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DESIGN AND FABRICATION OF COHESIOMETER APPARATUS FOR SOIL STABILITY AND LANDSLIDE ANALYSIS

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Abstract

This paper discussed the fabricated apparatus for geotechnical analysis, specifically for soil slope stability and landslide analysis. This study used the single–group design of experimental methods and design science research methods. The study used standard tools and equipment to fabricate, such as the metal shear box, shear box cover, clamps, probe ring, probe ring gauge, gear, rotating handle, weights, and base. This fabricated Cohesiometer is a vital laboratory or in situ apparatus to get the soil's shear strength, normal stress, cohesion, and angle of internal friction to test its stability factor for a possible landslide. The results show that the Cohesiometer apparatus is comparable to the standard apparatus tested in the Modified coulombs theory, Mohr's – coulombs theory, Coulombs theory, and Mohr's theory. This signifies that the fabricated Cohesiometer apparatus is acceptable and comparable to standard analog apparatus; hence, the fabricated Cohesiometer formula is formulated based on the results tested in three different landslide areas. This Cohesiometer is recommended for the soil slope stability analysis for possible landslides.

Keywords: Cohesiometer, soil stability, Landslides analysis, Shear Strength, safety factor, cohesion, direct shear test, slope stability.

1. INTRODUCTION

Geotechnical Analysis is a very problematic and challenging task for civil engineers, particularly geotechnical engineers. Apparatus for a soil test is critical in soil testing. From a geotechnical perspective, the soil is a natural body consisting of layers (soil horizons) primarily composed of mixed minerals (Gilluly, Waters, and Woodford 1975). Soil is the end product of the influence of the climate, relief slope, organisms, and parent materials (Berkland, Peter W., 1999). Soil can fail due to shear; the weight of an earth-filled dam may cause the subsoil to collapse, like a small landslide (Hibbeler, 2004). As a result, direct shear tests per standard ASTM D 3080 can be used to measure only drained strength parameters because undrained conditions cannot be achieved. After all, neither the specimen's water content nor axial deformation change is controlled in a conventional direct shear test (Bardet, 1997). The shear strength is needed for engineering situations such as determining the stability of slopes or cuts and finding the bearing capacity for foundations (Krishna Reddy, 2001). A shear test is a laboratory or field test used by geotechnical engineers to measure the shear strength properties of soil or rock material or discontinuities in soil or rock masses (Price, D.G. De Freitas, 2009). The advantages over other tests are the simplicity of setup and equipment used. According to (Gillesania, 2014) direct shear test is the simplest form, Supported by (Amy B. Cerato1 and Alan J. Lutenegger, 2014) ;(Prof. Krishna Reddy, 2001). the shear strength apparatus is needed for engineering situations such as determining the stability of slopes or cuts (Lamba and Whitman, 1979) Shear strength parameters are essential in all types of geotechnical designs

ISSN 1533-9211
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and analyses specifically for slopes and slides (Richard Thiel,1990) asserted by (Giroud,1993) provides an excellent method to describe hyperbolic strength envelopes of soil slide properties. The direct shear test is like Cohesiometer (Moutaouakkil and Niang, 1990). Data was first published and comes from a series of tests performed in a shear box with a circular height cross-section of 600 mm and internal diameter of 590 mm. Modified Direct Shear Tests were performed, and the interface friction parameters, such as Φ and δ, were obtained (Anna Grace N. Gravador,2004). Different size shear boxes in use today and the effect of the varying specimen size on the resulting friction and influence of box size is dependent on relative density. (Amy B. Cerato1 and Alan J. Lutenegger, 1998). Supported by (Lambe and Whitman, 1979) direct shear test gives shear strength parameters (cohesion and friction angle) of soil. The cohesion of the mixture was found to increase consistently in moisture content and cause a drop in both cohesion and angle of internal friction mentioned by (Muawia A. Dafalla., 1978). According to (Richard Thiel, 1987), both the friction angle and cohesion (or adhesion) parameters. Thus, the direct shear test is one of the oldest strength tests for soils. In this Laboratory, a direct shear device will be used to determine the shear strength of cohesive soil and the angle of internal friction. The shear strength is one of the most important engineering properties of soil. The above statements strengthen the study on fabricating a Cohesiometer for soil slide and slope stability analysis. At this juncture, fabrication of the direct shear test made of locally available materials at a cheaper cost will be fabricated to test accuracy compared to the results of a standard commercial model. Technology played an essential role in developing testing devices used by examiners. the main objective of this study is to fabricate the Cohesiometer apparatus with low-cost materials, determine the result of fabricated Cohesiometer apparatus to be tested in different types of soil, differentiate between the result of the fabricated Cohesiometer apparatus and the standard expected results for specific types of soil and formulate an intended formula to compute the soil strength parameters from the results of the test based on apparatus.

2. METHODOLOGY

This study used design science methods and the single–group design of the experimental research method. This study is about fabricating Cohesiometer apparatus and testing the soil strength parameters of different soil types in landslide areas. The direct shear apparatus was fabricated and made of Available local materials such as the following: metal shear box, shear box cover, clamps, probe ring, probe ring gauge, gear, rotating handle, weights, and base. It has undergone six stages (1) the first stage was fabricating the apparatus. Build the metal shear box with its cover and the base where the probe ring and a rotating handle are attached, then put the metal shear box to the base where four clamps will clip the metal clip body of the shear box, second (2) stage is the testing of the accuracy of apparatus and troubleshooting. This research used scientific sampling-Restricted random sampling; this type of sampling design involves certain restrictions intended to improve the validity of the sample. The experiment requires four soil types: Gravel, Sand, Clay, and Silt. Each soil type must have three samples to test. In the third Stage (3), the soil sample in undrained condition taken from three identified unstable slopes and landslide areas were tested and classified using ASTM D2487, AASHTO

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/BW92X

M415.,. ASTM D421, AASHTO T87ASTM 4318, AASHTO T89 and 90, at the fourth (4^{th}) stage soil cohesion and angle of internal friction were determined using fabricated Cohesiometer, (5) at fifth stage factor of slopes stability. The sixth (6^{th}) stage involved gathering data, computation, and formulating the derived. Inferential statistics were used to determine the significant difference between the standard results and the results using the fabricated apparatus and determine the significant relationships between the soil properties and the fabricated results. The base of standards results computation was the following formula, and the derivation of Bacosa Theories was derived from these formulas and equations (Parry, Richard Hawley Grey,2004); (Gere, James M, 2013).

Mohr's Normal strength formula

$$\sigma = \frac{P}{A} \tag{1}$$

Where:

σ = Normal stress

P = Normal loads

A = area of shear box apparatus

Mohr's Shear Stress Formula

$$\tau = \frac{F}{A} \tag{2}$$

Where:

τ = shear stress

F = shear force (came from the probe ring gauge)

A = area of shear box apparatus

The Mohr's shears strength formula for angle of internal friction, cohesion, normal shear stress, and shear stress formula.

For internal friction formula.

$$\tan \varphi = \frac{\tau_1 - C}{\sigma_1} \tag{3}$$

Where:

$$C = \frac{\sigma_1 \tau_1 - \sigma_2 \tau_1}{\sigma_1 - \sigma_2} \tag{4}$$

For normal shear stress formula.

$$\sigma' = \frac{9.81\,(H+L+P)}{A} \tag{5}$$

$$C' = \frac{\sigma_1 \tau_1 - \sigma_2 \tau_1}{\sigma_1 \sigma_2} \tag{6}$$

ISSN 1533-9211
DOI 10.17605/OSF.IO/BW92X

Where:

σ' = Normal shear stress

C = Cohesion

H = Hanger load

L = Load of plate

P = normal loads

For the shear stress formula.

$$\tau' = \frac{\tau_2 - \tau_1}{\sigma_2 - \sigma_1}\sigma' + C \quad (7)$$

$$m = \frac{\tau_2 - \tau_1}{\sigma_2 - \sigma_1} \quad (8)$$

$$\tan\varphi = m \quad (9)$$

Where:

Ʈ' = Shear stress

C = Cohesion

m = normal – shear stress slope

3. RESULTS AND DISCUSSION

The direct shear apparatus was fabricated and made of Available local materials such as the following: metal shear box, shear box cover, clamps, probe ring, probe ring gauge, gear, rotating handle, weights, and base. The complete illustration is shown below in Figure 1.

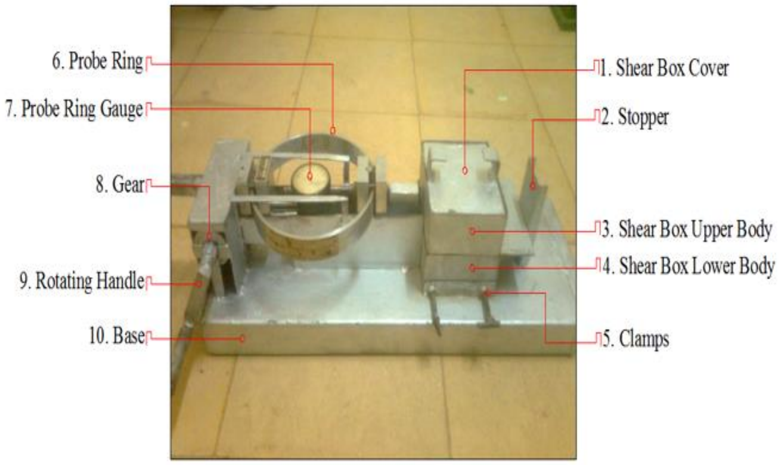

Figure 1: Fabricated Cohesiometer Apparatus (main body)

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/BW92X

Figure 1 shows the different min parts of the Cohesiometer and materials used; the Shear Box Cover, The 100 x 120 mm shear box cover where the loads will be placed, and the Stopper - Which is the limitation of the movement of the upper body of the shear box, Shear box upper body- The 100 x 120 mm shear box upper body, where the soil sample placed, this is part of the shear box that free to move. Shear box lower body. The clamps will clip the 100 x 120 mm shear box lower body, where the soil sample is also placed. The parts of the Fabricated Direct Shear Test Apparatus are made of metal (Gan et al, 1988). The intended formula to compute the soil strength parameters from the test results is based on the fabricated Cohesiometer apparatus (Parry, Richard Hawley Grey, 2004). Every soil sample's normal stress and shear stress (Gere, James M., 2013).

Modified Mohr shear strength formula for cohesion and angle of internal friction,

$$\mathbf{Cm} = \frac{\mathbf{P}\tau_1 - \mathbf{F}\sigma_1}{\mathbf{P} - \mathbf{A}\sigma_1} \qquad (10)$$

Where:

Cm= Mohr's Cohesion

σ = Normal stress

P = Normal loads

F = Normal Force

A = Area of shear box

For the Angle of internal friction,

$$\tan\varphi = \frac{\mathbf{F}\,(\sigma_1 - \sigma_2) - \mathbf{A}(\sigma_1\tau_2 - \sigma_2\tau_1)}{-\mathbf{P}(\sigma_1 - \sigma_2)} \qquad (11)$$

Modified Coulombs Shear strength formula and Angle of internal friction,

$$\tau = \frac{9.81\,(\tau_2 - \tau_1)(\mathbf{H+L+P})}{\sigma_1\sigma_2} + \frac{\sigma_1\tau_2 - \tau_1\sigma_2}{\sigma_1\sigma_2} \qquad (12)$$

Where:

τ = Shear stress

σ = Normal stress

H = Hanger load

L = Load of plate

P = normal loads

For the Angle of the internal friction formula.

$$\tan\varphi = \frac{9.81(\tau_2 - \tau_1)(\mathbf{H+L+P})}{\sigma_1\sigma_2} + \left(\frac{\sigma_1\tau_2 - \tau_1\sigma_2}{\sigma_1\sigma_2}\right) - (\tau' - \sigma m') \qquad (13)$$

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/BW92X

Modified Mohr – Coulombs.

$$\mathbf{Cmc = \tau mc - \sigma tan\ \varphi mc} \tag{14}$$

Where:

$$\mathbf{\tau mc = 0.5\ (\ \tau m + \ \tau c\ )} \tag{15}$$

$$\mathbf{\varphi mc = 0.5\ (\ \varphi m + \ \varphi c\ )} \tag{16}$$

$$\mathbf{\tau m = \frac{F\sigma_1 + CmP - CmA\sigma_1}{P}} \tag{17}$$

$$\mathbf{\tau c = \frac{9.81\ (\tau_2 - \tau_1\ )}{\sigma_1\sigma_2}((H + L + P\ )} \tag{18}$$

$$\mathbf{tan\ \varphi m = \frac{F\ (\sigma_1 - \sigma_2) - A(\sigma_1\tau_2 - \sigma_2\tau_1)}{-P(\sigma_1 - \sigma_2)}} \tag{19}$$

$$\mathbf{tan\ \varphi c = \frac{9.81(\tau_2 - \tau_1\ )(H+L+P\ )}{\sigma_1\sigma_2} + (\ \frac{\sigma_1\tau_2 - \tau_1\sigma_2}{\sigma_1\sigma_2}\ ) - (\tau' - \sigma m'\ )} \tag{20}$$

Where:

Cmc = Mohr-Coulomb cohesion

Ʈmc = Mohr-Coulomb shear strength

Φmc = Mohr coulomb angle of internal friction

Ʈm = Mohr's shear stress

Ʈc = Coulombs shear stress

Φm = Mohr's angle of internal friction

Φc =Coulombs angle of internal friction

Bacosa's Modified Shear Strength Theory. The following formulas below were derived based on the actual results of the fabricated apparatus.

$$\mathbf{bmf = \frac{Cmc}{\tau mc - \sigma tan\ \varphi mc}} \tag{21}$$

$$\mathbf{Crm = \tau md - (\ \sigma d\ tan\ \varphi mcd\ )bmf} \tag{22}$$

Where:

$$\mathbf{\tau md = 0.5\ (\ \tau m + \ \tau c\ )} \tag{24}$$

$$\mathbf{\sigma md = 0.5\ (\ \sigma m + \ \sigma c\ )} \tag{25}$$

$$\mathbf{tan\ \varphi md = 0.5\ (\ tan\ \varphi md + tan\ \varphi c\ )} \tag{26}$$

$$\mathbf{Crm = 2.6462\ (\ \tau - \ \sigma\ tan\ \varphi\ )} \tag{27}$$

ISSN 1533-9211

DOI 10.17605/OSF.IO/BW92X

Where:

bmf = Bacosa factor

Crm = Bacosa Cohesion

Cbc = Mohr's coulombs Cohesion.

To resolve the discrepancy in the result of the standard instrument, expected normal stress, shear stress, cohesion, and internal friction using different formulas and the fabricated Cohesiometer apparatus. The different normal stress, shear stress, cohesion and internal friction formula such as general normal stress, shear stress, cohesion, and internal friction equation, Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory has been tested using the experimental result of the fabricated Cohesiometer apparatus and it was found out a discrepancy then formula modification has been formulated and derived such as called Bacosa modified shear strength theory. Then the discrepancy factor has been derived such as 2.6462 for Bacosa modified shear strength theory.

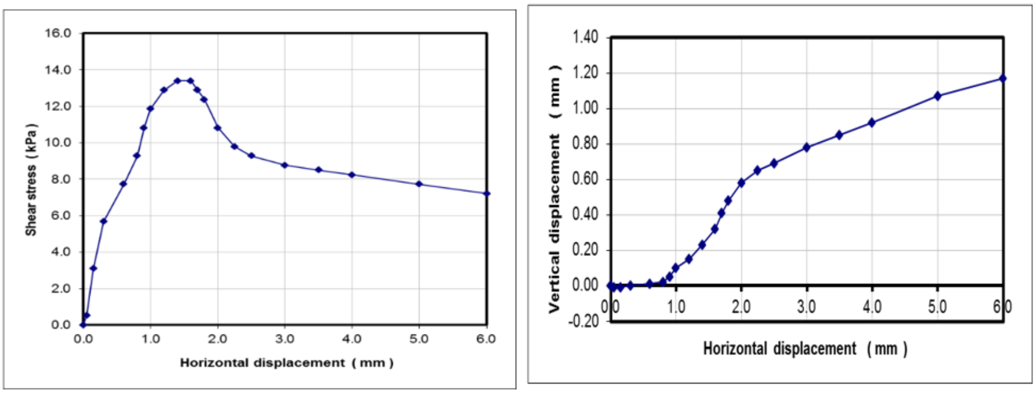

Figure 2: Fabricated Cohesiometer Shear Strength

Figure 2 reveals the result of the laboratory of the normal shear stress = 13.43 kPa and the horizontal displacement is 1.37 mm, and the vertical displacement is 1.20 mm. This means that wet soil structure has a strong attraction to water and swell and the cohesive clay soil tends to have the ability of like particles within the soil to hold onto each other and bind together (Duncan, J. M. et al, 2014). This implies that the soil has cohesive properties challenging it difficult to break apart when dry. This clearly defines when water is added to soils, and water plays a vital role in soil cohesion because of its surface tension that provides a weak bond among the soil grains to cause cohesion.

Table 1: Bacosa Shear Strength Theory

Area Tested	Shear Stress (kPa)	Normal Stress (kPa)	Angle (degrees)	Cohesion (kPa)
Landslide 1 (Organic silty clay)	0.26	0.06	45.10	0.17
Landslide 2 (Sandy Silty)	0.24	0.06	52.95	0.15
Landslide 3 (Organic silty sandy clay)	0.25	0.06	35.85	0.16

Table 1 reveals modified Mohr shear strength theory results, the silty Clay of Low Plasticity (landslide 1- organic Silty Clays) with the highest cohesion of 0.17KPa, shear stress 0.26 KPa, normal stress = 0.06 kPa and angle of internal friction of 45.10 degrees and followed by organic silty clayey (Landslide 2- Sandy silty) have a cohesion of 0.16 kPa, shear stress of 0.25 KPa, Normal stress of 0.06 kPa and angle of internal friction of 52.95 degrees, a then the sandy silty soil (Landslide 3- Organic Silty Sandy Clays), have a cohesion 0.15 kPa, shear stress 0.24 KPa, normal stress of 0.06 kPa and internal friction of 35.85 degrees. This implies that the soil has cohesive properties that are challenging to break apart when dry. This clearly defines when water is added to soils, and water plays a vital role in soil cohesion because of its surface tension that provides a weak bond among the soil grains to cause cohesion (Le, T. M. H., 2014). Also, this means that soil having a certain frictional angle of the maximum angle before one of the items will begin sliding due to the effect of water can cause erosion. In contrast, changes in pore water pressure can result in soil slip.

Table 2: Bacosa Shear Strength Theory Equation Results

Area Tested	Shear Stress (kPa)	Normal Stress (kPa)	Angle (degrees)	Mohr's-Coulombs Equation	bmf
Landslide 1 (Organic silty clay	6.02	0.35	25.32	5.00	0.912
Landslide 2 (Sandy Silty)	5.84	0.35	33.67	20.00	3.773
Landslide 3 (Organic silty sandy clay	5.88	0.35	27.27	10.00	1.873

The table reveals the Bacosa shear strength theory to determine the Bacosa- factor of discrepancy to determine the accuracy of the result. The bm_f was imposed to calculate the cohesion that will result in the same standards. The cohesion of 5.0 kPa for landslide 1 reached the same with standards by multiplying the bmf of 0.912 when the shear stress is 6.02kPa; the normal stress is 0.35 kPa and the angle of internal friction of 25.52. The cohesion of 20 kPa for Landslide 2 reached the same standards by multiplying the bmf of 3.773 when the shear stress is 5.84 kPa, the normal stress is 0.35 kPa, and the angle of internal friction of 33.67. The cohesion of 10 kPa for Landslide 3 reached the same with standards by multiplying the bmf of 1.873 when the shear stress is 5.88 kPa, the normal stress is 0.35 kPa, and the angle of internal

The Seybold Report
ISSN 1533-9211
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friction of 27.27. This implies that bmf is a factor to be multiplied in the formulated equation of Bacosa Shear Strength Theory (Roy, S., & Dass, G., 2014). The results are the same as the other theoretical equations.

Table 3: The factor of Stability Analysis

Area Tested	Unit Weight	Cohesion	Internal friction	The factor of Safety (FS)	Remark
Landslide 1 (Organic silty clay	12.0	0.06	43.93	0.92	Susceptible
Landslide 2 (Sandy Silty)	13.0	0.06	54.56	0.87	Susceptible
Landslide 3 (Organic silty sandy clay)	12.0	0.06	66.02	0.78	Susceptible

The table reveals that the safety factor tested in three landslide areas proved the Cohesiometer is an effective device for landslide and slope stability analysis. An actual landslide occurs when the factor of safety is below 1.0. This indicates that the safety factor ranging from 0.78 to 0.92 is less than 1.0 and more significant than 0.70. The areas are all susceptible to landslides. These signify that the safety factors obtained from landslide areas proved reliable results (Fuchs, M.et al., 2014). Thus, the results of the fabricated Cohesiometer apparatus are comparable and valuable.

Table 4: Comparison of the Test Results between the Result of the Fabricated Apparatus (Bacosa Theory) and the Commercial Apparatus (Mohr's Theory) Results

Fabricated Apparatus (Bacosa Theory) and	Comparison				
	F- Test	Degrees of Freedom	F- Critical (0.05)	Decisions	Significance
Commercial direct shear apparatus (Mohr's Theory)	0.7797	1,4	7.71	Accepted	No Significance

Table 4 shows that the F– test value of 0.7797 falls short with the F- Value of 7.71 at 0.05 level of significance (df =1/4). This accepts the null hypothesis. Therefore, there is no significant cohesion difference between the fabricated apparatus's result and the standard expected results for specific soil types. This implies the cohesion result of fabricated apparatus, standard direct shear apparatus and Bacosa theory, modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory did not differ. This means the fabricated apparatus is comparable to standard apparatus and Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory. Based on a previously established concept that the $\sigma t/\sigma c$ relationship is unique for each specific fine-grained soil, it is shown that the effective angle of shearing resistance of a given soil is and that the effective cohesion intercept is a direct function of σc (or σt) of the improved apparatus (Consoli, et al, 2014). Finally, the concepts are successfully tested for soils at two distinct apparatuses. This signifies that the fabricated apparatus is acceptable and comparable to the standard and expected result.

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/BW92X

Table 5: Comparison of Normal Shear Stress of the Fabricated Apparatus results (Bacosa Theory) and Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory.

Fabricated Apparatus results (Bacosa Theory) and other Theories	Comparisons				
	F- Test	**Degrees of Freedom**	**F- Critical (0.05)**	**Decisions**	**Significance**
	0.9999	1/4	7.71	Accepted	No Difference

Table 5. Shows that the F– test value of 0.9999 is less than the F- Value of 7.71 at 0.05 level of significance (df =1/4), this accepts the null hypothesis. Therefore, there is no significant difference in normal shear stress between the result of the fabricated direct shear test apparatus and the standard expected results for specific soil types. This implies that the normal shear stress result of fabricated apparatus, standard normal shear stress, modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory did not differ. This means the fabricated apparatus is comparable to standard apparatus and Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory. Based on the testing data of the yield strength of various types of soil principal stress, The calculating results are on the conservative side compared with the test results from fabricated laboratory and the commercial standard laboratory apparatus calculates the strength is consistent with other mohrs' strength theory (Jie, et al. (2014).), which suggests that Fabricated Cohesion meter and Bacosa Theory has a prospect and value for engineering applications. This signifies that the fabricated apparatus is acceptable and comparable to the standard and expected result.

Table 6. Comparison of the Shear Strength of the Fabricated Apparatus results(Bacosa Theory) and Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory

Bacosa Theory and Other Theories	Comparison				
	F- Test	**Degrees of Freedom**	**F- Critical (0.05)**	**Decisions**	**Significance**
	0.0224	1/4	7.71	Accepted	No Difference

The table shows that the F– test value of 0.0224 is less than the F- Value of 7.71 at 0.05 level of significance (df =1/4), this accepts the null hypothesis. Therefore there is no significant difference in shear strength between the result of the fabricated apparatus and the standard expected results for specific types of soil. This implies that the shear strength result of fabricated apparatus, standard, Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory did not differ. This means that the fabricated apparatus is comparable to standard apparatus and Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory. This signifies that the fabricated apparatus is acceptable and comparable to the standard and expected result.

ISSN 1533-9211

DOI 10.17605/OSF.IO/BW92X

Table 7: Comparison of the Angle of Internal Friction of the Fabricated Apparatus results (Bacosa Theory) and Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory

Fabricated Apparatus (Bacosa- Theory) and other Theories	Comparisons				
	F- Test	**Degrees of Freedom**	**F- Critical (0.05)**	**Decisions**	**Significance**
	0.6792	1/4	7.71	Accepted	No Difference

The table shows the F– test value of 0. Falls shorts with the F- Value of 7.71 at 0.05 level of significance (df =1/4), this accepts the null hypothesis. Therefore, there is no significant difference in the angle of internal friction between the result of the fabricated apparatus and the standard expected results for specific types of soil. The test results obtained for both the fabricated Cohesiometer and the commercial standard direct shear test showed that there were no differences, in the internal friction angle, In testing of the same internal friction angle significance did not differ using different theory computations (Hsiao, D. H., & Phan, T. A. V, 2014). This implies that the shear strength result of fabricated apparatus, standard angle of internal friction, modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory did not differ. This means that the fabricated apparatus is comparable to standard apparatus and Modified coulombs theory, Modified Mohr coulombs, Modified Mohr theory, Coulombs theory, and Mohr's theory. This signifies that the fabricated direct shear test apparatus is acceptable and comparable to a standard and expected result.

4. CONCLUSIONS

The 100 x 120 mm shear box upper body, where the soil sample is placed, is part of the shear box that is free to move. Shear box lower body. The 100 x 120 mm shear box lower body, where the soil sample is also placed and will be clipped by the clamps. The parts of the Fabricated Apparatus are made of metal. The digitalized – sensor Cohesiometer detector is an extension of the apparatus to be connected to get the digital display of the results.

The shear strength showed that soil structure has a strong attraction to water and swell and the cohesive clay soil tends to have the ability of like particles within the soil to hold onto each other and bind together. These soil cohesive properties are difficult to break apart when dry. This clearly defines, when water is added to soils, water plays a vital role in soil cohesion because of its surface tension that provides a weak bond among the soil grains to cause cohesion.

The factor of safety results is proven and reliable according to a required factor of safety for landslide occurred areas. There is no significant difference in cohesion between the result of the fabricated Cohesiometer apparatus and the standard expected results for specific types of soil. The fabricated Cohesiometer test apparatus is comparable to standard apparatus and Modified coulombs theory, Modified Mohr's- coulombs theory, Modified Mohr's theory, Coulombs theory, and Mohr's theory. The fabricated Cohesiometer apparatus is acceptable and comparable to a standard and expected result. The normal stress, shear stress Cohesion, angle of internal friction result of fabricated Cohesiometer apparatus, standard normal shear stress

Bacosa theory, Modified coulombs theory, Modified Mohr's - coulombs, Modified Mohr's theory, Coulombs theory, and Mohr's theory did not differ. The formulas derived based on the results of the fabricated apparatus are called Bacosa Theory and it is intended for the said apparatus only.

5. RECOMMENDATIONS

Fabricated Cohesiometer apparatus is applicable for laboratory experiments to measure the normal stress, shear stress, cohesion, and internal friction of the soil and factor of safety as well. The formulas modified by the researchers are applicable for the computation of normal stress, shear stress, cohesion, and internal friction of the soil as well as the factor of safety. Improved by computer and online generated Cohesiometer apparatus that will measure the normal stress, shear stress, cohesion, and internal friction of the soil online.

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