

# SO-Shear

Version 1.1.8628.1

## Scientific Manual

This software is developed by Soil Office Software Group and is aimed at the evaluation of direct shear tests (laboratory and insitu). Smart capabilities are implemented and outputs are presented in a variety of formats.



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## **1 INTRODUCTION**

### **1-1 SOIL OFFICE**

“Soil Office” is a developer of geotechnical engineering software since 2013. Our main objective is to develop functional and user friendly software, capable of performing precise calculations. The following software is currently considered:

- SO-Foundation: Bearing capacity of shallow foundations
- SO-Lab: Soil mechanics laboratory tests and boring logs including:
  - SO-Sieve: Sieve analysis, Hydrometer & Atterberg limits
  - SO-Shear: Direct shear
  - SO-Unconfined: Unconfined compression
  - SO-Triaxial: Triaxial compression
  - SO-Consolidation: One-dimensional consolidation
  - SO-Log: Geotechnical engineering boring logs

Feel free to contact us regarding any criticism, recommendation or additional information.

### **1-2 SO-SHEAR**

SO-Shear is aimed at the evaluation of direct shear tests (laboratory and insitu). It has a user-friendly interface and lots of smart capabilities are implemented. Individual tabs are assigned for project information (including basic information, borings and samples) and tests. In addition to test data and corresponding calculations, software outputs are available in 12 formats.

Note that direct shear tests could randomly be generated based on user-defined criteria.

### **1-3 SOFTWARE CAPABILITIES**

#### **1-3-1 GENERAL FEATURES**

- Supports “Metric”, “SI”, “English [ksf]” and “English [psi]” units.
- User is informed about the common ranges regarding input parameters.
- 12 templates are available for the export of software outputs.
- Test data and corresponding calculations are presented in a separate format.
- Blank laboratory data sheets may be used for test data input.
- Saving files with a minimal size.

### 1-3-2 DIRECT SHEAR TEST CALCULATIONS

- Sample properties are automatically calculated.
- Various data input options.
- Area correction can be applied.
- Test data can be edited using either graphs or tables.
- Random generation of direct shear tests based on user-defined criteria, including the following:
  - Simulation of soil behavior using hyperbolic equation
  - Custom definition of soil behavior
  - By user's will, area correction may or may not be applied
  - ...

## 2 SOFTWARE INTERFACE

### 2-1 GENERAL

After running SO-Shear, the following menus are visible on the top ribbon:

**File menu:** Contains commands relating to the handling of files, such as creating a new project, save, etc.

**Main:** Project information, borings and samples are determined using this menu.

**Test:** Contains the following:

- **Direct shear:** Is aimed at the evaluation of direct shear tests.
- **Edit:** Tests performed on a sample can be copied, moved or deleted using this menu.

**Export:** Contains the following:

- **Export:** Is used to export software outputs.
- **Blank:** Includes blank laboratory data sheets.

**Help:** Contains the following:

- **Scientific manual:** Describes functionality of different parts of the software and the theories of the utilized methods.
- **Index:** Contains indexed help topics.

**License:** The permit to use the software and information on the client.

**About:** Contains general information.

- **SO-Shear:** Brief description about the current software and its version.
- **Soil Office:** Introducing Soil Office Software Group.

**Units:** Switches between the available unit systems.

## 2-2 DETAILS ON MENUS

### 2-2-1 FILE MENU

This menu is consisted of the following:

**New:** Creation of a new project.

**Open:** Opens a previously defined project.

**Save:** Saves project (with \*.sosh extension).

**Save as:** Saves project with a different name.

**Sample project:** Sample project in order to demonstrate software features and easily work with it. A number of direct shear tests have been calculated or generated by a variety of methods.

**Close:** Closes project.

**Exit:** Closes project and exits SO-Shear.

### 2-2-2 MAIN

#### 2-2-2-1 PROJECT INFORMATION

Basic project information including name, client, location and code are entered in this section. A separate field is also dedicated for notes. The user can specify the project location on the map and the coordinates will be shown in the corresponding field. Project address is also presented by activating the “Reverse geocoding” option and the user may accept it or not.

#### 2-2-2-2 TABLE OF BORINGS

Project borings are identified through this table. The input parameters are listed below:

**Boring method:** Whenever the boring is machine-drilled and the method is not included in the available options or the user prefers it not to be specified, the “-” option can be used.

**Name:** Boring name.

**Depth:** Boring depth.

**Elev.:** Ground elevation at top of boring.

**GWT:** Depth to water table measured from boring top (Ground Water Table).

**Note:** Notes regarding the boring such as weather conditions including recent rain or other events that could affect subsurface conditions.

**Export:** Defines whether the boring is included in the output or not. This option is active by default.

**Contractor:** Name of the drilling contractor.

**Start date:** Start date of drilling.

**Finish date:** Finish date of drilling.

The up and down arrows located on the right side of the table, are for the purpose of altering the order of the borings.

### 2-2-2-3 TABLE OF SAMPLES

Samples obtained within each of the borings are introduced in this table. The input parameters are listed below:

Depth: Sample depth.

USCS: Soil type according to USCS (Unified Soil Classification System).

Sample category: Sample category including “Disturbed”, “Undisturbed” and “Rock core”.

Sample type: Varies by boring method and sample category. “-” may be used if empty for any reason.

Color: Sample color. Some colors are available by default and others can be defined by the user.

Code: Sample code.

Note: Notes regarding sample or its extrusion process.

## 2-2-3 TEST

### 2-2-3-1 DIRECT SHEAR

SO-Shear is aimed at the evaluation of direct shear tests and can be used in the following situations:

- Test data: are entered and calculations are performed.
- Test generation: This option is mainly for the generation of random direct shear tests based on user-defined criteria and includes two options: “Hyperbolic” and “Free sketch”.

Note that the mentioned methods are selectable using the radio buttons available in the “Graphs & Advanced Options” section.

#### 2-2-3-1-1 TEST DATA

This option is active by default. Various sections are considered for the input and evaluation of test data which are described below:

#### ❖ General

General test properties are determined through this section including:

Test type: Fast or Slow.

Number of tests: is between 2 and 4.

Shear box:

- Shape: Circular or Square.
- Width/Diameter: Specimen diameter or lateral dimension in direction of shear.



### ❖ Data Input

This section is dedicated to the input of test data and includes the following tabs:

- Test No.: A separate tab is considered for each of the tests performed on a sample and the user can input test data using these tabs.
- Vertical displacement: Variation of vertical displacement in all tests is summarized and presented in this tab.
- Summary: Shear stress variation in all tests is presented in this tab.

Unlike the “Test No.” tabs, the “Vertical displacement” and “Summary” tabs are not editable and no extra parameters are used within them. Therefore, only the “Test No.” tabs will be described:

#### *Sample properties*

Sample properties are determined through this section.

Moisture status:

- Inundated
- Natural
- Other

$G_s$ : specific gravity of soil solids.

The following parameters are used in the table:

$H$ : sample height.

$\gamma_d$ : dry unit weight.

$w$ : moisture content.

$e$ : void ratio.

$S$ : degree of saturation.

$H_s$ : equivalent height of soil solids.

Note that each row indicates a single stage of the test:

*Initial*: The beginning of the test.

*Inundated*: After the sample is inundated. This row is disabled in case each of the “Natural” or “Other” choices are selected regarding moisture status. Also “-” is displayed as parameters values.

*Preshear*: Prior to the application of shear force to the specimen.

*Final*: After the test completion.

**Note:**

- 1- Two options are considered for data entry in the “Preshear” stage:
  - a. Height: is entered. Dry density and other parameters are calculated.
  - b. Dry density: is directly determined by the user. Other parameters are accordingly calculated.
- 2- Data entry in the “Final” stage can be done using each of the three following methods:
  - a. Height: is entered. Dry density and other parameters are calculated.
  - b. Dry density: is directly determined by the user. Other parameters are accordingly calculated.
  - c. Manual: Sometimes, there is significant soil loss during shear and the specimen shape is such that the final phase relations (density, water content, and saturation) cannot be determined with any degree of reliability. In these cases, dry density and moisture content of a representative sample can individually be measured and further calculations are accordingly proceeded.

***Above the table***

This section mainly contains settings regarding data entry of the test table.

- Vertical:
  - Load
  - Stress
  - Gauge factor, 1 div.
- Horizontal:
  - Load
    - Ring factor
    - Load
    - Stress
  - Rate of displacement
  - Gauge factor, 1 div.

*Test table*

Table columns are as follows:

Horizontal

- Disp. Reading
- Disp.
- Relative disp.

Vertical

- Disp. Reading
- Disp.

Corrected area (in case area correction is enabled)

Shear

- Load reading
- Load
- Stress

Normal stress (in case area correction is enabled)

The following are available below the test table:

More ...: Is displayed in red when filled and contains:

Date: Test date.

Time: Test time.

Tested by: Name of the technician.

Note: Notes regarding the test.

Delete test: The test in the relevant section will be deleted.

❖ Graphs & Advanced Options

Three graphs are available in this section. Every change within each of the graphs, results in the test table to update and alter accordingly.

**Note:**

- 1- Whenever “Area correction” is enabled (this option is accessible through the “Results summary” section), **the corrected values of normal and shear stresses being marked with an asterisk (\*)**, are considered for calculations.
- 2- Two modes are available for displaying horizontal displacements; Absolute and Relative. **Parameters regarding the relative mode, are marked with (%)**. Switching between the mentioned modes are done using the two radio buttons located in the lower part of the current section.

*Test summary* ( $\tau_{max} - \sigma_n / \tau_{max}^* - \sigma_{n-max}^*$ )

Variation of maximum shear stress with normal stress is plotted. The corresponding table is embedded next to the graph and contains the following columns:

$\sigma_n$ : Normal stress.

$\tau_{max}$ : Maximum shear stress.

$\Delta_{h-max}$ : Horizontal displacement corresponding to the maximum shear stress.

$\Delta_{h-max[\%]}$ : Relative horizontal displacement corresponding to the maximum shear stress.

$\sigma_{n-max}^*$ : Corrected normal stress corresponding to the maximum shear stress.

$\tau_{max}^*$ : Corrected maximum shear stress.

Note that both the table and the graph are synced with “Data Input” section and thus:

- By altering the  $\sigma_n/\sigma_{n-max}^*$  (via the table or graph), the corresponding values are updated above the test table.
- By altering the  $\tau_{max}/\tau_{max}^*$  (via the table or graph), shear stress values of the corresponding test are accordingly multiplied by the same ratio.
- By altering the  $\Delta_{h-max}/\Delta_{h-max[\%]}$ , horizontal displacement values of the corresponding test are accordingly multiplied by the same ratio.

**Shear stress** ( $\tau - \Delta_h / \tau^* - \Delta_h / \tau - \Delta_{h[\%]} / \tau^* - \Delta_{h[\%]}$ )

Variation of shear stress with horizontal displacement is plotted. Changes in the current graph are automatically applied to the test table.

$\tau$ : Shear stress.

$\tau^*$ : Corrected shear stress.

$\Delta_h$ : Horizontal displacement.

$\Delta_{h[\%]}$ : Relative horizontal displacement.

**Vertical displacement** ( $\Delta_v - \Delta_h / \Delta_v - \Delta_{h[\%]}$ )

Variation of vertical displacement with horizontal displacement is plotted. Changes in the current graph are automatically applied to the test table.

$\Delta_v$ : Vertical displacement.

#### ❖ Results Summary

The results summary of the performed tests along with some final settings (regarding calculation methods and sample type) are accessible through this section. The following columns are included in the table:

*BH/TP*: Borehole or test pit name.

*Depth*: Sample depth.

$\phi$ : Internal friction angle.

*c*: Cohesion.

Also the following options are available below the table:

*Remolded*: Reports the sample as “remolded” in the output.

*Set cohesion to zero*: Forces the trendline to cross the origin.

*Set negative cohesion to zero*: Forces the trendline to cross the origin whenever the intercept is negative.

*Area correction*: Applies area correction to the calculations.

### 2-2-3-1-2 HYPERBOLIC

This option enables the generation of sample direct shear tests using the following equation:

$$\tau = \frac{\Delta h[\%]}{\frac{1}{\frac{E}{2(1+\nu)}} + \frac{\Delta h[\%]}{\tau_{hyp}}}$$

Where:

$\tau$ : Shear stress.

$\Delta h[\%]$ : Relative lateral displacement.

$E$ : Modulus of elasticity.

$\nu$ : Poisson's ratio.

$\tau_{hyp}$ : Hyperbolic shear stress.

Note that shear stress variations using hyperbolic formula are as below:

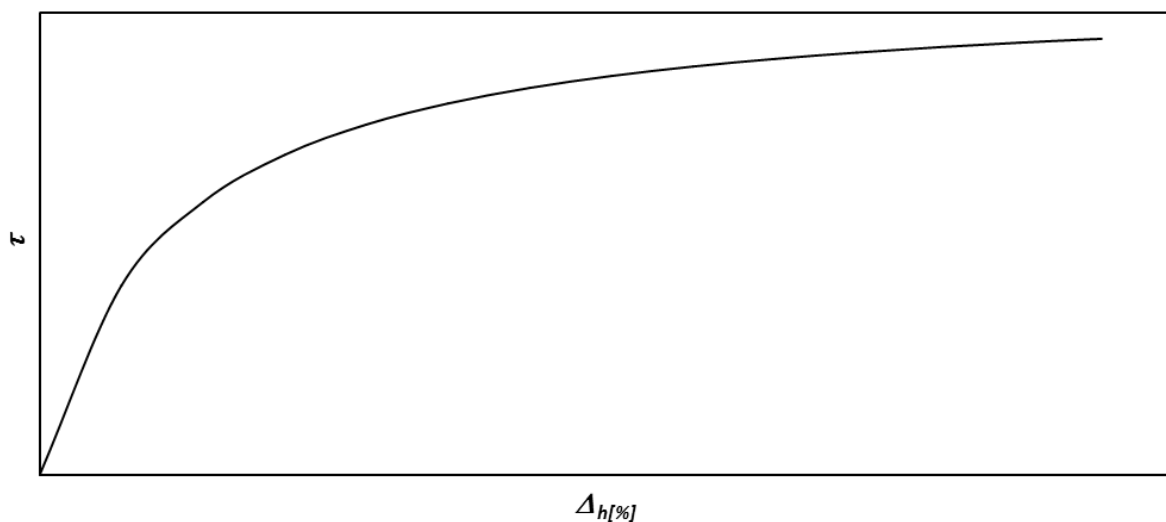


Figure 2-1 Shear stress variations using hyperbolic formula

The table next to the “shear stress plot” is used for the generation of sample tests. The following parameters are included:

$\sigma_n$ ,  $\tau_{max}$ ,  $\nu$ ,  $E$ ,  $\sigma_{n-max}^*$  &  $\tau_{max}^*$ : are previously defined.

$\Delta h_{-ult}$ : Horizontal displacement corresponding to the ultimate shear stress.

$\Delta h_{-ult}[\%]$ : Relative horizontal displacement corresponding to the ultimate shear stress.

After the completion of the table, the below options are available for the generation of sample tests:

Apply to: Depending on the user's choice, table settings may be applied to each or all of the tests.

Readings: Horizontal displacement readings regarding sample test generation, can be determined using the following two criteria:

- Divisions: The horizontal displacement corresponding to the ultimate shear stress, is divided to the number defined by the user.
- User-defined: The user can define custom readings regarding each test.

Tolerance: This option specifies the maximum allowable difference of the shear stress in calculated and generated modes.

Create nodes: Clicking on this button, creates sample direct shear tests based on the available data and settings, and the test table is updated accordingly.

**Note:** Using the “Adjust” option, maximum shear stresses regarding various tests can be set in a way that leads to the user's desirable internal friction angle and cohesion.

### 2-2-3-1-3 FREE SKETCH

This option is also dedicated to the generation of sample direct shear tests. In this method, unlike the “Hyperbolic” method where the shear stress values are calculated using the mentioned formula, the overall shape of the shear stress variations' graph is determined by user's will. Corresponding table is located next to the “shear stress plot” and contains the following:

$\sigma_n$ ,  $\tau_{max}$ ,  $\sigma_{n-max}^*$  &  $\tau_{max}^*$  : are previously defined.

*Type:* Overall graph shape; Peak & Ultimate. Peak identifies situations where the shear stress reaches a peak value and decreases afterwards. Ultimate refers to situations where the shear stress reaches the maximum at the ultimate reading.

$\Delta_{h-peak}$ : Horizontal displacement corresponding to the peak shear stress.

$\Delta_{h-peak[\%]}$ : Relative horizontal displacement corresponding to the peak shear stress.

$\Delta_{h-ult}$ : Horizontal displacement corresponding to the ultimate shear stress.

$\Delta_{h-ult[\%]}$ : Relative horizontal displacement corresponding to the ultimate shear stress.

After the completion of the table, the following options can be used for the generation of sample tests:

Apply to: Depending on the user's choice, table settings may be applied to each or all of the tests.

Primary points: Indicates the number of main points creating the overall graph shape. The number of primary points can be changed by user's will and is limited to a minimum of 5.

**Create shape:** By clicking this button, the overall shape of the shear stress variation graph is created. Note that the graph shape is random and a new graph is created each time the button is clicked.

**Readings:** Horizontal displacement readings regarding sample test generation, can be determined using the following two criteria:

- **Divisions:** Each segment of the shear stress variation graph (between two adjacent primary points) is divided to the number defined by the user.
- **User-defined:** The user can define custom readings regarding each test.

**Tolerance:** This option specifies the maximum allowable difference of the shear stress in calculated and generated modes.

**Create nodes:** Clicking on this button, creates sample direct shear tests based on the available data and settings, and the test table is updated accordingly.

**Note:**

- 1- Using the “Adjust” option, maximum shear stresses regarding various tests can be set in a way that leads to the user’s desirable internal friction angle and cohesion.
- 2- Shear stress graph shape in dense sands and heavily overconsolidated clays ( $OCR > 2$ ) are mostly as in the “Peak” condition.
- 3- Shear stress graph shape in loose sands, normally consolidated and lightly overconsolidated clays ( $OCR \leq 2$ ), are mostly as in the “ultimate” condition.

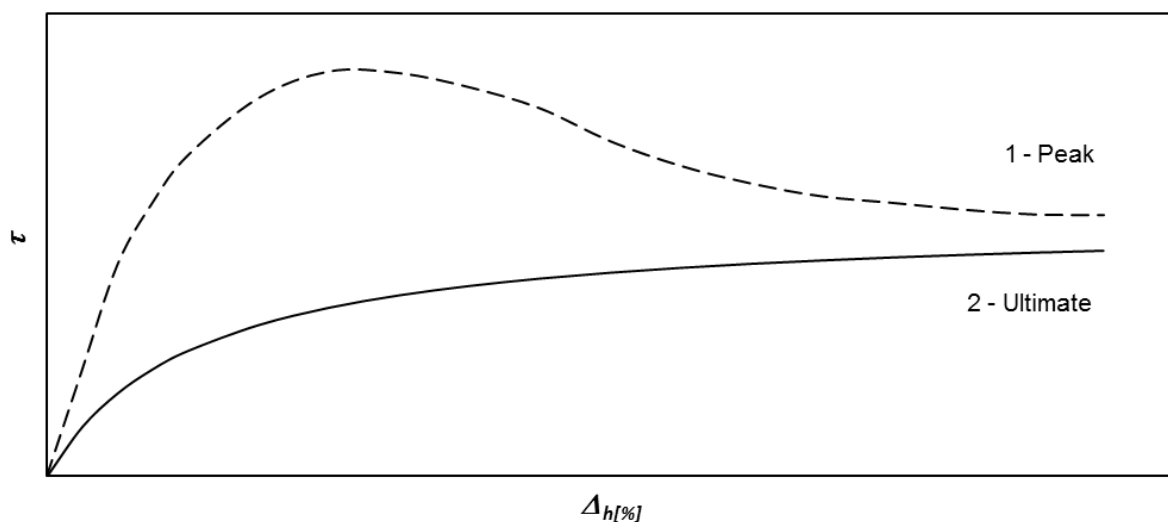


Figure 2-2 Shear stress graph shape: 1- Dense sands and heavily overconsolidated clays ( $OCR > 2$ )  
 2- Loose sands, normally consolidated and lightly overconsolidated clays ( $OCR \leq 2$ )



### 2-2-3-2 EDIT

Tests performed on a sample can be copied, moved or deleted using this menu.

Whenever the destination sample contains some data, **the user is not asked for overwrite confirmation.** Therefore the user has to be cautious while using this menu.

### 2-2-4 EXPORT

#### 2-2-4-1 EXPORT

Is used to export software outputs, including:

#### ❖ Output

Final test results available in a variety of templates, using the options below:

Sample properties: are reported from the initial stage till the following:

- Initial
- Preshear
- Final

Mode: Outputs can be exported in two modes:

- Displacement
- Relative displacement

Type: 4 outputs templates are available containing the following charts:

- Type a :  $\tau - \Delta_h$  ,  $\tau_{max} - \sigma_n$ .
- Type b :  $\tau - \Delta_h$  ,  $\Delta_v - \Delta_h$ .
- Types c & d :  $\tau - \Delta_h$  ,  $\tau_{max} - \sigma_n$  ,  $\Delta_v - \Delta_h$ .

#### ❖ Test data

Test data and corresponding calculations

#### 2-2-4-2 BLANK

Blank laboratory data sheets are accessible through this menu.

### 3 ERRORS

Possible errors in the software are divided to primary and secondary errors which are described in the current chapter.

#### 3-1 PRIMARY ERRORS

Whenever wrong or illogical data are entered, the corresponding cells' colors are altered and a message is shown in the bottom ribbon to guide the user. The utilized colors are described below:

**Red:** The cell is empty or of the wrong data type.

**Orange:** The entered value is not acceptable.

**Green:** Calculations may be performed, but the cell value seems to be illogical.

**Pink:** Demo version limitations.

**Note:** Project data cannot be exported while primary errors (except green type) exist.

#### 3-2 SECONDARY ERRORS

Unlike primary errors, secondary errors do not apply any limitations on exporting project data and are mostly encountered when changes in some data, cause some others to be inaccurate or incompatible. These errors are of 2 types; compatibility and depth:

**Compatibility errors:** Identify incompatibility among input data.

**Depth errors:** Identify errors due to depth values.

Secondary errors have the following advantages:

- Software does not crash.
- All errors regarding each input data are individually specified.

**Note:** By clicking on the error types located beneath the tables, a message is shown and the user is informed about the probable cause (or causes) of the errors.

## **4 CALCULATION THEORIES**

In this chapter, brief description regarding direct shear test is presented. Also utilized parameters along with calculation methods are fully described. Note that all parameters are defined in this chapter for the ease of access and the calculational parameters are marked with an asterisk (\*).

### **4-1 TEST SUMMARY**

The direct shear test is suited to the relatively rapid determination of consolidated drained strength properties because the drainage paths through the test specimen are short, allowing excess pore pressure to dissipate more rapidly than other drained stress tests. The specimen is deformed at a controlled rate on or near a single shear plane determined by the configuration of the apparatus.

This test method consists of placing the test specimen in the direct shear device applying a predetermined normal stress, providing for wetting or draining of the test specimen, or both, consolidating the specimen under the normal stress, unlocking the shear box halves that hold the test specimen, and shearing the specimen by displacing one shear box half laterally with respect to the other at a constant rate of shearing deformation while measuring the shearing force, relative lateral displacement, and normal displacement. Note that the shearing rate must be slow enough to allow nearly complete dissipation of excess pore pressure.

## 4-2 SAMPLE PROPERTIES

The first step for the evaluation of sample properties is to determine the specific gravity of soil solids and the moisture status of the sample during test.

Moisture status

- Inundated
- Natural
- Other

$G_s$ : Specific gravity of soil solids.

Below parameters are calculated using soil volume and density relations:

$H$ : sample height.

$\gamma_d$ : dry unit weight.

$w$ : moisture content.

$e$ : void ratio.

$S$ : degree of saturation.

$H_s$ : equivalent height of soil solids.

**Note:**

- 1- Saturation is assumed to be “100 [%]” for inundated samples.
- 2- In the calculation process, it is assumed that the decrease in sample volume is applied to the air and water volumes, respectively.

### 4-3 TEST TABLE

Current section is separately presented regarding each of the four unit systems; “Metric”, “SI”, “English [ksf]” and “English [psi]”.

#### 4-3-1 METRIC

Direct shear test contains the following parameters:

Horizontal:

- Gauge factor.
- Displacement reading ( $R_{\Delta h}$ ).
- (\*) Displacement ( $\Delta_h$ ), [mm].
- (\*) Relative displacement ( $\Delta_{h(\%)}$ ), [%].

Vertical:

- Gauge factor.
- Displacement reading ( $R_{\Delta v}$ ).
- (\*) Displacement ( $\Delta_v$ ), [mm].

Shear box:

- Width ( $D$ ), [cm].
- Diameter ( $D$ ), [cm].
- (\*) Area ( $A$ ), [cm<sup>2</sup>].

Shear:

- Ring factor, [kg].
- Load reading ( $R_{Fs}$ ).
- (\*) Load ( $F_s$ ), [kg].
- (\*) Stress ( $\tau$ ), [kg/cm<sup>2</sup>].

Normal:

- Load ( $F_n$ ), [kg].
- (\*) Stress ( $\sigma_n$ ), [kg/cm<sup>2</sup>].

Initial calculations are as follows:

$$\Delta_h = R_{\Delta h} \times \text{Horizontal gauge factor}$$

$$\Delta_{h(\%)} = \frac{\Delta_h}{D}$$

$$\Delta_v = R_{\Delta v} \times \text{Vertical gauge factor}$$

$$A = \begin{cases} D^2 & \text{Square} \\ \frac{\pi D^2}{4} & \text{Circular} \end{cases}$$

$$F_s = R_{F_s} \times \text{Ring factor}$$

$$\tau = \frac{F_s}{A}$$

$$\sigma_n = \frac{F_n}{A}$$

**Note:**

- 1- Each of the parameters  $\Delta_h$ ,  $\Delta_v$ ,  $F_s$ ,  $\tau$  and  $\sigma_n$ , can be directly defined by the user.
- 2- In case the “Area correction” is enabled, the “A\*” (corrected shear box area) replaces “A” in the above equations.

$$A^* = \begin{cases} D(D - \Delta_h) & \text{Square} \\ \frac{D^2}{2} \left( \theta - \frac{\Delta_h}{D} \sin \theta \right) ; \theta = \cos^{-1} \left( \frac{\Delta_h}{D} \right) ; \theta \text{ is in radians} & \text{Circular} \end{cases}$$

- 3- Parameters calculated using “A\*”, are marked by an asterisk (\*).

$$\tau^* = \frac{F_s}{A^*} ; \sigma_n^* = \frac{F_n}{A^*}$$

### 4-3-2 SI

Direct shear test contains the following parameters:

Horizontal:

- Gauge factor.
- Displacement reading ( $R_{\Delta h}$ ).
- (\*) Displacement ( $\Delta_h$ ), [mm].
- (\*) Relative displacement ( $\Delta_{h(\%)}$ ), [%].

Vertical:

- Gauge factor.
- Displacement reading ( $R_{\Delta v}$ ).
- (\*) Displacement ( $\Delta_v$ ), [mm].

Shear box:

- Width ( $D$ ), [cm].
- Diameter ( $D$ ), [cm].
- (\*) Area ( $A$ ), [cm<sup>2</sup>].

Shear:

- Ring factor, [N].
- Load reading ( $R_{F_s}$ ).
- (\*) Load ( $F_s$ ), [N].
- (\*) Stress ( $\tau$ ), [kPa].

Normal:

- Load ( $F_n$ ), [N].
- (\*) Stress ( $\sigma_n$ ), [kPa].

Initial calculations are as follows:

$$\Delta_h = R_{\Delta h} \times \text{Horizontal gauge factor}$$

$$\Delta_{h(\%)} = \frac{\Delta_h}{D}$$

$$\Delta_v = R_{\Delta v} \times \text{Vertical gauge factor}$$

$$A = \begin{cases} D^2 & \text{Square} \\ \frac{\pi D^2}{4} & \text{Circular} \end{cases}$$

$$F_s = R_{F_s} \times \text{Ring factor}$$

$$\tau = \frac{F_s}{A}$$

$$\sigma_n = \frac{F_n}{A}$$

**Note:**

- 1- Each of the parameters  $\Delta_h$ ,  $\Delta_v$ ,  $F_s$ ,  $\tau$  and  $\sigma_n$ , can be directly defined by the user.
- 2- In case the “Area correction” is enabled, the “A\*” (corrected shear box area) replaces “A” in the above equations.

$$A^* = \begin{cases} D(D - \Delta_h) & \text{Square} \\ \frac{D^2}{2} \left( \theta - \frac{\Delta_h}{D} \sin \theta \right) ; \theta = \cos^{-1} \left( \frac{\Delta_h}{D} \right) ; \theta \text{ is in radians} & \text{Circular} \end{cases}$$

- 3- Parameters calculated using “A\*”, are marked by an asterisk (\*).

$$\tau^* = \frac{F_s}{A^*} ; \sigma_n^* = \frac{F_n}{A^*}$$



### 4-3-3 ENGLISH [KSF]

Direct shear test contains the following parameters:

Horizontal:

- Gauge factor.
- Displacement reading ( $R_{\Delta h}$ ).
- (\*) Displacement ( $\Delta_h$ ), [in.].
- (\*) Relative displacement ( $\Delta_{h(\%)}$ ), [%].

Vertical:

- Gauge factor.
- Displacement reading ( $R_{\Delta v}$ ).
- (\*) Displacement ( $\Delta_v$ ), [in.].

Shear box:

- Width ( $D$ ), [in.].
- Diameter ( $D$ ), [in.].
- (\*) Area ( $A$ ), [in.<sup>2</sup>].

Shear:

- Ring factor, [lb].
- Load reading ( $R_{Fs}$ ).
- (\*) Load ( $F_s$ ), [lb].
- (\*) Stress ( $\tau$ ), [ksf].

Normal:

- Load ( $F_n$ ), [lb].
- (\*) Stress ( $\sigma_n$ ), [ksf].

Initial calculations are as follows:

$$\Delta_h = R_{\Delta h} \times \text{Horizontal gauge factor}$$

$$\Delta_{h(\%)} = \frac{\Delta_h}{D}$$

$$\Delta_v = R_{\Delta v} \times \text{Vertical gauge factor}$$

$$A = \begin{cases} D^2 & \text{Square} \\ \frac{\pi D^2}{4} & \text{Circular} \end{cases}$$

$$F_s = R_{F_s} \times \text{Ring factor}$$

$$\tau = \frac{F_s}{A}$$

$$\sigma_n = \frac{F_n}{A}$$

**Note:**

- 1- Each of the parameters  $\Delta_h$ ,  $\Delta_v$ ,  $F_s$ ,  $\tau$  and  $\sigma_n$ , can be directly defined by the user.
- 2- In case the “Area correction” is enabled, the “A\*” (corrected shear box area) replaces “A” in the above equations.

$$A^* = \begin{cases} D(D - \Delta_h) & \text{Square} \\ \frac{D^2}{2} \left( \theta - \frac{\Delta_h}{D} \sin \theta \right) ; \theta = \cos^{-1} \left( \frac{\Delta_h}{D} \right) ; \theta \text{ is in radians} & \text{Circular} \end{cases}$$

- 3- Parameters calculated using “A\*”, are marked by an asterisk (\*).

$$\tau^* = \frac{F_s}{A^*} ; \sigma_n^* = \frac{F_n}{A^*}$$

#### 4-3-4 ENGLISH [PSI]

Direct shear test contains the following parameters:

Horizontal:

- Gauge factor.
- Displacement reading ( $R_{\Delta h}$ ).
- (\*) Displacement ( $\Delta_h$ ), [in.].
- (\*) Relative displacement ( $\Delta_{h(\%)}$ ), [%].

Vertical:

- Gauge factor.
- Displacement reading ( $R_{\Delta v}$ ).
- (\*) Displacement ( $\Delta_v$ ), [in.].

Shear box:

- Width ( $D$ ), [in.].
- Diameter ( $D$ ), [in.].
- (\*) Area ( $A$ ), [in.<sup>2</sup>].

Shear:

- Ring factor, [lb].
- Load reading ( $R_{Fs}$ ).
- (\*) Load ( $F_s$ ), [lb].
- (\*) Stress ( $\tau$ ), [psi].

Normal:

- Load ( $F_n$ ), [lb].
- (\*) Stress ( $\sigma_n$ ), [psi].

Initial calculations are as follows:

$$\Delta_h = R_{\Delta h} \times \text{Horizontal gauge factor}$$

$$\Delta_{h(\%)} = \frac{\Delta_h}{D}$$

$$\Delta_v = R_{\Delta v} \times \text{Vertical gauge factor}$$

$$A = \begin{cases} D^2 & \text{Square} \\ \frac{\pi D^2}{4} & \text{Circular} \end{cases}$$

$$F_s = R_{F_s} \times \text{Ring factor}$$

$$\tau = \frac{F_s}{A}$$

$$\sigma_n = \frac{F_n}{A}$$

**Note:**

- 1- Each of the parameters  $\Delta_h$ ,  $\Delta_v$ ,  $F_s$ ,  $\tau$  and  $\sigma_n$ , can be directly defined by the user.
- 2- In case the “Area correction” is enabled, the “A<sup>\*</sup>” (corrected shear box area) replaces “A” in the above equations.

$$A^* = \begin{cases} D(D - \Delta_h) & \text{Square} \\ \frac{D^2}{2} \left( \theta - \frac{\Delta_h}{D} \sin \theta \right) ; \theta = \cos^{-1} \left( \frac{\Delta_h}{D} \right) ; \theta \text{ is in radians} & \text{Circular} \end{cases}$$

- 3- Parameters calculated using “A<sup>\*</sup>”, are marked by an asterisk (\*).

$$\tau^* = \frac{F_s}{A^*} ; \sigma_n^* = \frac{F_n}{A^*}$$

#### 4-4 RESULTS ANALYSIS

After the completion of all test data, soil internal friction angle ( $\phi$ ) and cohesion ( $c$ ) can be calculated as follows:

- 1- Maximum shear stress in each of the tests ( $\tau_{max}$ ) is determined.
- 2- Normal ( $\sigma_n$ ) and maximum shear stresses ( $\tau_{max}$ ) regarding all tests, are plotted (on the horizontal and vertical axes, respectively) in a chart.
- 3- The linear trendline best fitted to the points, is drawn.
- 4- The slope and the intercept of the trendline, are soil internal friction angle ( $\phi$ ) and cohesion ( $c$ ), respectively.

**Note:**

- 1- In case the “Area correction” is enabled, the above steps are performed using  $\sigma_{n-max}^*$  and  $\tau_{max}^*$ . Note that by applying the “Area correction”, normal stress is constantly changed during test.

$\tau_{max}^*$ : maximum shear stress when area correction is applied.

$\sigma_{n-max}^*$ : normal stress corresponding to  $\tau_{max}^*$ .

- 2- According to ASTM D3080, failure is often taken as the maximum shear stress attained, or in the absence of a peak condition, the shear stress at 10 [%] relative lateral displacement. Depending on soil behavior and field application, other suitable criteria may be defined at the direction of the requesting agency.

## 5 CONTACT US

Feel free to contact us regarding any criticism, recommendation or additional information.

- 1- Visit [www.soiloffice.com/ContactUs](http://www.soiloffice.com/ContactUs)
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(Also available on WhatsApp)
- 4- Call “Emad.Zargaran” via Skype.

## 6 LIST OF SYMBOLS

Symbol	Description
$A$	area of the shear box
$A^*$	corrected area of the shear box
$c$	cohesion
$D$	specimen diameter or lateral dimension in direction of shear
$e$	void ratio
$E$	modulus of elasticity
$Elev.$	ground elevation at top of boring
$F_n$	normal load
$F_s$	shear load
$g_d / \gamma_d$	dry unit weight
$G_s$	specific gravity of soil solids
$GWT$	depth to water table measured from boring top (Ground Water Table)
$H$	sample height
$H_s$	equivalent height of soil solids
$R_{Fs}$	shear load reading
$R_{\Delta h}$	horizontal displacement reading
$R_{\Delta v}$	vertical displacement reading
$S$	degree of saturation
$USCS$	Unified Soil Classification System
$w$	moisture content
$\Delta_h$	horizontal displacement
$\Delta_h(\%)$	relative horizontal displacement
$\Delta_{h-max}$	horizontal displacement corresponding to the maximum shear stress
$\Delta_{h-max}[\%]$	relative horizontal displacement corresponding to the maximum shear stress
$\Delta_{h-peak}$	horizontal displacement corresponding to the peak shear stress
$\Delta_{h-peak}[\%]$	relative horizontal displacement corresponding to the peak shear stress
$\Delta_{h-ult}$	horizontal displacement corresponding to the ultimate shear stress
$\Delta_{h-ult}[\%]$	relative horizontal displacement corresponding to the ultimate shear stress
$\Delta_v$	vertical displacement
$\phi$	internal friction angle
$\nu$	Poisson's ratio
$\sigma_n$	normal stress
$\sigma_n^*$	corrected normal stress
$\sigma_{n-max}^*$	corrected normal stress corresponding to $\tau_{max}^*$
$\tau$	shear stress
$\tau^*$	corrected shear stress
$\tau_{hyp}$	hyperbolic shear stress
$\tau_{max}$	maximum shear stress
$\tau_{max}^*$	corrected maximum shear stress