Direct / Residual Shear Machine

S-492

ASTM D 3080  AASHTO T236

Operator’s Manual

Version 1.0

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RECORD THE FOLLOWING INFORMATION FOR FUTURE REFERENCE

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Vendor (Purchased From)

- Direct from Durham Geo Slope Indicator
- From Distributor (Name) ______________________

Other
INTRODUCTION

The purpose of the direct shear test is to determine drained strength parameters $c'$ and $\Phi'$. Since pore water pressure is neither controlled nor measured in the direct shear test, sufficient time must be allowed for consolidation and the shearing rate of the test must be sufficiently slow to allow complete dissipation of pore water pressure. If these conditions are met, imposed total stresses are equal to effective stresses.

The test method consists of placing a test specimen in the direct shear (DS) device, applying a predetermined normal stress, providing access to water for the specimen, consolidating the specimen under the normal stress, unlocking the frames that hold the test specimen, and displacing one frame horizontally with respect to the other at a constant rate of shearing deformation and measuring the shearing force and horizontal displacements as the specimen is sheared.

The direct shear test imposes a normal stress and a shear stress on a horizontal plane bisecting the sample. These stresses are computed by dividing the normal load ($P_n$) by the cross sectional area of the sample ($A_s$). Similarly, the imposed shear stress is computed by dividing the shear load ($T_s$) by the cross sectional area.

Shear stress and normal stress at failure are plotted on a Mohr-Coulomb diagram to determine drained strength parameters. Typically, three or more experiments on a similar soil at increasing levels of normal stress are required to define the Mohr-Coulomb strength envelope.
Figure 1 shows the Direct Shear (DS) device as it should be at the beginning of an experiment. The components associated with the DS device are grouped into

1) Sensors
2) Specimen Container
3) Controls.

Each set of components is described below.

1.0 SENSORS:

The DS device contains four electronic instruments or sensors that are monitored throughout the test.

These four instruments are as follows and are shown in Figures 2-5.

- Channel 1: Pressure for normal load
- Channel 2: Load cell for shear load, $T_s$.
- Channel 3: Horizontal shear displacement, $\Delta H$.
- Channel 4: Vertical displacement, $\Delta V$.

The normal load and stress applied to the specimen is controlled by compressed air.
RUNNING A TEST

acting through a pneumatic cylinder (actuator) contained in the body of the device and causes the load cross-arm seen in Figure 2 to move down. The pressure transducer, also housed in the body of the device, and corresponding readout measures air pressure supplied to the pneumatic cylinder and not normal stress or pressure on the sample. The manner in which normal stress imposed on the sample is calculated knowing the air pressure supplied to the pneumatic cylinder is described later in this section. The load cell reading, $T_s$, is output directly in pounds. Both displacement readings are in inches. The capacities and ranges associated with each instrument is as follows:

- Air Pressure for Normal Load: 0-90 psi (1500 lb)
- Shear Load Cell:
  - 0-2000 lb
  - Horizontal Displacement: 0-2 in.
  - Vertical Displacement: 0-1 in.

Figure 3: Load cell for shear load, $T_s$

Figure 4: Horizontal shear displacement, $\Delta_H$

Figure 5: Vertical displacement, $\Delta_v$
2.0 SPECIMEN CONTAINER

The soil specimen sits within an upper and lower frame which in turn sits within a specimen bath container. The entire assembly is shown in Figure 6 and can be seen on the DS device in Figure 1. The assembled specimen frames are shown in Figure 7. The two bolts shown in the middle of the frame sides (one lying on its side) are used to align and secure the two frames together during sample preparation. The four thumb screws in the corners of the upper frame are used to set a gap between the two frames prior to shearing.

Figure 8 shows the parts to the bottom frame. These parts include the frame itself, a lower platen with drainage channels that allow access to the two drainage ports seen in the bottom sides of the frame and a porous stone which sits atop the lower platen. Figure 9 shows the parts to the upper frame and include the frame, a porous stone, a top platen and a load transfer ball.

The specimen bath is shown in Figure 10. Three spacers are seen in the bottom of the container and allow for proper alignment of the specimen frame. The shear load shaft is seen extending into the box on the right side of the bath. The left end of the shaft fits into a recess in the top specimen frame as seen in Figure 6. Two reaction bolts are seen on the left side of the bath and are used to secure the specimen frame in place.
3.0 CONTROLS

A control panel with manual readout indicator boxes for the four transducers is shown in Figure 11. Each readout box is used for two channels. The display on a given readout box is for one channel only, with the channel number displayed intermittently on the readout display as seen for the top indicator box in Figure 11. To toggle back and forth between the two channels, press and briefly hold the up arrow (the left most touch button directly below the readout display) for the first channel; press and hold the down arrow (the middle touch button) for the second channel; do not press the S key (the right most touch button). This allows for setup and calibration of the sensor.

The electronic values displaced on the readout box can be tarred (zeroed) using the tare switches at the bottom of Figure 11 and below the readout indicators.
RUNNING A TEST

Four switches are provided for the four transducers. The tare feature is used typically only for the LDT’s. To tare a channel, flip the switch up, hold for a second and then release the switch. A TARE message should appear on the readout display as the operation proceeds. The readout value should then be displayed as zero. The same switch can be pushed down to clear the tarring operation. This returns the instrument reading back to its original value. A CLEAR message should appear on the display when the switch is used to clear the tare.

The three remaining control units shown in Figure 11 are the pressure regulator hob, a high-low-off pressure switch and an on-off pressure switch. The pressure regulator hob controls the amount of pressure applied to the normal load actuator. Turning the knob counterclockwise reduces pressure. The high-low-off valve is used for different ranges of applied normal load. The low load setting is used for applied normal sample loads of less than 100 lbs. The high load setting is used for loads exceeding 100 lbs. The low and high load settings activate two different pneumatic actuators having different cross-sectional piston areas. As a result, the same air pressure will create different applied normal loads for the high and low load settings. When the low load switch is selected, the normal load to the sample is computed from the equation:

\[ F_N = P_{act} \times 1.064 - 7.374 \]

where \( F_N \) is the applied normal load to the sample in pounds and \( P_{act} \) is the air pressure supplied to the actuator in pounds per square inch and as read directly on the channel 1 readout.

When the high load switch is selected, the normal load is computed from:

\[ F_N = P_{act} \times 17.609 - 4.306 \]

Equations 1 and 2 can be divided by the cross sectional area of the specimen to compute the normal stress applied to the sample. The off position for the high-low-off load switch results in no load being applied to the specimen.

The second off-load switch allows air pressure to be applied to the selected high or low load actuator. In the load position, the pressure displayed on channel 1 will be delivered to the selected high or low load actuator and the corresponding normal load applied to the specimen.

Figure 12 shows the switches necessary to control motor speed and direction. The motor controls the rate of shear displacement. The displacement rate is set with the thumb wheel selectors shown at the top of Figure 12 and can range from 0.2999 inch/minute to 0.0001 inch/minute. Changing this setting is effective only when the motor is off. The direction switch controls the displacement direction. The switch is pushed
RUNNING A TEST

either to the left or to the right and then returns on its own to the center position. Pressing the red stop button stops the motor.

Two motion control devices are attached to the deck of the DS device. These devices are the two small blue instruments shown at the back of the DS device in Figure 1. These devices have a trip switch that shuts the motor off when the water bath container holding the specimen has traveled to a predetermined limit in either direction. The red indicator lights seen in Figure 12 are lit when the corresponding motion control sensor is activated.
Figure 1 shows the DS device as it should be found at the beginning of the test. This section describes the steps involved in removing the specimen water bath from the device such that a sample can be placed.

1. Turn the power switch to the DS device shown in Figure 12 to the on position.

2. Turn the pressure regulator knob shown in Figure 11 counterclockwise to ensure that no pressure acts in the cylinders.

3. Turn both load switches shown in Figure 11 to the off position (as displayed in Figure 11).

4. Loosen the two large black plastic wing nuts that hold the load cell assembly to the vertical load cell support (see Figure 13).

5. Disconnect the shear load shaft from the load cell at the left side of the load cell (see Figure 14).

6. Loosen the large black plastic wing nut shown in Figure 5 that attaches the cross-arm for the vertical LDT and swing the vertical LDT out of the way of the DS specimen water bath. Loosen the nuts holding the horizontal LDT and swing it downwards until it rests on the DS deck. The position of the two LDT’s and the load cell after steps 4-6 are shown in Figure 15.
7. Remove the two large black plastic wing nuts holding the normal load cross arm in place and remove the cross arm as shown in Figure 16.

8. Remove the specimen water bath. It is critical to keep the roller and screw assembly beneath the bath as clean as possible. This area is shown in Figure 17.

9. Place the specimen water bath assembly on a clean sheet of paper resting on a countertop as seen in Figure 6.

10. Remove the specimen container and disassemble as seen in Figures 8 and 9.
Specimens for direct shear testing can be created by compacting materials directly into the specimen mold or by placing intact samples extruded from sampling tubes. Samples compacted directly into the specimen mold will typically be granular, non-cohesive soils. Intact samples will most likely be cohesive soils. Slightly different specimen preparation procedures are required for granular versus cohesive specimens and for specimens sheared with and without water in the bath chamber. These differences will be pointed out during the following discussion.

1.0 CONTAINER ASSEMBLY

1.1 Clean and reassemble the parts shown in Figure 8 for the bottom specimen assembly. If samples are to be soaked in water during the shear test, the porous stones should be soaked in water overnight. Alternatively, the stones can be "boiled" in a water bath under an applied vacuum. This removes air from the stones.

1.2 Place the top half of the specimen mold over the bottom half, making sure to match up the two alignment bolt holes and making sure that the four gap-set screws (seen in figure 7) are fully backed into the top specimen mold. Hand-tighten the two alignment bolts fully while making sure the inside of the mold is well aligned.

2.0 SPECIMEN PREPARATION

2.1 If granular soil is to be compacted into the mold, measure the height from the bottom porous stone to the top of the upper specimen half. This measurement should be approximately 1.5 inches. Place a predetermined and pre-weighed amount into the mold such that the compacted thickness of the specimen is approximately 1 inch. The maximum particle size for this 2.5 inch diameter mold shall be 0.25 inch or material passing the No. 3 sieve. If a No. 3 sieve is not available, then all material shall pass the No. 4 sieve. If the soil is placed with any moisture, take a separate sample for a water content determination.

2.2 Compact the granular soil by an appropriate means (hand tamping or vibration) to the desired density. Density should be calculated by measuring the height from the top of the sample to the top of the upper platen and subtracting this from the initial height from step 3. This process is shown in
2.3 If an intact cohesive sample is to be placed, trim the sample to a diameter of 2.5 inch. This can be accomplished using a consolidation cutting ring, as shown in Figure 19 along with a clay specimen.

2.4 Cut the ends of the sample to form a 1 inch specimen thickness. Slightly thicker samples can be used if appreciable consolidation is expected during application of the normal load.

2.5 Weigh the sample. Determine water content on a separate sample.

2.6 Place filter paper on the bottom porous stone, place the sample into the assembled specimen mold and place a sheet of filter paper on top of the sample.

2.7 For either soil, place the top porous stone on the specimen and then the top platen.

2.8 Place the two side spacers and one front spacer in the water bath container as shown in Figure 10.

2.9 Place the specimen mold between the spacers in the water bath container making sure the shear load shaft fits into the recess in the specimen mold.

2.10 Hand-tighten the two reaction bolts shown in Figure 20.
3.0 MOUNTING SPECIMEN BATH

3.1 Place the water bath assembly back on to the DS device. Make sure that the upper load platen is centered over the sample.

3.2 Making sure that nothing is in the way of the motion of the water bath container, set the motor speed to 0.2999 in/minute and using the direction controls, move the water bath box until it just touches the rightmost motion control sensor. The position of the box at this point is shown in Figure 21.

3.3 Place the normal load cross arm onto the vertical posts. Do not let the cross arm rest on top of the sample. If need be, move the bottom bolts on which the cross arm rests up. Move these bolts down until the load ball is just resting inside the recess in the cross arm while the two still do not touch.

3.4 Place a mini bubble level on the cross arm and level the arm by adjusting the two bottom bolts (Figure 22).

3.5 Lifting the cross arm, remove the load ball. Peer down through the hole in the middle of the cross arm to sight on top of the load platen (Figure 23).

3.6 The hole in the cross arm should align with the center of the load platen when the load platen is centered on the sample. Make fine forward and backward adjustments to the water bath assembly using the motor until alignment is achieved.
APPARATUS ASSEMBLY

Replace the load ball. Place the two large black plastic wing nuts onto the vertical posts and tighten against the cross-arm.

4.0 SENSOR SETUP

4.1 With the horizontal LDT fully extended, tare channel 3. Swing the horizontal LDT up until the tip rests against the front of the water bath box. Move the LDT in its holder until the gage reading is approximately 1.75 inch. At this point the LDT should have an additional 0.25 inch of travel into the gage. Since shear will take place by moving the box to the left, a range of 1.75 inch will be available. Tare channel 3.

4.2 Swing the vertical LDT over such that the tip rests on the cross arm near its center. With the LDT fully extended, tare channel 4. Position the LDT such that the reading is 0.5 inch, which places the LDT midway through its range.

4.3 Thread the left side of the load cell back into the shear load shaft. Leave the large black plastic wing nuts loose for the time being. The assembled DS device at this point is as shown in Figure 24.

4.4 If the samples are to be submerged in water, place water in the water bath. Squirt water into the recess around the top platen. The sample now has access to water from the top and bottom. Allow sufficient time for water to infiltrate into the sample.

5.0 NORMAL LOAD APPLICATION

5.1 Place the high-low-off switch on low. Make sure the off-load switch is off. Turn the pressure regulator knob to supply sufficient pressure to place 1 psi of normal stress on the sample. The air pressure reading (channel 1) should be 11.5 psi. Turn the off-load switch to the load position. This supplies a seating load to the sample.

5.2 If granular materials are being tested where the consolidation time is short, the data acquisition system does not need to be used during the application of the normal load. In this event, using the readout indicator for channel 4, make a record of the reading.

5.3 Turn the load-off switch to off. Note that the previous load stays on the sample while the switch is temporarily off. Depending on the normal stress selected, choose either the high or low load setting. The low load setting is
APPARATUS ASSEMBLY

for under 100 pounds of normal load while the high setting is used otherwise. Calculate the required air regulator pressure using either equation 1 or 2.

5.4 With the load-off switch still on OFF, set the desired air pressure for channel 1. When ready, flip the load-off switch to load. Full normal load is now on the sample. Note: if the specimen is a soft clay, the full normal load may need to be placed in increments to avoid squeezing of the soil up around the top porous stone and platen.

5.5 Visually monitor channel 4. The reading should stabilize within a minute or two. Write down the final reading. Use the final reading (corrected by the vertical compression of the machine parts as described in the Data Reduction section) to determine the height and density of the sample prior to shear. If consolidation time will be slow, then the data acquisition system (DAS) should be used to monitor vertical movement of the sample to ensure that primary consolidation is complete prior to conducting the shear test. Setup and execution of the DAS is described in the next section. The system should be configured and ready to run prior to the application of normal load. When ready, follow steps 24 and 25 while executing the DAS immediately prior to flipping the load-off switch to load.

5.6 Monitor the data being collected to determine when primary consolidation is complete. The process used for this determination is given in the following section. The vertical deformations should be corrected by the vertical compression of the machine parts.

6.0 TIME RATE OF CONSOLIDATION

The vertical displacement versus time record of the normal load application step is used to determine when primary consolidation is complete and to aid in the selection of a shear displacement rate. At an appropriate point in time after the normal load has been applied (typically one day for low permeability clays) stop the data collection program and copy the data file to a disk to analyze elsewhere. Immediately restart the data collection program while the data is being analyzed. Plot the data using either the square root of time or log of time method. Using this data, verify that primary consolidation has occurred. Determine the time necessary for 50 % consolidation \( t_{50} \) for later use in determining the shear displacement rate. Special precautions are required for heavily over-consolidated soils and swelling clays. Reference should be made to ASTM 3080 for techniques to deal with these situations. The vertical compression data needs to also be corrected for the compression of the device components.

7.0 SHEAR LOAD APPLICATION

7.1 When the shear test is ready to start, reposition the vertical LDT if necessary to provide adequate travel during shear.

7.2 Remove the alignment bolts. This is very important. Starting the shear test without removing these bolts will cause damage to the specimen ring and will overload the load cell.
APPARATUS ASSEMBLY

7.3 Tighten the two large black plastic wing nuts for the load cell shaft. Adjust the bolts so that a slightly negative (-2-3 pounds) load is applied to the load cell. Remember that negative loads will be registered when the sample is being sheared.

7.4 A gap between the top and bottom specimen halves is required to prevent friction between the two during shear. This is accomplished by turning (clockwise) the four gap bolts. First, turn the bolts until they just touch the bottom specimen half. If the sample is a fine grain soil, turn the bolts 3/4 of a revolution. If a fine to medium sand is used, turn the bolts 1 ¼ revolution. For coarser sands, use 1 ¾ of a revolution. Turn the bolts evenly so as to prevent tilting of the top ring. Retract the bolts such that the tips are within the body of the upper ring.

7.5 Tare the horizontal and vertical LDTs.

7.6 Select an appropriate displacement rate that allows complete dissipation of pore water pressure during shear. For clean sands, choose a time to failure of 10 minutes. For sands with large amounts of clay and all cohesive materials estimate the time to failure by the equation

\[ t_f = 50t_{50} \]

where \( t_{50} \) has been determined from consolidation data for this normal stress application. For normally to lightly overconsolidated clays, choose a displacement to failure of 0.5 inch. For all other soils, choose 0.2 inch. Calculate the displacement rate by dividing the appropriate displacement to failure by the time to failure, i.e.

\[ d_{rate} = \frac{d_f}{t_f} \]

7.7 Select channel 2 to monitor on indicator 1 and channel 3 to monitor on indicator 2.

7.8 Turn the computer on and configure the DAS for the shear test following the instructions given in the next section.

7.9 Start the DAS data collection while at the same time switching the motor direction switch to the left (limit direction).

7.10 Expect to shear the sample by a horizontal shear displacement of 0.25 to 0.5 inch. The load versus time curve should be monitored to determine when the test should be terminated.

8.0 TEST DISASSEMBLY

8.1 When the test is complete, stop the data collection program and the DS motor.

8.2 Run the motor in reverse just until the load cell shows a zero reading.

8.3 Release the air pressure from the pressure regulator.

8.4 Turn both load switches to the off position.

8.5 Disconnect the load cell and move the two LDT’s out away from the device.

8.6 Remove the water bath.
APPARATUS ASSEMBLY

8.7 Disassemble the specimen mold, clean, dry and reassemble.

8.8 Place the water bath back onto the DS device as it should have been found at the beginning of the test.
LIMITED WARRANTY

The S-492 Machines are guaranteed against defective materials and workmanship for a period of one year from the date of shipment. We will repair or replace such items as may prove defective at our option. Under no condition will we allow labor charges or other expenses to repair defective merchandise without our approval. Durham Geo Slope Indicator makes no other warranties of any kind or nature and all implied warranties or merchantability or fitness for a particular purpose which exceeds the previously stated obligation are expressly excluded. We accept no responsibility for damage or abuse to apparatus due to improper installation or operation. We accept no responsibility for and will not pay for any lost profits incidental, consequential or special damages.

For a complete warranty disclosure, please refer to the printed statement on the back of any Durham Geo Slope Indicator original invoice, or

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