International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

Development of Computer Program for Calculating Shear Parameters of Soil

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Abstract: ***In the current era of electronic data, analysis and storage each spectrum of manufacturing and service industries is migrating from manual system to electronic system. This electronic system uses a tool which is called software or program. In civil engineering also for various software are used for activities like analysis & design, drawings, estimates, project planning and final documentations. As some software available in market are of general in nature designed for all industries and for common utility functions, customized software for a particular problem or stream of knowledge is becomes very essential. In case of soil testing and reporting engineers prefer excel or its equivalent cell based calculation software or applications. The cell based calculations provide a wide range of mathematical functions, graph facilities etc. but many times lacks in clear output, systematic data storage and retrieval, on account of generic nature of the software. An application or customized program devised as per need of the testing procedure which can be used for calculations, deriving correct and non-ambiguous results and data storage provides efficiency in testing activities. The content in this paper is an effort to develop a program for testing calculations and drawings graphs as per Indian standard code of practice for soil tests. This paper covers programing for working out shear parameters of soil by (i) Direct Shear Test and (ii) Triaxial Shear Test.***

Keywords: Soil Testing, Shear Parameters, Computer program

1. Introduction

In construction industry the quality control is one of the prime activities. The quality control starts from soil investigations, finding out sources for the construction materials, asserting its supply during full tenure of project, during construction stage testing of the materials used as per standard guidelines, and after construction integrating all certification of the structure on the basis of the design and quality control.

The quality control part is mostly taken care by Quality Control (QC) Department of an organization. The QC department generally carries out the investigation and testing activities with (1) in house and (2) outsourced activities.

In both cases the materials are sampled as per the codal / standard procedures, tested as per the codal provisions, and finally results are reported in prescribed format stating the merits of the materials used in construction in terms of qualitative / quantitative results.

In case of soil testing first disturbed and (or) undisturbed soil samples are taken from field by various methods. The samples are brought to the laboratory for testing and finding out various parameters of it.

Generally, soil samples are tested for moisture content, wet and dry densities, specific gravity, particles sizes and its proportion and shear parameters for Safe Bearing Capacity Calculations. Some specific tests like permeability, consolidation properties, CBR etc are also worked out as per specific project requirements

To find out shear parameters viz cohesion ‘c’ and angle of internal friction ‘ϕ’ of soil sample there are two methods viz (1) Direct shear Test and (2) Triaxial Shear Tests are suggested in Indian Standard Code of Practice for Soil Tests.

IS: 2720 (Part 13):1986 Reaffirmed 2016 suggests method of testing soil sample by Direct Shear Method. In this method a soil sample of size 60 x 60 x 20 mm either from undisturbed soil sample or from compacted or remoulded sample is used for testing. Sometimes Soil specimen may also be directly prepared in the box by compaction. The sample so prepared is placed in the shear testing machine as per Figure-1

The sample is loaded for a predetermined vertical stress and shear load is applied at constant rate of strain to the sample to make it fail by shear. The sample is tested for three vertical set of stresses and corresponding shear stresses are recorded. A plot of Normal Stress V/s Shear Stress is drawn for various normal stress values and a best fit straight line is drawn through the graph points. The intercept of graph line

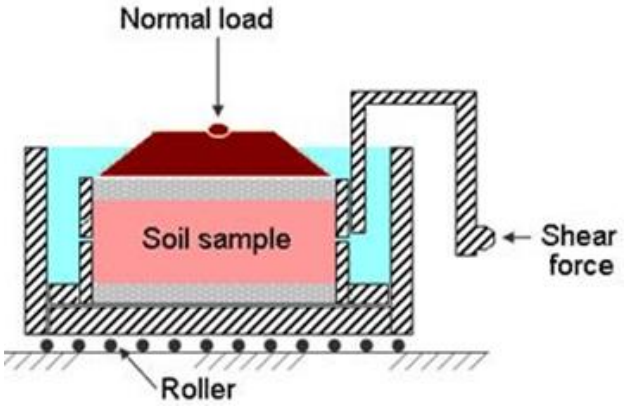

Figure 1: Box Shear Test Arrangement

to the Y axis denotes Cohesion value ‘c’ and angle with the horizontal axis gives value of angle internal friction ‘ϕ’. Figure-2 While drawing graph manually a good judgement of averaging of observed value needs to be applied. In case

of MS Office tool like Excel linier trendline tool is used to find the draw the best fit line. The equation displayed on the graph needs to interpreted for cohesion value 'c' and angle value 'ϕ'.

IS: 2720 (Part 11):1993 Reaffirmed 2016 suggests method of testing soil sample by Triaxial Shear Method. In this method a soil sample of size 38mm diameter x 76mm height either from undisturbed soil sample or from compacted or remoulded sample is used for testing. The sample so prepared is placed in the shear testing machine as per Figure-3.

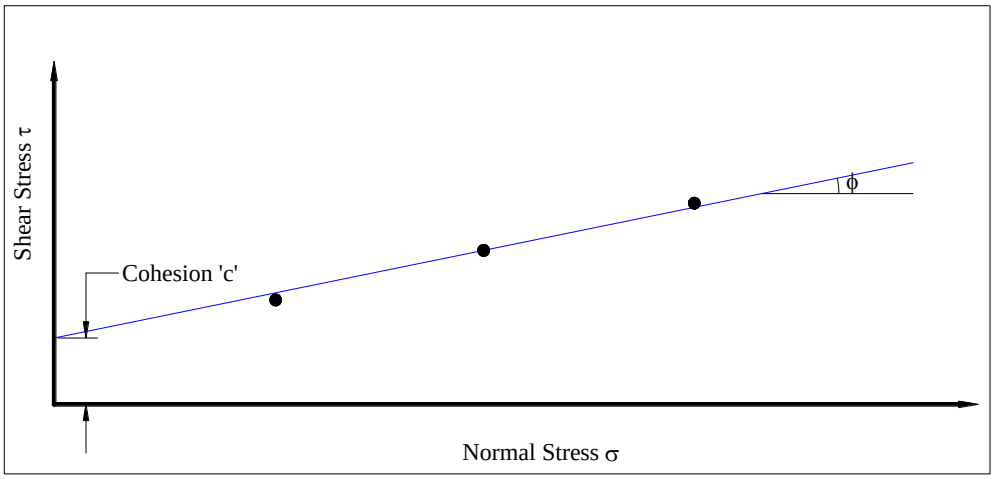

Figure 2: Box Shear Test Typical graph

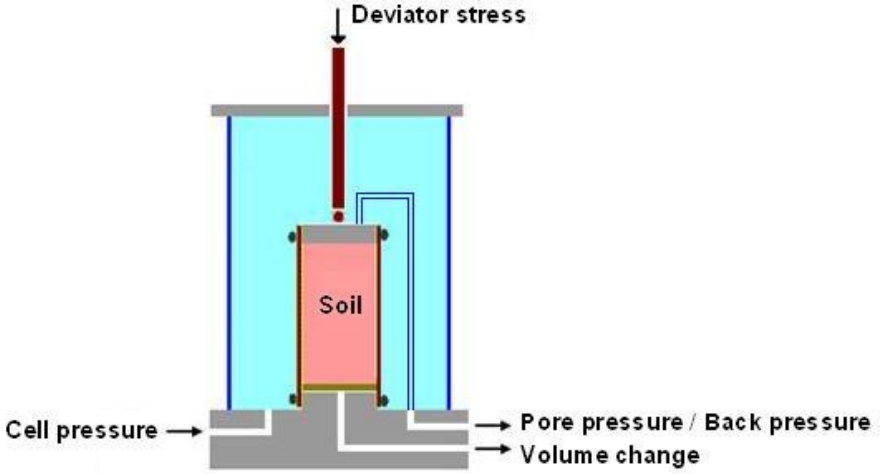

Figure 3: Triaxial Shear Test Arrangement

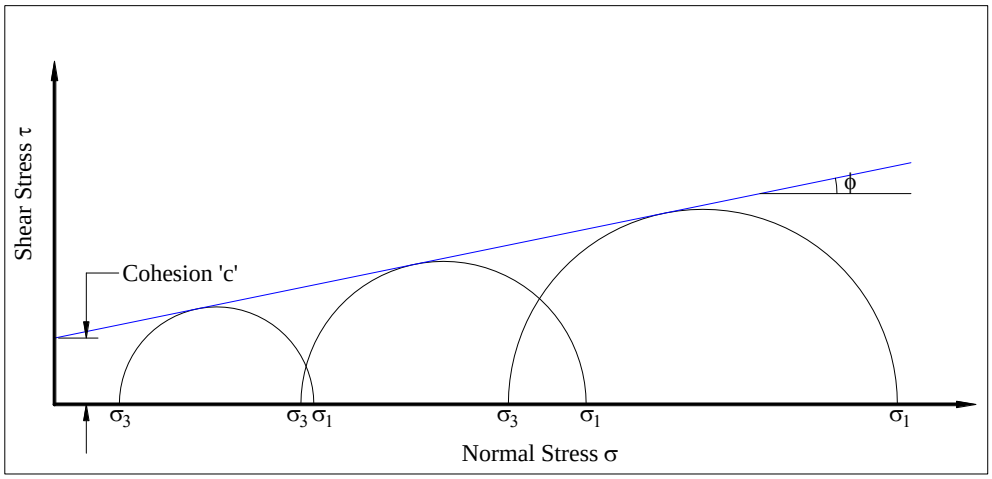

Figure 4: Typical graph for Triaxial Test

The sample is loaded for a predetermined confining stress (σ3) and normal stress (σ1) is applied at constant rate of strain to the sample to make it fail by shear. The sample is tested for three set of confining stresses and corresponding normal stresses are recorded. The normal stress and confining stress for each set of observations are plotted as Mohr's circle and tangent to the Mohr's circles is drawn. The intercept of the tangent and Y axis gives value of cohesion

'c' and angle of the tangent with horizontal axis gives the angle 'ϕ'. Figure-4.

The said procedure for the drawing graph for normal and shear stress, drawing best fit line by linier regression and finding out cohesion 'c' and friction angle 'ϕ' for direct shear test and drawings Mohr's circles, drawing tangents, and finding out cohesion 'c' and friction angle 'ϕ' for triaxial shear test is programmed in C-sharp language as per method described subsequently.

Current Project:
From the host of computer programming languages available in the market C# pronounced as C Sharp is used for programing in the current study. C Sharp is a multi-paradigm programming language that supports imperative, generic and object-oriented programming. It is a part of the Microsoft .NET Framework. It is similar to C++ in its object-oriented syntax and is also influenced by Java and Delphi. The flexibility of C Sharp for desktop standalone application and web applications with static local data and dynamic server data is also merits for its section.

The development of any computer program has five parts or divisions.

1) **Clarifying / Defining the Problem:** In this part the objectives of the program, desired output, desired input, processing of input with methods, feasibility of the implementing the program as decided.
2) **Designing the problem:** In this part the flow of the operation on input parameter and deriving output parameter is planned. In case of object oriented Graphic User Interface (GUI) based program, forms are designed to house the inputs and output are also designed. Flow charts with logics are prepared in this part and all the raw work made ready for the coding.
3) **Coding the Program:** In this parts forms with control like, textboxes, buttons, labels, combo / list boxes, radio buttons or any other type of user friendly & understandable controls are prepared. Variable of appropriate type like, string, integer, single, double, Boolean etc. are assigned to the input and out put data. Arithmetic, trigonometrical operations with and without iterative actions are coded as per the syntax of the language. Errorless and correct results are ensured by putting intermediate checks and debugging commands. The final results with input data and output data if required is stored on local hard disk or server as per the requirement.
4) **Testing the Program:** In this part the program coded as above is tested for its correctness and accuracy. The input data is entered in the forms and the output obtained is checked / verified / validated though other tools. Errors, ambiguities etc. traced in the program and removed / corrected and final correct output is obtained.
5) **Documentation:** Once the coding of the program is established as correct one giving desired validated results the code is cleaned up for the unnecessary debug /checking points, duplicated variables, temporary sub programs etc. are streamlined and a neat and clean code is prepared and backed up as security.

Programing in C Sharp

(1) Clarifying and defining the problem.
In this part two soil tests viz direct shear test and triaxial shear test were selected for programing. The objectives to find out cohesion 'c' and angle 'ϕ' are fixed for the program. Also drawing graph for the same is fixed as objective. The output or the results like 'c' and 'ϕ' parameters are also defined as variables. The input data / parameters like normal stresses, confining stresses in form of variables are defined.

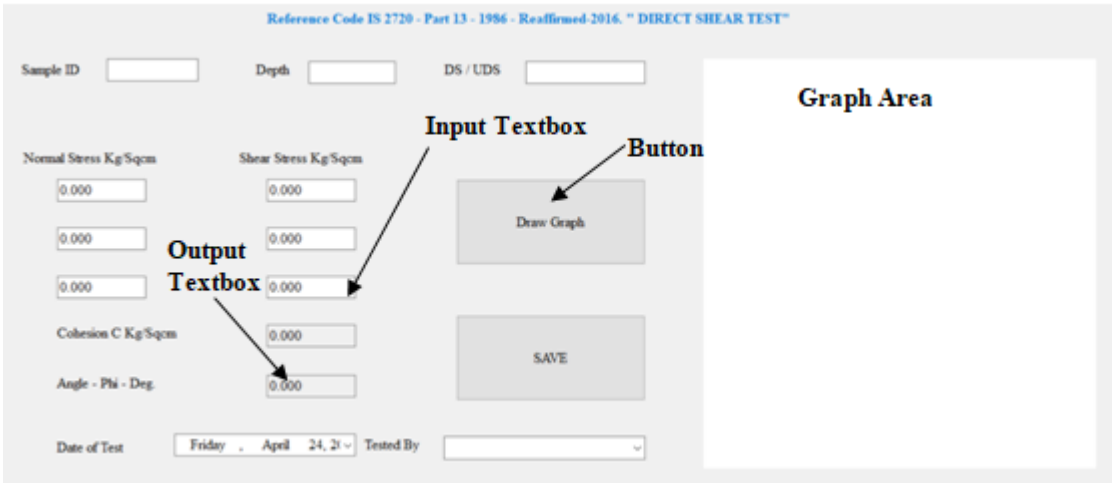

Figure 5: Form Design for Direct Shear Test

(2) Designing the problem
In case of direct shar test steps for the linier regression of normal stress and shear stress values are designed. In case of triaxial shear test the method to derive co-ordinates of Mohr's circle for set of σ3 and σ1 values, and method for drawing tangent to the Mohr's circle is decided. Also, general validations for input like preventing alphabet, symbol, null values, multiple decimal points etc. in to input data, and specific validations like values shall be more than zero, relative validations like σ3 shall not be less than σ1 etc. are perceived.

(3) Coding the Program

(A) Direct Shear Test Calculation of Cohesion 'c' and angle 'ϕ'.

The actual work of form design with programing is done in this part. The form for Direct Shear Test is designed considering data to be entered. Different names to variable are assigned on form and in code as follows

Variables	On Form	In Code
Three normal stress and Three shear stresses.	BXTFX1, BXTFX2, BXTFX3, BXTFY1, BXTFY2, BXTFY3- Open for Input, the input shall be non - zero, non-negative, non-alphabetic	X1C, X2C, X3C, Y1C, Y2C, Y3C, as double
Cohesion 'c' and Angle 'f'	BXTInterCept_F, BXTSlope_F - Locked for input	Intercept, Slope as double

The figure5 shows form design for direct shear test. The general data like Sample ID, Depth at which sample is taken, type of sample Disturbed / Undisturbed is entered as string. The data required for calculations are three pairs of normal and shear stress readings obtained from the test. These readings may or may not have decimal points hence those data are defined as double. Same way out put of cohesion 'c' and angle 'ϕ' is defined as double. The description for data entry, titles etc. known as labels. The save and Draw Graph are the buttons which takes click or any other command and actions are performed on it is known as events.

The variables used in the input, output and during calculations are defined initially with respective data type. The general data types are integer, single, double, Boolean etc. Here double type is used to define variables which are numbers. The input of normal and shear stresses are defined as X1C, X2C, X3C and Y1C, Y2C, Y3C as double data type. The data entered on the form is always a string data from the textbox hence it needs to be converted in to double data type. The whole calculations are triggered and executed by clicking button Draw Graph and event DrawGraph_Click.

As per the statistical method the X and Y data needs to be processed with Sum of X Data, Sum of Y Data, Sum of (X multiplied by Y) Sum of X Squared operations to arrive at slope and intercept of a linier equation. The code and its explanation of the code is as follows.

The bold and italic text is explanation and other text is the code.

Defining variables and its types

Numbers of observation sets = 3

```
int N = 3;
double X1C, X2C, X3C, Y1C, Y2C, Y3C;
double SumOfX, SumOfY, SumOfXY, SumOfXsq, Intercept, Slope;
```

Defining event on button click.

```
private void DrawGraph_Click (object sender, EventArgs e)
{
```

Comment statement doesn't participate in program.

```
// linier regression
```

Converting string or text to double type number

```
X1C = double.Parse(BXTFX1.Text);
X2C = double.Parse(BXTFX2.Text);
X3C = double.Parse(BXTFX3.Text);
Y1C = double.Parse(BXTFY1.Text);
Y2C = double.Parse(BXTFY2.Text);
Y3C = double.Parse(BXTFY3.Text);
```

Calculating intermediate parameters, slope and intercept.

```
SumOfX = X1C + X2C + X3C;
SumOfXsq = (X1C * X1C) + (X2C * X2C) + (X3C * X3C);
SumOfY = Y1C + Y2C + Y3C;
SumOfXY = (X1C * Y1C) + (X2C * Y2C) + (X3C * Y3C);
Slope = ((N * SumOfXY) - (SumOfX * SumOfY)) / ((N *
SumOfXsq) - (SumOfX * SumOfX));
Intercept = ((SumOfY) - (Slope * SumOfX)) / N;
```

Defining drawing points on graph in form of array.

```
double[] Ptx = { X1C, X2C, X3C };
double[] Pty = { Y1C, Y2C, Y3C };
```

Drawing best fit regression line.

```
BXTChart.Series[0].IsValueShownAsLabel = true;
BXTChart.Series[0].Points.DataBindXY(Ptx,Pty);
```

Extrapolating the equation for the intercept and drawing extended line

```
double X4C =X3C+( X3C - X2C)/10;
double Y4C = Intercept + Slope * X4C;
double[] Ptxx = {0, X4C};
double[] Ptyy = {Intercept, Y4C};
BXTChart.Series[1].IsValueShownAsLabel = false;
BXTChart.Series[1].Points.DataBindXY(Ptxx, Ptyy);
```

Calculating slope and converting it in to degrees

```
Slope = Math.Atan(Slope);
Slope = Slope * 180 / Math.PI;
```

Writing intercept and slope values cohesion 'c' and angle 'f'

```
BXTInterCept_F.Text = (Math.Round(Intercept, 2).ToString());
BXTSlope_F.Text = (Math.Round (Slope,2).ToString());
}
```

(4) Testing the Program

Figure-6 shows input and output obtained by clicking the Draw Graph button. The cohesion 'c' is 0.58 kg/sqcm and angle 'ϕ' is 8.3 degrees for the given set of normal stress and shear stress. The same is verified by using Microsoft Excel and verification is shown in Figure-7. The intercept value 0.5833 is rounded in to 0.58. The angle shown in excel is in radian as 0.1458 which if converted in degrees turns to 8.30°.

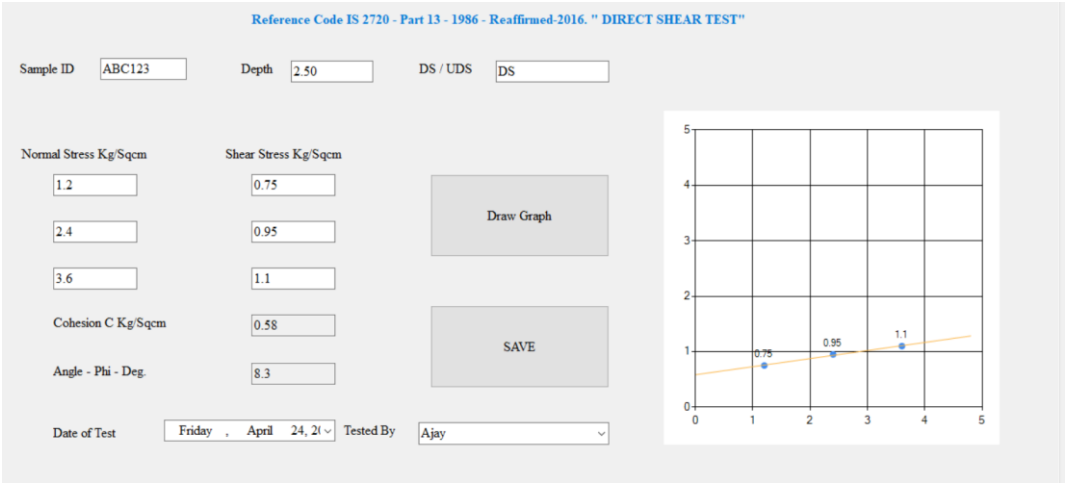

Figure 6: Input and Output of Direct Shear Test Form

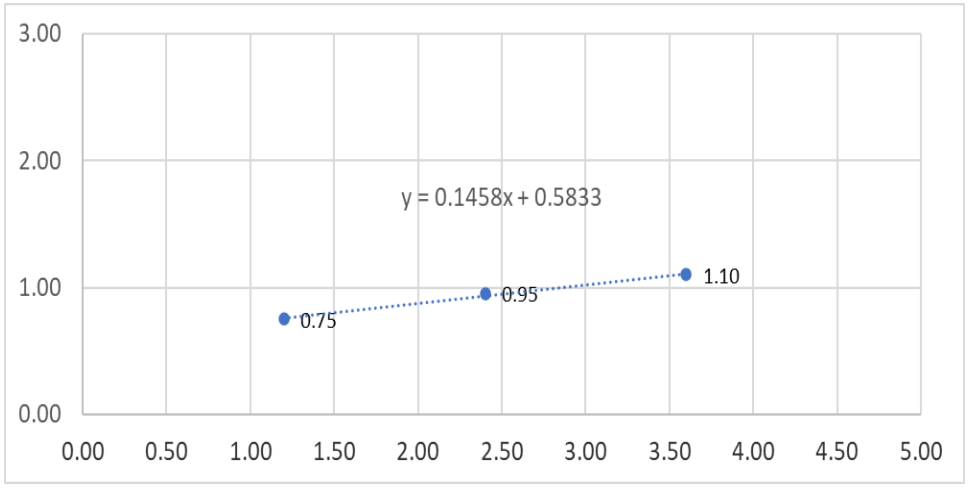

Figure 7: Validation with excel

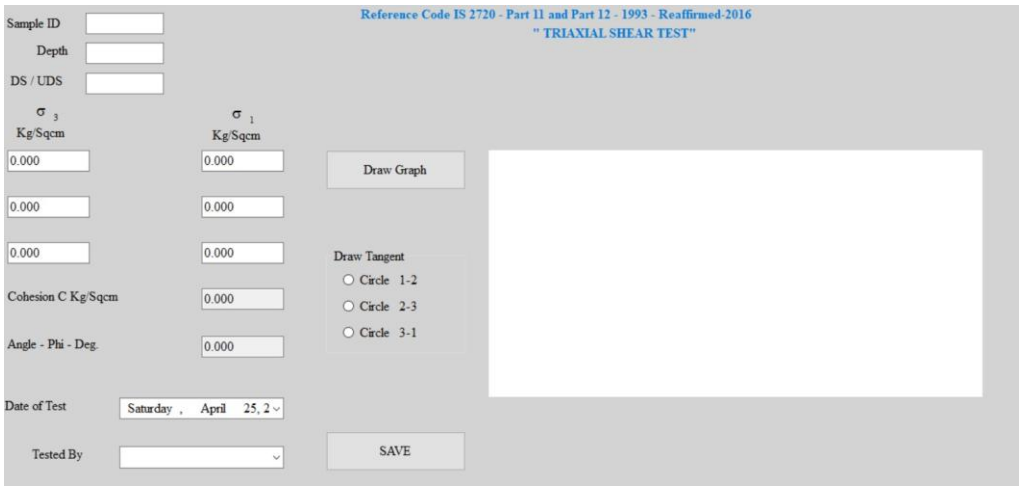

Figure 8: Triaxial Test Input form

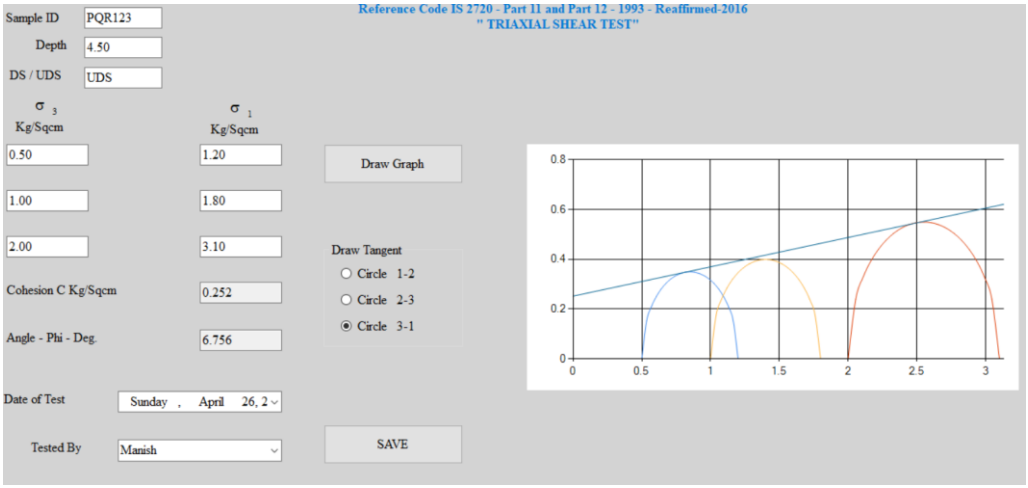

Figure 9: Triaxial Test output

(B) Triaxial Shear Test Calculation of Cohesion 'c' and angle 'ϕ'.

Similarly form design and output for the triaxial shear test is shown in figure-8 and figure-9. As per the above figure-8 genraral input for Sample ID, Depth and Type of Sample is stored as string. The Confining stress σ3 and normal stress σ1 are stored as double number. After data entry of all the inputs Draw Graph is button used to draw Mohr's Circle. The user is given option by mean of radiobuttons to draw one tangent either for circle 1-2 or 2-3 or 3-1. From set of confining and normal stresses co-ordinates of Mohr's circle are worked and three Mohr's circles are ploted for three sets of confining and normal stresses. and radiobuttons are used to draw tangent and working out cohesion and angle for the given set of circles. The same have been varified with manual as well excel application and found correct and accurate.

2. Conclusion

The working of shear parameters by Direct Shear Test and Triaxial Shear Test be programed by using programing language making the results fast correct and accurate compared to other conventional tools. Also other tests can be programed. Programing assignments / projects for civil engineering problems also adds opens one more carrier avenue for the civil engineers.

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