firms. This solution can be effective only if the project foundation designer can confidently request the necessary testing and review the results to select design values. A fair estimate of the costs associated with a private testing laboratory may be obtained by assuming the following number of person-days (pd) per test and multiplying by current labor costs:

- visual description of an SPT sample including moisture content (0.05 pd),
- visual description of a tube sample including moisture content and unit weight (0.1pd),
- classification tests (0.7 pd),
- undrained triaxial test (0.9 pd),
- drained triaxial test (2.0 pd),
- consolidation test (2.0 pd).

These values include all work required to present a completed test result to the foundation designer. Alternatively, most private testing laboratories provide a schedule of services and associated costs that can be used to obtain a more accurate estimate of the cost of a proposed laboratory test program.

TESTING PROCEDURE

The overall testing procedure will be reviewed first, without covering details, and then each aspect of the test will be considered separately. It is assumed that the test is to be fully drained and the sample is undisturbed and cohesive, and is in a sampling tube. Minor modifications cover other cases.

The soil sample is extruded from the sampling tube. The extruded sample must typically be trimmed to fit into the shear box. The soil cannot conveniently be trimmed directly into most direct shear devices because the shear box is typically too large and heavy to be handled conveniently. Instead, a special trimming ring is used. The trimming ring has a height that is standard for that laboratory. If a thinner sample is desired, then after the soil has been trimmed into the ring and one face has been trimmed, a spacer plate is used on the surface just trimmed, to push the soil up into the ring an appropriate distance, and then the other face is trimmed.

The shear box is then assembled with the top and the bottom halves of the box screwed (or otherwise rigidly attached) together. The inside of the shear box is typically lightly greased to minimize side friction, just as for consolidation tests. The lower porous stone is placed in the shear box. Sometimes spacer disks are placed below this stone to adjust the elevation of its top to accommodate soil samples of different thicknesses.

A dial indicator, or other suitable device for measuring the change in thickness of the sample, is quickly mounted and a zero reading taken. A consolidation pressure is then added to the top of the sample using the load-application system of the apparatus (typically a lever arm or a pneumatic system). The consolidation stage proceeds as for a standard incremental one dimensional consolidation test.

During the consolidation stage, the upper and lower halves of the shear box have been tightly screwed together to prevent the soil from extruding out from between the boxes. Typically, only two locking screws are used. Prior to shearing the sample, the upper half of the box is typically raised to provide a small separation between the boxes and ensure that the shearing and normal stresses are actually transmitted through the soil rather than from box to box.

CONCLUSION

This paper provides a new perspective which unifies the soil mechanics observed in an interface shear test and a direct shear test under the concept of “boundary-induced” soil behavior. Based on the detailed analysis of micromechanical data from DEM simulations, a complete understanding of the mechanisms by which the different types of testing device boundaries control the shear strength and stress ratio-displacement behavior of granular soils is achieved. It is shown that the mobilized shear strength measured either at the testing device boundaries or inside the sampling window depends on the degree and extent of the strain localization and shear banding developed inside the specimen. The peak stress ratios measured in ISTs and DSTs can be well quantified using the principal direction of the contact total force anisotropy. However, a subtle distinction is found in the roles of the principal direction and the magnitude of contact force anisotropy in controlling the stress ratio-displacement behavior as the contact force chains extend from the boundary into the interphase soil. The origin of this distinction is the pure geometric factor, i.e., the rigid boundary surface geometry vs. the adjustable interphase soil fabric.

For many years the direct shear test had been the main tool used by
engineers in foundations design. They recognized its weaknesses and adjusted their estimates accordingly. The ring shear test, while not used frequently, is a valuable tool in obtaining residual strengths. Devices of the Hvorslev type which do not necessitate reversal are possibly the best available today in obtaining this quantity.

It is the opinion of the authors that simple shear tests are of no value for research purposes. In practice they can be used in comparative studies but intrinsically they cannot pretend to give material properties. Because of the enormous amount of data accumulated with these devices, their proper place is in the hands of designers who have calibrated their thinking in terms of the results of those tests and have successfully applied those results in their practice.

The standard triaxial test is an improvement over direct shear and simple shear. It is clear, however, that if it is to lead to meaningful information, lubricated platens should be used for soils where one expects high volume changes or high volume change tendencies. Membrane penetration has to be reduced when granular soils are tested in an undrained condition, since it appears that the pore water pressures could easily differ by a factor of two if such precautions are not taken.

REFERENCES

- ASTMD5321-02: StandardTest Method forDetermining theCoefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method. ASTM,West Conshohocken, PA, USA
- ASTM D3080-04: Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions. ASTM,West Conshohocken, PA, USA
- Bathurst, R.J., Rothenburg, L.: Observation on stress-force-fabric relationships in idealized granular materials. Mech. Mat. **9**, 65–80 (1990)
- Dove, J.E., Jarrett, J.B.: Behavior of dilative sand interface in a geotribology framework. J. Geotech. Geoenviron. Eng. **12**(1), 25–37 (2002)
- Dove, J.E., Bents, D.D., Wang, J., Gao, B.: Particle-scale surface interactions of non-dilative interface systems. Geotext. Geomembr. 24(3), 156–168 (2006)
- Jacobson, D.E., Valdes, J.R., Evans, T.M.: A numerical view into direct shear specimen size effects. Geotech. Test. J. **30**(6), 512–516 (2007)
- Jewell, R.A., Wroth, C.P.: Direct shear tests on reinforced sand. Géotechnique **37**(1), 53–68 (1987)
- Converse, F. J. (1952), "The Use of the Direct Shear Testing Machine in Foundation Engineering Practice," Symposium on Direct Shear Testing of Soils, ASTM, Vol. 131, pp. 75-80.
- Gibson, R. E., and D. J. Henkel (1954), "Influence of Duration of Tests at ConstahTTlate orStrain on Measured 'Drained' Strength", Geotechnique, Vol. 4, No. 1, pp. 6-15.
- Hirschfeld - ref where he smeared soil on stones, should be in a Harvard soil mechanics series

- Hvorslev - find reference on effects of groove height on disturbance Lee, K. L, and A. Singh (1968), "Report on the Direct Shear Comparative Study", unpublished report.

- Wang, J., Gutierrez, M.S.: Modeling of scale effects on the micromechanics of granular media under direct shear condition. In: Nakagawa, M., Luding, S. (eds.) Powders and Grains 2009, pp. 365–368. Golden, Colorado (2009)

- Wang, J., Gutierrez, M.S.: Discrete element simulations of direct shear specimen scale effects. Géotechnique **60**(5), 395–409 (2010)

- Johnson. L. D.. Psychrometric Measurement of total Suction in a Triaxial Compression Test," U. S. Army Engineers Water ways Experiment Station. Miscellaneous Paper S-74-I9. Vicksburg, Miss.. June 1974.

- Tuna, F. X., Use of Thermocouple Psychrometric for Measuring Soil Suction in Triaxial Compression Testing," M.S. Degree Independent Study Report, Department of Civil and Environmental Engineering. University of Wisconsin-Madison, 1979.