Test Procedure for

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR UNDISTURBED SOILS

TxDOT Designation: Tex-131-E

Effective Date: August 1999

1. SCOPE

1.1 This method determines the angle of internal friction (ϕ) and cohesion (c) strength parameters of soils by triaxial compression testing.

1.2 When pore pressures are measured, the effective values of internal friction and cohesion, (ϕ') and (c') respectively, can be calculated.

1.3 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. APPARATUS

2.1 *Loading device*, a variable-speed, motor-driven, screw, or other compression system that is strain-controlled, having sufficient capacity and sensitivity. (See Figure 1.)

2.2 *Load measuring device*, such as a proving ring, normally mounted on the outside of the test chamber, capable of measuring axial loads to within 1.0% of the anticipated load at failure. An electronic load cell may also be used to measure the axial loads applied to the test specimen, mounted inside the test chamber. When a load cell is used, the following accessory electronic equipment may be needed to indicate the loads:

2.2.1 *Amplifier*, to increase the electrical signals from the load cell so they are sufficiently large to be detected by a digital voltmeter or strip chart recorder.

2.2.2 *Power source*, constant voltage, to excite the load cell or pressure transducer.

2.2.3 *DC bridge balance*, to balance the electrical circuits of the measuring system.

2.2.4 *Data recording device*, to indicate the load or pressure.

2.3 *Deformation indicator*, a dial extensiometer graduated to 0.03 mm (0.001 in.), with a travel of about 10% of the length of the test specimen, or other comparable device.

2.4 *Trimming equipment*, including a frame, equipment capable of measuring the dimensions of the specimen to the nearest 0.3 mm (0.01 in.), sample cutter, end-trimming device, trimming and carving tools.

2.5 *Pore pressure device, a closed manometer, a null indicator, or a pressure transducer*. When a pressure transducer is used, the same data acquisition system used to monitor loads may be used.

2.6 *Drying oven*, thermostatically controlled, capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F).

2.7 *Balance*, Class G2 in accordance with Tex-901-K, minimum capacity of 4000 g.

2.8 *Pressure chamber*, including sample base plate, porous stone, two lubricated end plates (optional), O-rings or other seals, stopcock valve, sample header, tubing for drainage, top cap, load piston, rubber membrane, and filter paper.

2.9 *Miscellaneous apparatus*, including vacuum pump and pressure device with associated regulators and gages, membrane expander, moisture content cans, and data sheets.

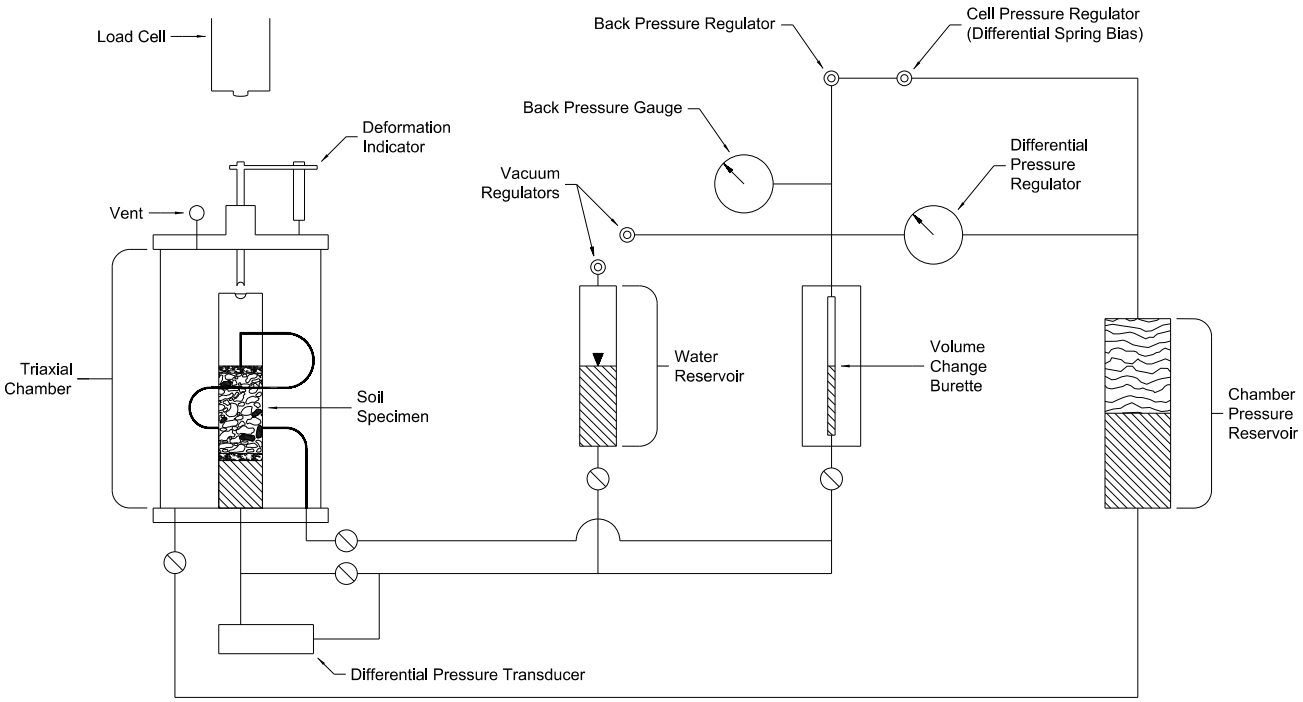


Figure 1—Schematic Diagram of a Typical Consolidated Undrained Triaxial Apparatus

3. PREPARING SPECIMEN

3.1 Specimens should have a minimum diameter of 33.0 mm (1.3 in.)

- The largest particle in the test specimen should be smaller than one-tenth of the specimen diameter.
- For specimens that have a diameter of 71.1 mm (2.8 in.) or larger, the largest particle size should be smaller than one-sixth of the specimen.
- If larger particles are present after the completion of a test of an undisturbed specimen, make appropriate notations in the report of the test data.

3.1.1 The height to diameter (H/D) ratio must be between 2.0 and 3.0 with a recommended value of 2.0, except that:

- When lubricated end plates are used, the (H/D) ratio may be lowered to 1.25.
- The height and diameter of the specimen will be measured to the nearest 0.3 mm (0.01 in.) using a vernier caliper or other suitable device.

Note 1—This method requires testing a minimum of three specimens.

3.2 Undisturbed specimens may be prepared from large undisturbed samples or from samples secured in accordance with AASHTO T 207 or the Bridge Division's Geotechnical Manual.

3.3 When tubes are received in the laboratory, extrude the samples using a jack or other methods that will not disturb the sample.

3.4 When samples are not tested immediately, place in plastic bags to preserve moisture content.

3.5 Any method of trimming is acceptable which, for the material being tested, produces minimum disturbance.

3.5.1 Place the specimen in the end-trimming device and trim so the ends are perpendicular to the longitudinal axis of the uniform circular specimen.

3.5.2 Obtain diameter and height of the specimen and determine the initial mass.

3.5.3 If the entire test specimen is not to be used for determination of moisture content, secure and immediately place a representative sample of cuttings for this purpose in a covered container, in accordance with Tex-103-E.

4. PROCEDURE

4.1 Prepare pedestal by placing a saturated porous stone on the pedestal, with a filter paper disk on top. Place the specimen on the porous stone and a filter paper strip cage alongside the specimen to provide the desired drainage path, as shown in Figure 2.

4.2 Using a vacuum membrane expander, place a thin, leak-proof membrane over the specimen. Place O-rings or other pressure seals around the membrane at the baseplate or cap of the pedestal to provide a positive seal. Place an additional filter paper disk, porous stone, and header or top cap, on top of the specimen. Place O-rings or other pressure seals around the membrane at the cap to provide a positive seal. Place the hollow cylinder on the base and secure. Place the loading piston into the chamber through the bushings and lower until it enters, but does not touch, the recess in the top cap. Secure the loading piston with the locking device.

4.3 Place the test chamber containing the specimen in the loading frame and fill with fluid. Saturate the drainage line, header caps, and filter paper surrounding the specimen, to remove air from between the sample and membrane.

4.4 Apply a small back pressure and chamber pressure with chamber pressure approximately 1 to 13.8 kPa (2 psi) greater than back pressure, to cause water to flow slowly from the pore pressure line. Connect pore pressure line to pore pressure-measuring device. Increase back pressure and chamber pressure increments whenever pore pressure readout indicates pressure equalization has been achieved throughout the sample. Maintain chamber pressure approximately 34.4 kPa (5 psi) greater than back pressure, to prevent flow between the sample and membrane.

4.5 Check the degree of saturation by closing the drainage valve and increasing the confining pressure 34.4 kPa (5 psi) or more. The ratio of pore pressure change to the change in confining pressure for a saturated sample is:

$\Delta U / \Delta\sigma_3 = 1.0 = B$, Pore Pressure Coefficient.

4.6 Continue to increase back pressure and confining pressure until pore pressure response indicates a B value of at least 0.95.

Note 2—If pore pressure measurements are not required, eliminate this step.

4.7 The consolidation phase of the test allows the specimen to reach equilibrium in a drained state under the effective consolidation stress for which a strength determination is required. During consolidation, data is obtained for use in determining when consolidation is complete, and for computing a rate of strain to be used for the shear portion of the test. The consolidation procedure is as follows:

4.7.1 When the saturation phase of the test is completed, bring the axial load piston into contact with specimen cap and record the reading on deformation indicator.

4.7.2 Take care not to apply an axial load to the specimen exceeding 0.5% of the estimated axial load at failure.

4.7.3 After recording the reading, raise the piston a small distance above specimen cap and lock in place.

4.8 With the specimen drainage valves closed, hold the back pressure constant and increase the chamber pressure until the difference between the chamber pressure and the back pressure equals the desired effective consolidation pressure.

4.9 Obtain an initial buret reading and then open appropriate drainage valves so specimen may drain from both ends into the buret.

4.9.1 At increasing intervals of elapsed time (0.1, 0.2, 0.5, 1, 2, 4, 8, 15, and 30 min. and at 1, 2, 4, and 8 hr., etc.) observe and record buret readings.

4.9.2 After the 15 min. reading, record the accompanying deformation indicator readings obtained by carefully coupling the piston with the specimen cap.

4.9.3 Depending on soil type, intervals may be changed to convenient intervals that allow for adequate definition of volume change versus time.

4.10 Plot buret and deformation indicator readings versus the logarithm of elapsed time.

4.10.1 Allow consolidation to continue for at least one log cycle or one overnight period, after 100% primary consolidation has been achieved.

4.10.2 A marked deviation between the slopes of the buret and deformation indicator curves toward the end of consolidation, based on deformation indicator readings, indicates fluid leakage from the chamber into the specimen. Test should be terminated.

4.11 Determine the time for 50% primary consolidation, t_{50}:

4.11.1 Plot the buret readings versus the log of time in minutes.

4.11.2 Find the buret reading representing 100% primary consolidation.

4.11.3 First, draw a straight line through the points representing the final readings and that exhibit a straight line trend and a flat slope.

4.11.4 Draw a second straight line tangent to the steepest part of the buret-log time curve.

4.11.5 The intersection represents the buret corresponding to 100% primary consolidation.

4.11.6 Compression that occurs subsequent to 100% primary consolidation is secondary compression.

4.11.7 Time required for 50% consolidation, t_{50}, may be found graphically from buret-log time curve by observing the time that corresponds to 50% of primary consolidation of the curve.

4.12 Before axial load is applied, close the valve between the chamber and the buret so that the specimen is sheared in an undrained condition. Measure any volume change that occurs during consolidation.

4.13 Start loading device and slow it to run a few minutes at desired testing speed to compensate for piston friction or upward thrust on the piston due to chamber pressure or both. Record zero reading of load and deformation measuring devices when piston makes contact with top header.

Note 3—Remove the piston lock before starting the loading device. If the chamber pressure is insufficient to restrain the loading piston from falling onto the top cap, then the additional load applied to the sample by the loading piston will have to be added to the deviator load.

4.14 In the triaxial test:

4.14.1 The rate of strain should allow for equalization of pore pressures (if measured) in the test specimen.

4.14.2 Assuming failure will occur after 4%, a suitable rate strain may be obtained by dividing 4% by ten times the value of t_{50}.

4.14.3 This rate of strain will allow determination of accurate stress paths in the range necessary to define effective strength envelopes.

4.14.4 If however, it is estimated that failure will occur at a strain value lower than 4%, obtain a suitable strain rate by dividing the estimated failure strain by ten times the value of t_{50}.

4.14.5 Record load and deformation readings at sufficiently small intervals to accurately define the stress-strain curve.

4.15 The criterion of failure shall be the maximum value of the deviator stress, provided a maximum does occur.

4.15.1 If no definite maximum occurs and the deviator stress continued to increase with strain, failure will be taken as the deviator stress at 15% strain.

4.15.2 If pore pressures are measured, the maximum effective principal stress ratio may be used as the failure criterion.

4.16 After failure, release all pressures and drain the confining fluid from the test chamber.

4.16.1 Disassemble the testing apparatus, examine the specimen, and sketch the mode of failure.

4.16.2 Obtain the specimen weight, height, and diameter for density and determine final moisture content.

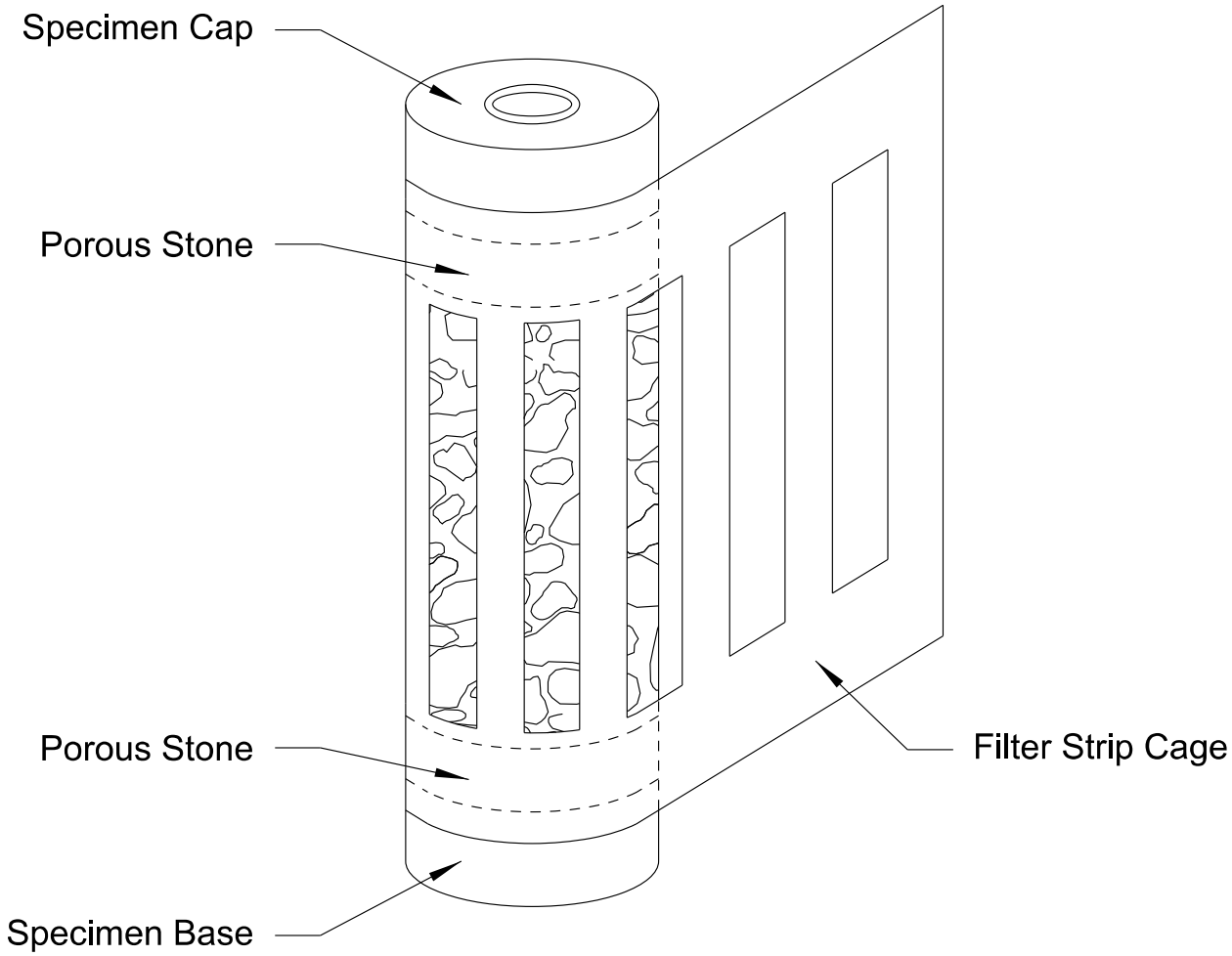


Figure 2—Filter Strip Cage

5. CALCULATIONS

5.1 Calculate the volume strain (ϵ_V):

$$\epsilon_V = \Delta V / V$$

$$V = \pi\ Ld^2\ / 4$$

$$\Delta V = \pi\ \Delta Ld^2\ / 4$$

Where:

V = original volume of specimen

ΔV = volume change as measured by buret

L = length of specimen as determined by physical measurements, mm (in.)

ΔL = change in length of specimen during consolidation, mm (in.)

d = average of a minimum of three physical diameter measurements, mm (in.)

5.2 Assuming that the specimen strains equally in all directions during consolidation, the length of the specimen after consolidation may be determined by $\in_1 = \in_v / 3$. Alternately, measure the change in length of the specimen directly.

5.3 Calculate the axial strain for a given applied load:

$$\in V = \Delta l / ls$$

Where:

Δl = change in length of the specimen as determined from the deformation indicator, mm (in.)

ls = length of specimen after consolidation, mm (in.)

5.4 Calculate the average cross-sectional area for a given applied load (A) or from dimensions obtained by direct measurement:

$$A = A_0 / (1 - \in)$$

5.5 Calculate the deviator load per unit area for a given applied load:

$$\sigma_d = P / A = \sigma_1 - \sigma_3$$

Where:

P = applied deviator load, kg (lbs.)

A = corresponding average cross-sectional area, mm^2 ($in.^2$)

σ_d = deviator load per unit area

A_0 = initial average cross-sectional area of the specimen, m^2 ($in.^2$)

6. GRAPHS

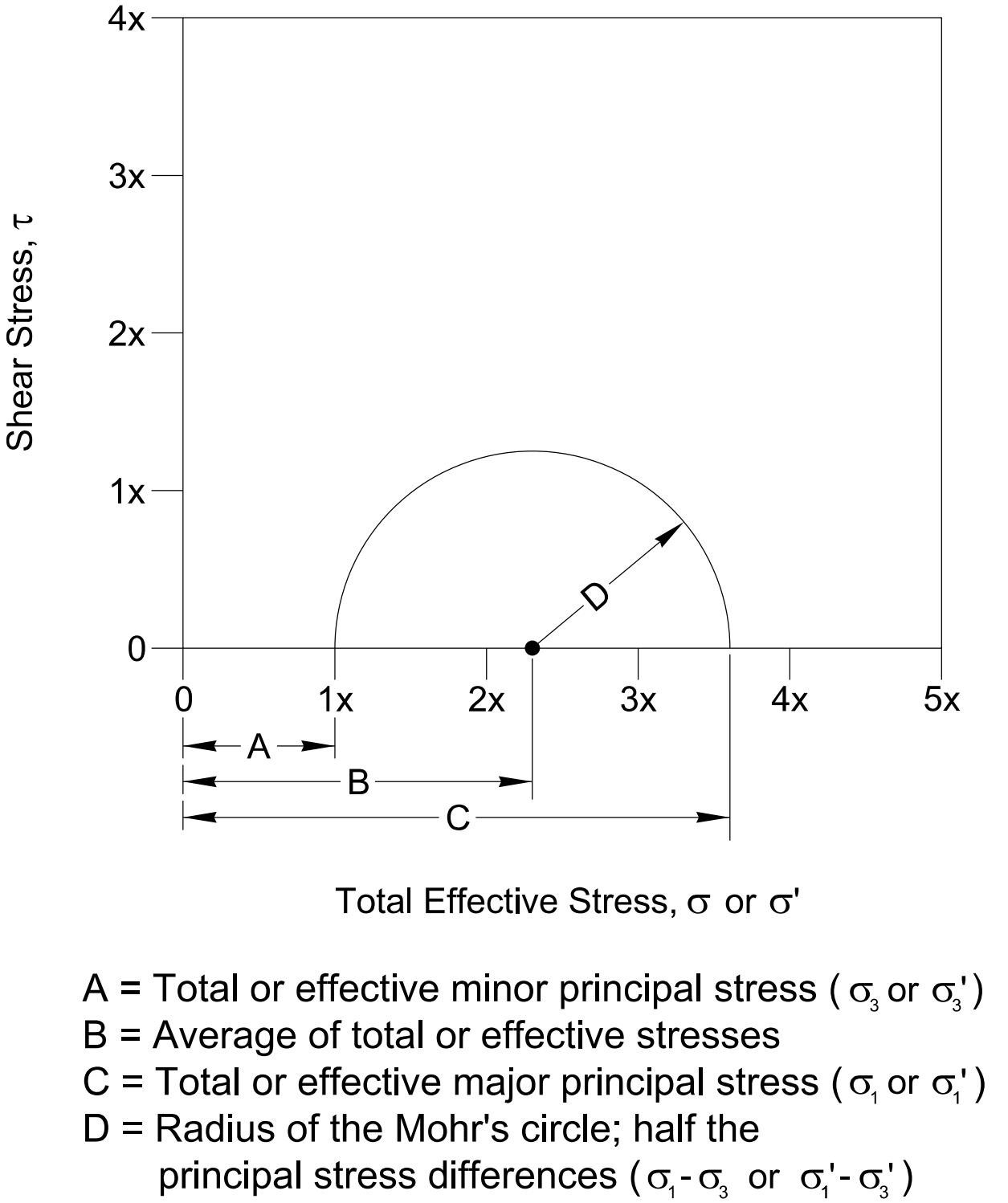
6.1 The maximum value of the deviator stress ($\sigma_d = \sigma_1 - \sigma_3$), or the maximum effective principal stress ratio σ_1 / σ_3, is selected and used to construct the Mohr's circles.

6.1.1 If pore pressure, U, was measured, subtract U from principal stresses.

6.1.2 When all Mohr's circles have been plotted, draw a line that is most nearly tangent to all the circles.

6.1.3 The construction of a Mohr Stress Circle is shown in Figure 3.

6.1.4 The intersection of this line with the ordinate axis is the cohesion (effective U is measured) value, c (c') and the angle between this line and the horizontal is the angle of internal friction, (effective is U is measured) ϕ (ϕ').



A = Total or effective minor principal stress (σ_3 or σ_3')
B = Average of total or effective stresses
C = Total or effective major principal stress (σ_1 or σ_1')
D = Radius of the Mohr's circle; half the principal stress differences ($\sigma_1 - \sigma_3$ or $\sigma_1' - \sigma_3'$)

Figure 3—Construction of Mohr Stress Circle

7. REPORTING

7.1 Project information and location of sample

7.2 Type of test performed, i.e., consolidated undrained triaxial test with pore pressure measurements or consolidated undrained triaxial test without pore pressure measurements

7.3 Type and shape of specimen, i.e., undisturbed, remolded, cylindrical, or prismatic

7.4 Initial density and moisture content

7.5 Remarks – note any unusual conditions or other data that would be considered necessary to properly interpret the results obtained

7.6 Plot of Mohr circles and envelope with cohesion and angle of internal friction.