CORRELATION OF FULLY-SOFTENED SHEAR STRENGTH OF CLAY SOIL WITH INDEX PROPERTIES PHASE I

FINAL REPORT - FHWA-OK-10-04

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16 . ABSTRACT

Shallow slope failures in clay soils cause many millions of dollars of damage annually on highway embankments and cut slopes and necessitate difficult and expensive repairs that negatively impact budgets, traffic flow, and the environment. The embankments typically fail when clay soils become “fully softened” due to shrink-swell action during wet-dry-wet cycles and experience downhill creep. Slope analyses using either peak or residual strength properties do not properly model most slope failure or potential failure conditions. The use of peak strength in the analyses tends to overestimate the factor of safety (stability) and the use of residual shear strength in the analysis tends to underestimate the factor of safety (stability). The use of fully-softened shear strength values results in a more accurate analysis and leads to designs or repair methods that provide long-term stability at reasonable costs. Understanding the mechanisms of these slope failures and being able to economically predict the fully softened shear strength of clay soils is key to successful design, repair, and stabilization of clay slopes.

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SI (METRIC) CONVERSION FACTORS									
Approximate Conversions to SI Units					***Approximate Conversions from SI Units***				
Symbol	***When you know***	***Multiply by***	***To Find***	***Symbol***	***Symbol***	***When you know***	***Multiply by***	***To Find***	***Symbol***
		LENGTH					***LENGTH***		
in	inches	25.40	millimeters	mm	mm	millimeters	0.0394	inches	in
ft	feet	0.3048	meters	m	m	meters	3.281	feet	ft
yd	yards	0.9144	meters	m	m	meters	1.094	yards	yds
mi	miles	1.609	kilometers	km	km	kilometers	0.6214	miles	mi
		AREA					***AREA***		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.00155	square inches	in^2
ft^2	square feet	0.0929	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.8361	square meters	m^2	m^2	square meters	1.196	square yards	yd^2
ac	acres	0.4047	hectacres	ha	ha	hectacres	2.471	acres	ac
mi^2	square miles	2.590	square kilometers	km^2	km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME					***VOLUME***		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.0338	fluid ounces	fl oz
gal	gallon	3.785	liters	L	L	liters	0.2642	gallon	gal
ft^3	cubic feet	0.0283	cubic meters	m^3	m^3	cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.7645	cubic meters	m^3	m^3	cubic meters	1.308	cubic yards	yd^3
		MASS					***MASS***		
oz	ounces	28.35	grams	g	g	grams	0.0353	ounces	oz
lb	pounds	0.4536	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)					***TEMPERATURE (exact)***		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C	°C	degrees Fahrenheit	9/5(°C)+ 32	degrees Celsius	°F
		FORCE and PRESSURE or STRESS					***FORCE and PRESSURE or STRESS***		
lbf	poundforce	4.448	Newtons	N	N	Newtons	0.2248	poundforce	lbf
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa	kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

The contents of this report reflect the views of the author(s) who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views of the Oklahoma Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. While trade names may be used in this report, it is not intended as an endorsement of any machine, contractor, process, or product.

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INTRODUCTION

Shallow slope failures in clay soils cause many millions of dollars of damage annually on highway embankments and cut slopes and necessitate difficult and expensive repairs that negatively impact budgets, traffic flow, and the environment. The embankments typically fail when clay soils become “fully softened” due to shrink-swell action during wet-dry-wet cycles and downhill creep. Slope analyses using either peak or residual strength properties do not properly model most slope failure or potential failure conditions. The use of peak strength in the analyses tends to overestimate the factor of safety (stability) and the use of residual shear strength in the analysis tends to underestimate the factor of safety (stability). The use of fully-softened shear strength values results in a more accurate analysis and leads to designs or repair methods that provide long-term stability at reasonable costs. Understanding the mechanisms of these slope failures and being able to economically predict the fully softened shear strength of clay soils is key to successful design, repair, and stabilization of clay slopes.

Peak strength values of clay soils are commonly available and can be tested economically in geotechnical engineering laboratories. However, fully-softened shear strength values require non-routine expensive procedures in the laboratory and are seldom practical, especially for small to average size projects.

Report Format

The main sections of this research report include the body (main text) of the report and an appendix which contains all laboratory test results. Photographs, tables, and figures are included in the body of the report. The report is divided into main headings and subheadings for the convenience of the reader. However, the headings and subheadings are not intended to fully describe all items that may be included under the particular heading or subheading. Any reader or user of this report should read, review, and become familiar with the entire report and individual items should not be considered individually or taken out of context of the overall intent of the report.

Terms used in the report such as “we” or “our” should be understood to refer to the author(s) of the report unless specifically stated otherwise. The term “author” refers to Garry H. Gregory, Ph.D., P. E., D.GE unless specifically stated otherwise. Selected portions of the text may be presented in italic and/or bold font to illustrate specific points. However, the reader should not assume that all important or salient points are presented in italic or bold font.

The term “property” or “properties” related to soils in this report refer to characteristics of the soil that are independent of moisture content and density and include items such as liquid limit, plastic limit, and gradation. The term “parameter” or “parameters” related to soils in this report refer to characteristics of the soil that are dependent on moisture content and density such as shear strength, compressibility, and permeability. The term “sample” as used in this report refers to the entire individual soil samples prior to any length or diameter trimming. The term “specimen” refers to the individual test specimens trimmed from the larger samples, or to processed and re-molded specimens of material taken from the larger samples. The term “slurry-processed, normally-consolidated (SPNC)” refers to preparation of soil specimens into the fully-softened condition. This process is described in more detail in later sections of this report. Additional definitions may be presented in other appropriate sections of the report.

Objectives

The objectives of this research project are to develop a correlation between peak strength values and fully-softened strength values using index properties (Atterberg Limits and Percent Passing No. 200 Sieve) and moisture content of the test samples and to formalize an equation for calculating fully-soften shear strength values from available peak values. The current research (Phase I) includes only one clay soil type and is based upon peak strength testing of samples in the “in-situ” condition. Previous research performed by the author was on embankment fill soils only and did not include in-situ soil materials. The conclusions and parameters developed in this research study apply only to soils with the same or very similar properties as those considered in this study.

Background

The author has developed a preliminary equation for estimating fully-softened shear strength values of clay soils using the standard peak strength values and correlation with index properties and moisture content of the peak strength specimens at the time of testing. The equation is based on embankment fills consisting of clay soils. The equation appears to provide a good correlation, but is based on limited test data. This research project included additional testing of clay samples using both undrained peak strength and undrained fully-softened strength test procedures to verify and quantify the coefficients in the equation for the particular soil type considered. A proposed future research study (Phase II) will address four additional soil types and will include testing of soils in the in-situ condition, recompacted condition, and soil specimens prepared in the fully-softened condition. Phase II will also include both undrained and drained shear strength testing. Phase II has not been funded or authorized at this time.

Research Funding

The funding for this research consisted of both private industry funding (two firms at \$5,000 and \$6,000 each, respectively) and ODOT funding (\$5,000) for a total of \$16,000 public/private funding for Phase I. The collaborative funding approach was adopted due to the current economic environment. Due to the modest funding

($16,000) for Phase I, only one type of clay soil was included as previously stated, and only undrained shear strengths were considered.

Implementation

The full impact of this research will be realized upon completion of proposed future Phase II. However, it is expected that the current Phase I research will result in technical publications in refereed journals and conference proceedings and that the initial model for calculating the fully-softened shear strength of clay soils based on peak shear strength will provide an interim basis for design and analysis of slopes in clay soils of the type researched in this study. It is also anticipated that upon completion of the proposed Phase II research the complete model for all common clay types will be incorporated into Departments of Transportation, Federal Highway Administration, and private practice standard procedures for analysis and design of clay slopes.

Benefits

The results of this study should allow rapid calculation of "fully-softened" shear strength values of the particular clay type from peak strength values from routine laboratory tests or from previous test data. This will facilitate more accurate and cost effective analysis and design of new highway slopes and repair/stabilization of existing slopes. The anticipated reduction in related slope failures is expected to contribute to sustainability and reduce negative environmental impacts caused by frequent highway slope failures.

TASKS PERFORMED IN PHASE I

The research tasks for Phase I included the following:

1. Selection and collection of soil samples of the candidate soil. These samples were provided by Terracon Consultants-Oklahoma City office (Terracon) and were from a site near Cushing, Oklahoma.

2. Peak shear strength testing of 18 specimens of soil in the “in-situ” condition (Shelby-tube specimens trimmed in diameter to limit disturbance) using the Triaxial shear apparatus and Unconsolidated-Undrained (UU) test procedures.

3. Following testing described in “2” above, each individual specimen (18 total) was processed into a thick slurry, preconsolidated in a special mold device under normally-consolidated conditions, and tested in the fully-softened state in a Triaxial shear device, again using UU test procedures.

4. The peak strength and fully-softened strength test results were analyzed numerically and statistically to refine the coefficients for the equation and a simple model was developed to facilitate calculation of fully softened shear strength values from peak strength data for the particular soil type considered in this study.

5. Preparation of this research report which includes the results of the study and conclusions and recommendations for proposed Phase II and implementation of the model.

SOIL DESCRIPTION AND PROPERTIES

Soil Sample Site Description

The site location where the soil samples were collected (by others) is approximately 4 miles south of Cushing, Oklahoma. The site is southwest of the intersection of CR EW750 and CR NS3510. This location is within Map Index number 53 of the NRCS Soil Survey of Payne County, Oklahoma (1987) and is within the Stephenville fine sandy loam soil series. Geologically, the site is within the Vanoss-Ada Unit.

Soil Sample Depths and Diameter

The 18 soil samples actually used in the research were obtained from various depths in 10 borings previously performed by Terracon. The sample depths ranged from approximately 1-foot to 29 feet. Two samples were obtained from the same boring in numerous cases. The samples were obtained with nominal 3-inch OD thin-walled (Shelby) tube samplers, which produce a sample of approximately 2.8 inches in diameter. A photograph of the original samples prior to trimming is presented in Figure 1. The actual boring logs are proprietary and are not included in this research report. Moreover, the actual boring logs are not relevant to the research.

Soil Classification

The majority of the soil samples classified as Lean Clay (CL) in general accordance ASTM D 2488, commonly referred to as the "Unified Soil Classification System (USCS). Three of the soil samples classified as Fat Clay (CH). However, these samples were on the borderline between CL and CH classifications with liquid limit values of 50 and 51. In the USCS classification system, clay soils with liquid limit of 50 or greater classify as CH, while those with liquid limit less than 50 classify as CL. Therefore, soils near the liquid limit boundary between CL and CH may have different classification, but also may be very similar soils if only a few points in liquid limit result in the different classifications.

Figure 1 – Soil Samples Prior to Trimming

A summary of the depths, properties, and classifications of the samples used in the research are presented in Table 1 on the following page.

Sample Selection and Identification

The 18 samples were selected from the total available soil based upon minimal length required and visual condition of the samples. In a few instances the individual samples were long enough to obtain two specimens of suitable length, but in a majority of cases only one specimen could be obtained from each sample. Each sample was given a unique lab number, and was also identified by boring number and depth.

Table 1 – Soil Properties and Sample Locations						
No./Location/ Depth (ft)	**Classification**	**Visual Color**	**LL**	**PL**	**PI**	**% < 200 Sieve**
1 - B-6, 3-5	Lean Clay (CL)	Dark Yellowish Brown	33	14	19	83
2 - B-11, 3-4	Lean Clay (CL)	Brown	37	12	25	84
3 - B-11, 4-5	Lean Clay (CL)	Yellowish Brown	41	15	26	84
4 - B-13, 1-3	Fat Clay (CH)	Brown	51	37	41	77
5 - B-23-, 1-3	Lean Clay (CL)	Dark Yellowish Brown	39	13	26	73
6 - B-23, 3-5	Lean Clay (CL)	Dark Yellowish Brown	39	13	26	73
7 - B-27, 8-9	Lean Clay (CL)	Dark Yellowish Brown	35	12	23	81
8 - B-28, 1-2	Sandy Lean Clay (CL)	Dark Brown	26	11	15	78
9 - B-28, 3-5	Sandy Lean Clay (CL)	Dark Brown	26	11	15	78
10 - B-31, 1-2	Lean Clay (CL)	V. Dk. Grayish Brown	36	15	21	87
11 - B-31, 6-7	Lean Clay (CL)	V. Dk. Grayish Brown	36	15	21	87
12 - B-31, 28-29	Lean Clay (CL)	Dk. Yellowish Brown	30	11	19	80
13 - B-32, 1-3	Lean Clay (CL)	Dk. Yellowish Brown	38	12	26	83
14 - B-32, 3-5	Lean Clay (CL)	Dk. Yellowish Brown	38	12	26	83
15 - B-34, 3-4	Lean Clay (CL)	Dk. Yellowish Brown	39	12	27	86
16 - B-34, 4-5	Lean Clay (CL)	Dk. Yellowish Brown	39	12	27	86
17 - B-38, 1-3	Fat Clay (CH)	Brown	50	12	38	82
18 - B-38, 3-5	Fat Clay (CH)	Dk. Grayish Brown	51	12	39	82

The lab numbers are for internal quality control and identification purposes and only the boring numbers and depths are used in the report for specimen identification.

LABORATORY TESTING PROGRAM

The laboratory testing program consisted of liquid and plastic limits tests (ASTM D 4318), percent passing the number 200 sieve test (ASTM D 1140), hydrometer tests (ASTM D 422), and UU Triaxial Tests (ASTM D 2850). The hydrometer tests were performed only on two samples generally representative of the two basic soil classifications to determine the percent silt and clay. The liquid and plastic limits tests and percent passing the number 200 sieve tests were performed to provide data for classification of the specimens. The UU triaxial tests were performed on the specimens in the in-situ condition and again on the fully-softened condition, as described more fully later in this section. The individual specimens were protected from moisture loss in double-layer cling wrap and were stored in a chest-type cooler inside the controlled temperature geotechnical laboratory.

The laboratory testing program was documented with photographs and selected photographs are included in this section.

Specimen Preparation – In-Situ Condition

Following selection of the 18 samples, they were initially trimmed to length in a laboratory miter box to provide specimens with planar ends that are perpendicular to the longitudinal axis of the specimens. The specimens were trimmed in length to a range between 4.0 and 4.7 inches to provide the appropriate height to diameter ratio for 2-inch diameter specimens. Following end trimming, the specimens were carefully trimmed to nominal 2-inch diameter in a hand-operated soil lathe. The diameter trimming is desirable to remove the more disturbed outer periphery of the specimens. Some of the trimmed specimens are shown in Figure 2. The trimmed dimensions and dry unit weights of the in-situ condition specimens are shown on the Triaxial Shear Test Reports, Plates UUIS.1 through UUIS.18, in the Appendix.

A portion of the soil cuttings from the trimming operation were used to obtain in-situ moisture of the specimens and for liquid limit, plastic limit, and percent passing number 200 sieve determinations. The results of these tests are also included on Plates UUIS.1 through UUIS.18 in the Appendix. The two hydrometer tests were performed on specimens from Boring B-6 at 3 to 5 feet, and from B-38 at 3 to 5 feet. The hydrometer tests indicated that specimens consisted of about 55 percent silt and 28 percent clay.

UU-Triaxial Shear Testing – In-Situ Condition

The 2-inch diameter in-situ condition specimens were tested for undrained shear strength (Cu) in a special UU triaxial cell. The cell is equipped with an aluminum cylinder rather than a plastic cylinder which permits the tests to be conducted safely with air rather than water as the cell fluid. A latex membrane is installed on the specimen which isolates it from the cell fluid, but allows an all-around pressure to be applied to the surfaces of the specimen to simulate the in-situ conditions.

Figure 2 – Selected Specimens Trimmed in Length and Diameter

The tests were conducted in a manner that prevents drainage from the specimen during the test. The strain rate was 0.03 inches per minute during the tests. The specimens were not consolidated prior to beginning the test. A photograph of the triaxial cell during testing of the in-situ specimens is presented in Figure 3.

The undrained shear strength test results from the in-situ specimens are presented on Plates UUIS.1 through UUIS.18a in the Appendix. The test results are summarized and discussed in more detail in the Data Analysis section of the report.

Figure 3 – Triaxial Testing of In-Situ Specimens

Figure 4 – In-Situ Specimen after Shear Testing

Figure 5 – All 18 In-Situ Specimens after Shear Testing

Specimen Preparation – Fully Softened Condition

Each individual specimen from the in-situ condition testing was prepared by chopping the specimen into small pieces, mixing with distilled water, and blending with a spatula by hand into a slurry about the consistency of a thick milk-shake. Specimen mixing is illustrated in Figure 6.

Figure 6 – Slurry Processing of Specimen

The individual slurry specimens were placed in zip-lock bags and allowed to hydrate a minimum of 16 hours. Following hydration, the specimens were placed into a special consolidation device consisting of a split mold, base with threaded rods and cross arms, a loading piston, weights and a digital dial gauge. The annotated consolidation device is shown in Figure 7. Placement of the slurry processed specimens into the mold is shown in Figure 8. The devices are shown during testing in Figure 9. The specimens were consolidated under a load of 10 psi, the same as the designated cell pressure for the triaxial tests. This process produces a normally-consolidated specimen and is referred to as a slurry-processed normally-consolidated (SPNC) specimen. The diameter of the SPNC specimens is 1.4 inches and is consistent throughout all the specimens since the ID of all the molds is 1.4 inches. The initial length of the specimens had to be approximately 4.25 inches in order to produce a minimum specimen length of 2.8 inches following consolidation.

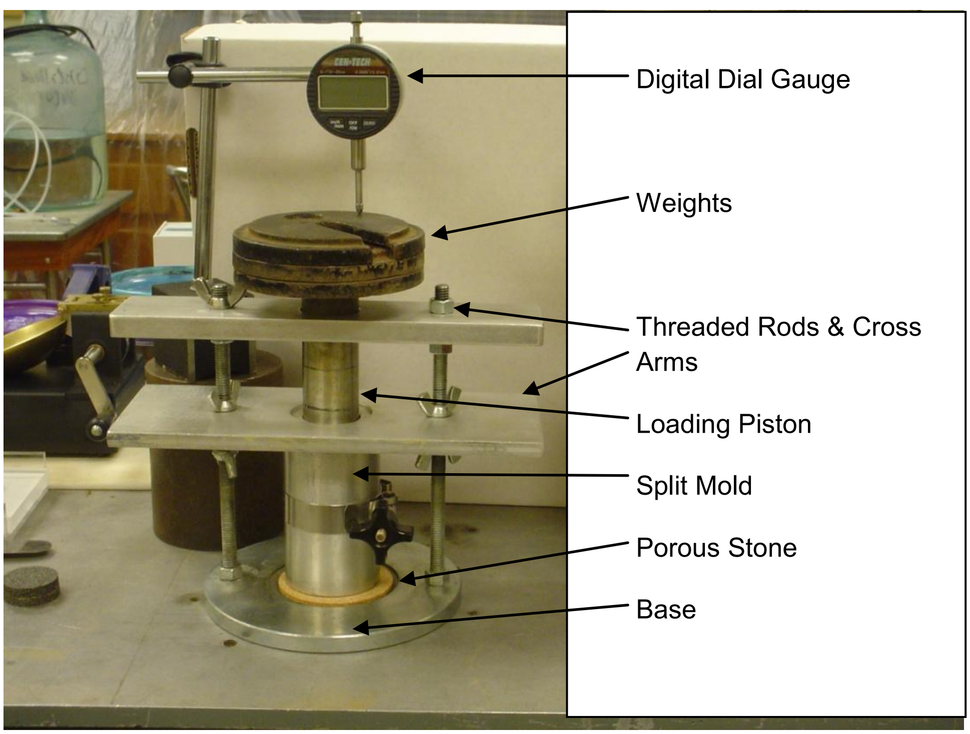


Figure 7 – SPNC Device

The specimens were allowed to consolidate until the end of primary consolidation was indicated by no movement of the digital dial gauge during three readings over a four hour period. The specimens required a minimum of 72 hours for consolidation.

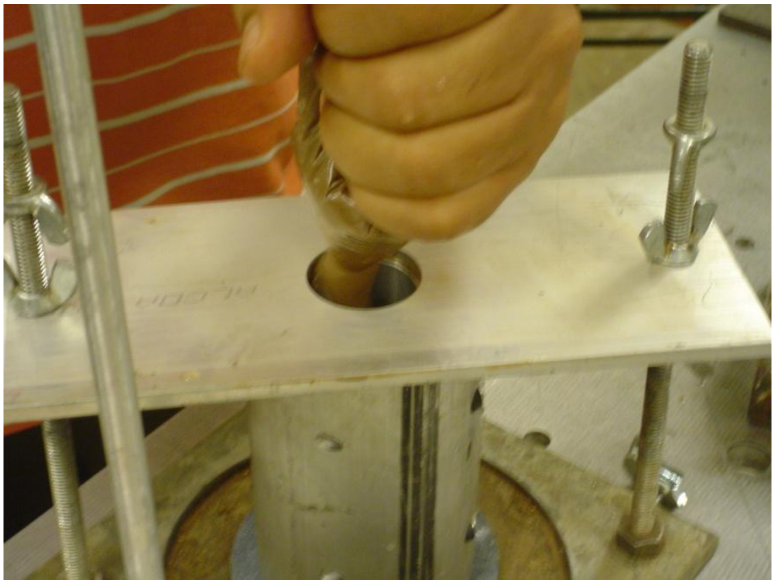


Figure 8 – Placing Slurry Specimen into Mold

Figure 9 – SPNC Devices During Consolidation

Following completion of consolidation, the specimens were carefully extracted by removing the mold from the device, loosening the split mold slightly, inverting the mold, and extruding the specimen by hand pressure on the piston. The specimens were carefully double packaged in cling wrap, labeled, and stored in protective racks in the chest cooler.

UU-Triaxial Shear Testing – Fully-Softened Condition

The 1.4-inch diameter fully-softened specimens were tested for undrained shear strength (Cu) in the special UU triaxial cell previously described. These tests were also conducted at 10 psi cell pressure and at a strain rate of 0.03 inches per minute. Selected photographs of shear strength testing of the fully softened specimens are presented in Figures 10 through 14.

Figure 10 – Mounting Specimen on Triaxial Base

Figure 11 – Specimens on Triaxial Base

The testing sequence involved mounting the specimen on the Triaxial Cell base as illustrated in Figures 10 and 11, followed by installing the latex membranes as shown in Figure 12. The membranes were installed with a membrane stretcher and a hand operated vacuum pump. The membranes are retained with O-Rings.

Figure 12 – Installing Membrane on Specimen

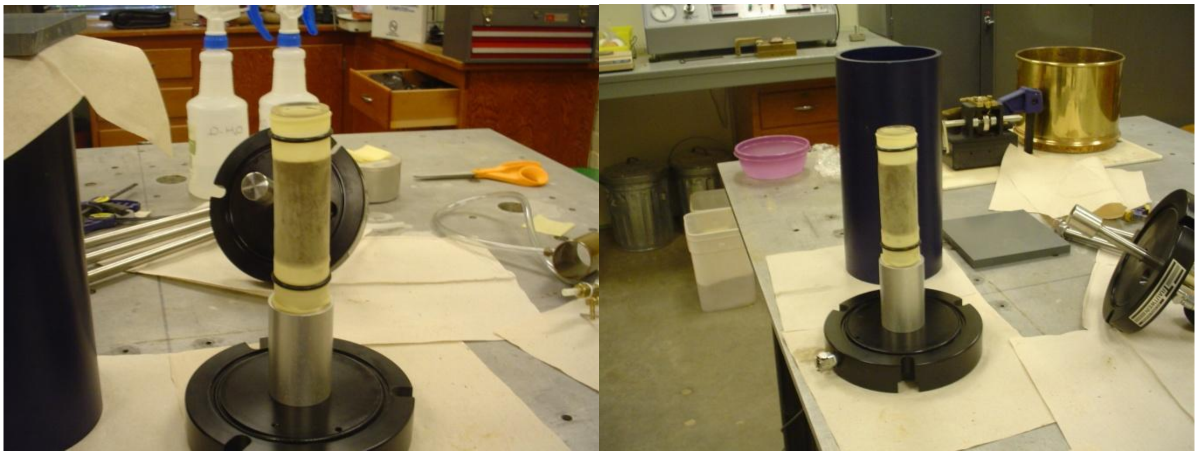


Figure 13 – Membrane Installed on Specimen with O-Rings

Figure 14 – Assembly of the Triaxial Cell

The tests were conducted in a manner that prevents drainage from the specimen during the test. The strain rate was 0.03 inches per minute during the tests, as previously discussed. Photographs of the Triaxial Cell during testing of the fully-softened specimens are presented in Figure 15.

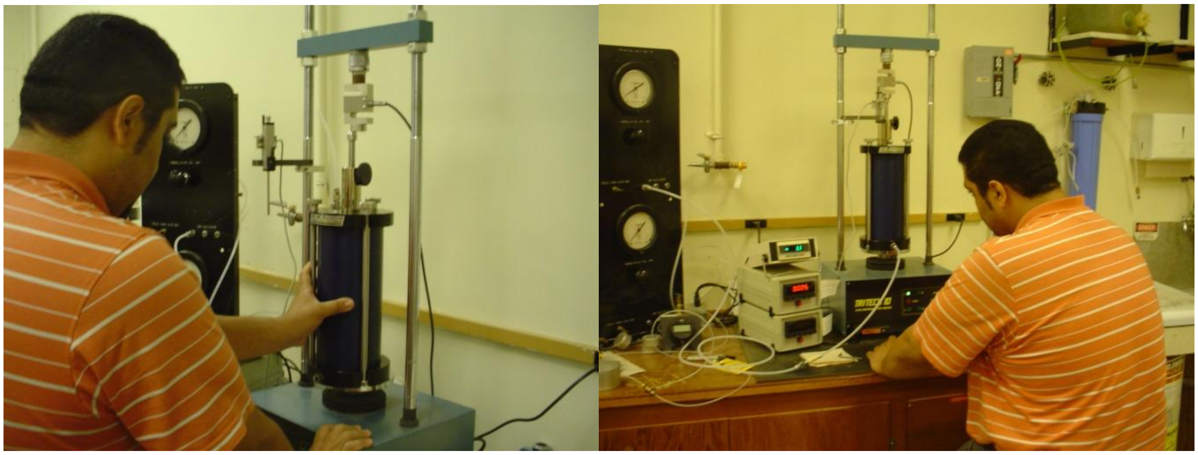


Figure 15 – Triaxial Testing of Fully-Softened Specimens

The undrained shear strength test results from the fully-softened specimens are presented on Plates UUF.1 through UUF.18a in the Appendix. The test results are summarized and discussed in more detail in the Data Analysis section of the report.

DATA ANALYSIS AND MODEL DEVELOPMENT

The analysis of data from the in-situ and fully-softened tests and development of the preliminary model are described in this report section.

Data Analysis

The data from the laboratory testing program were analyzed statistically and mathematically to develop property relationships and to observe general trends of the results. The values analyzed include the in-situ moisture content (*wi*) fully-softened moisture content (*wf*), liquid limit (*LL*), plastic limit (*PL*), plasticity index (*PI*), and percent passing the number 200 sieve (*<200*). These values were used to calculate parameters including the Cohesion Index (*CI*), Softening Index (I_S), the Limit Coefficient (α), and the basic Reduction Factor for Moisture (RF_M). These parameters were previously proposed by the author (Gregory 2008) and are identified in the following equations.

$$CI = \frac{(PI)(<200)}{100} \quad (1)$$

Where:

CI = Cohesion Index

PI = Plasticity Index

<200 = Percent Passing No. 200 Sieve

$$I_s = \frac{w_i}{\alpha(LL+PL)} \quad (2)$$

Where:

I_s = Softening Index

w_i = In-situ moisture content (moisture content at time of shear testing)

α = Limit Coefficient (w_f/(LL+PL) ~= 0.5 for shear strength correlation)

LL = Liquid Limit

PL = Plastic Limit

$$RF_M = I_s^{\log(CI)} \quad (3)$$

Where:

RF_M = Basic Reduction Factor for moisture content at time of shear testing

Others as previously defined

The values represented by equations 1 through 3 are presented in the spreadsheet table on Plate A.1 in the Appendix. The table lists individual values for each specimen and also lists the minimum, maximum, and average values for each column. The average values from Plate A.1 were used to develop the model as discussed in the next section. The table also contains a chart of In-Situ undrained shear strength (Cu) values versus calculated fully-Softened (FS) Cu values. This graph is also discussed in the next section.

Model Development

As previously discussed, the average data from Plate A.1 along with preliminary equations previously developed by the author were used to develop the model for the clay type included in Phase I of the research. The model is a proposed equation for prediction of the fully-softened undrained shear strength (C_{uf}) based on the undrained shear strength of the in-situ condition (C_{uis}) samples and index properties of the clay soil.

The individual test results varied over a relatively wide range as is typical of comparisons between in-situ and fully-softened test comparisons of individual specimens. This is the same condition that would be involved if fully-softened shear strength testing was conducted on any particular site. The variations dictate that an average or weighted average value is required for design purposes. The same is true for the prediction of fully-softened shear strength values from correlations with in-situ condition shear strength and index properties. Accordingly, the average values from the data on Plate A.1 were used to develop the model equation.

The equation previously developed by the author utilizes the RF_M value as a basic multiplier to predict the C_{uf} value from the known C_{uis} value, with an additional β

factor which is based upon the density ratio (ratio of fully-softened density to in-situ density) and is specific to each clay type and in-situ density range. Based upon previous limited studies and the current research, the β factor is expected to range between about 1 and 10. The calculation of the β factor is illustrated in equation 4.

$$\beta = 0.1\gamma_{di}D_r \tag{4}$$

Where:

0.1 = a scaling coefficient believed to be constant for all clay soils

γ_{di} = dry density of in-situ specimen

D_r = ratio of fully softened dry density to in-situ dry density

The average γ_{di} for the clay specimens was 113.4 pcf, and the D_r was 0.85. This resulted in an average β value of 9.64 for the clay specimens. The final proposed equation for the clay type considered in this study is presented as equation 5.

$$C_{uf} = \frac{RF_M(C_{uis})}{\beta} \tag{5}$$

This equation predicts an average C_{uf} value of 2.98 psi compared to the average test value of 3.0 psi. The graph on Plate A.1 is an indication of the consistency of the equation in prediction of C_{uf} values of the individual specimens. The R^2 value of the power curve fit to the data is approximately 0.74, which indicates an acceptable consistency for the equation. As previously stated there is considerable scatter in the data as is expected for individual specimens. However, the equation is believed to be a reasonable interim predictor of C_{uf} values from C_{uis} test values and index properties for the clay type considered in this research.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations developed during the current research project are discussed in this section.

Conclusions

Based upon data developed in this research, it appears that a viable model has been identified for prediction of fully softened undrained shear strength of clay soil based upon correlation with in-situ condition undrained shear strength and index properties. The model equations are applicable only to the clay type considered in this study. The equations should be used with caution, since they are based on a limited amount of data in this Phase I study. However, the equations will provide an interim basis for prediction of the fully softened undrained shear strength of similar clay soils by performing only routine laboratory undrained shear strength testing on the in-situ condition and performance of routine laboratory testing to determine index properties consisting of liquid limit, plastic limit, percent passing the number 200 sieve and unit dry weight.

Recommendations

A future Phase II research study is proposed to further develop and expand the model. The Phase II study should include a minimum of four additional clay soil types and should include testing of specimens in the in-situ condition, laboratory re-compacted condition, and fully-softened condition. Phase II should also include both drained and undrained shear strength testing. A minimum of 18 specimens for each clay soil type for the undrained test condition should be considered. This would involve a minimum of 216 individual specimens for the undrained condition. A minimum of 6 drained test series (either CU triaxial with pore pressure measurement or CD triaxial) for each soil type and test condition should be considered. This will also involve a minimum of 216 specimens for 72 test series of 3-specimens each to develop drained parameters (ϕ' and c'). This effort is anticipated to require between two and three years to complete.

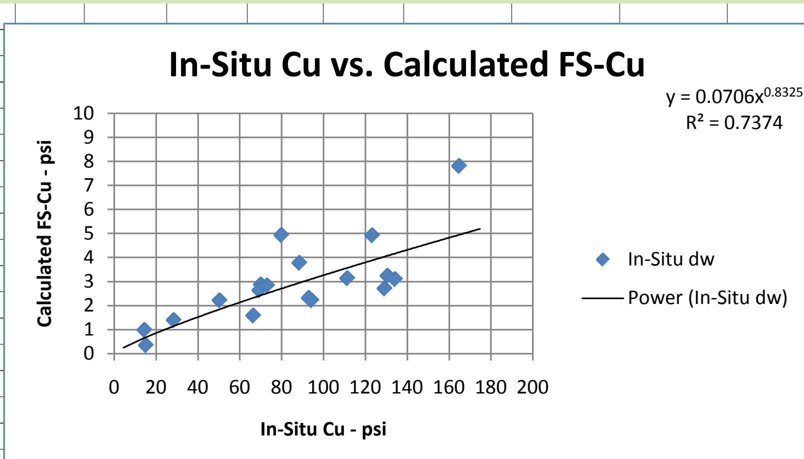
REFERENCES

Gregory, Garry H. (2008). "The role of the cohesion Index in Correlation of Soil Parameters." Part of a one-day lecture "Slope Stability Issues in the Constructed Environment" presented at the University of Texas at Arlington (UTA) May 21, 2008.

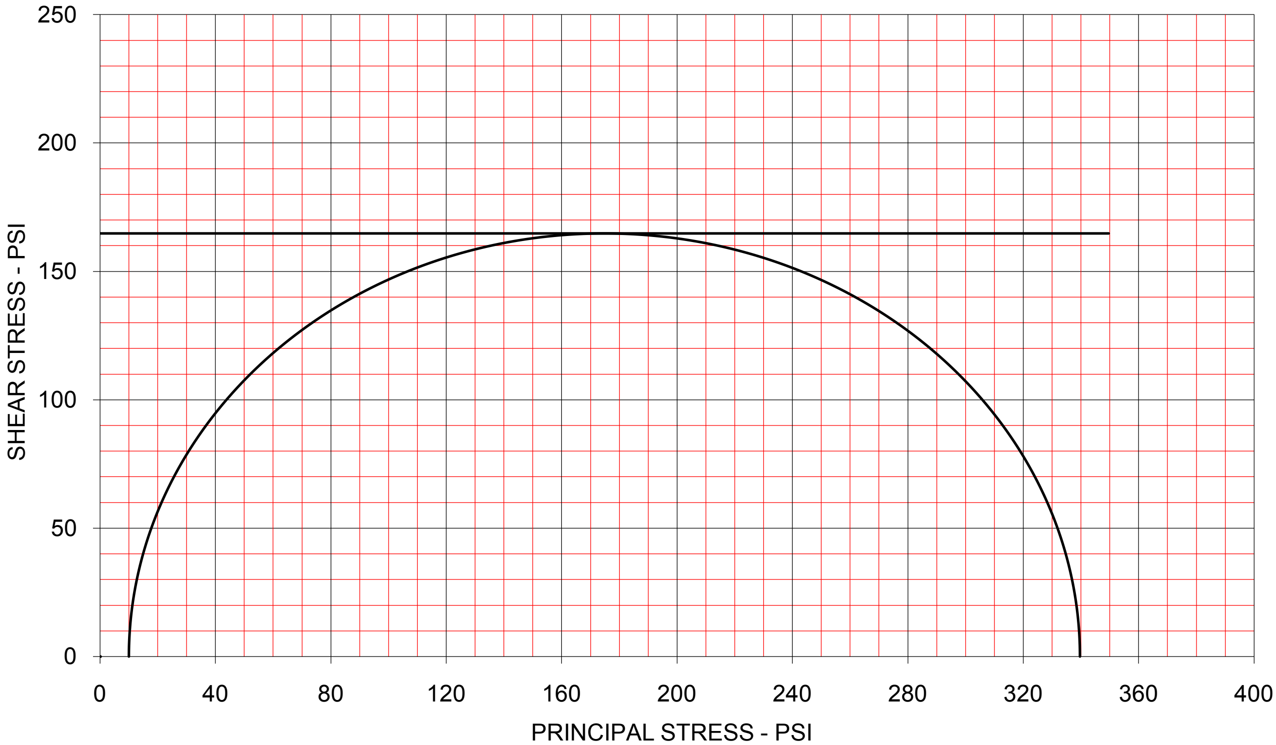
APPENDIX

MOISTURE REDUCTION FACTORS FOR SHEAR STRENGTH

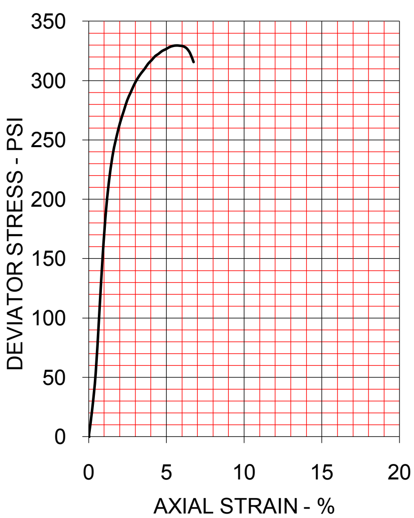
	LOCATION	wi	wf	LL	PL	PI	< 200	I_S	CI	RF_M	In-Situ Test Cu (psi)	Max. In-Situ Cu(psi)	FS Calc. Cu (psi)	FS Test Cu (psi)	Test Density	In-Situ Density	Density Ratio	
	α (Limit Coef) =	0.54																
1	B-6, 3-5 ft	13.2	34.1	33	14	19	83	0.520	15.77	0.457	164.8	164.8	7.81	1.3	85.2	120.7	0.705882	
2	B-11, 3-4 ft	8.5	25.7	37	12	25	84	0.321	21.00	0.223	134.2	134.2	3.10	3.3	97.3	117.7	0.826678	
3	B-11, 4-5 ft	10.4	23.5	41	15	26	84	0.344	21.84	0.239	130.6	130.6	3.24	2.6	100.1	117.1	0.854825	
4	B-13, 1-3 ft	11.7	23.8	51	14	37	77	0.333	28.49	0.202	129.2	129.2	2.71	4.1	100.3	110.6	0.906872	
5	B-23, 1-3 ft	13.6	27.8	39	13	26	73	0.484	18.98	0.396	70.1	70.1	2.88	1.1	91.6	109.2	0.838828	
6	B-23, 3-5 ft	12.8	26.5	39	13	26	73	0.456	18.98	0.366	69.4	69.4	2.64	3.1	96.6	113.6	0.850352	
7	B-27, 8-9 ft	11.7	30.1	35	12	23	81	0.461	18.63	0.374	73.1	73.1	2.84	1.5	94.7	114.9	0.824195	
8	B-28, 1-3 ft	12.3	23.9	26	11	15	78	0.616	11.70	0.596	79.9	79.9	4.94	3.5	98.1	108.3	0.905817	
9	B-28, 3-5 ft	8.7	25.8	26	11	15	78	0.435	11.70	0.411	88.5	88.5	3.78	1.9	98.4	118.7	0.828981	
10	B-31, 1-2 ft	15.2	28.2	36	15	21	87	0.552	18.27	0.472	28.5	28.5	1.40	2.5	93.9	100.0	0.939	
11	B-31, 6-7 ft	9.8	33.9	36	15	21	87	0.356	18.27	0.272	111.4	111.4	3.14	1.5	91.8	123.0	0.746341	
12	B-31, 28-29 ft	15.5	24.7	30	11	19	80	0.700	15.20	0.656	14.5	14.5	0.99	3.3	97.5	105.2	0.926806	
13	B-32, 1-3 ft	14.2	25.6	38	12	26	83	0.526	21.58	0.424	50.4	50.4	2.22	5.9	98.6	114.6	0.860384	
14	B-32, 3-5 ft	13.2	25.3	38	12	26	83	0.489	21.58	0.385	123.3	123.3	4.92	4.2	99.8	111.0	0.899099	
15	B-34, 3-4 ft	9.7	26.7	39	12	27	86	0.352	23.22	0.240	93.0	93.0	2.32	3.6	98.0	119.5	0.820084	
16	B-34, 4-5 ft	9.3	24.8	39	12	27	86	0.338	23.22	0.227	94.3	94.3	2.22	2.8	97.9	116.9	0.837468	
17	B-38, 1-3 ft	12.5	32.1	50	12	38	82	0.373	31.16	0.230	66.5	66.5	1.58	3.2	93.4	113.3	0.82436	
18	B-38, 3-5 ft	12.5	28.7	51	12	39	82	0.367	31.98	0.222	15.2	15.2	0.35	5.3	96.1	107.5	0.893953	
																		9.64
	Calc. on Ave's	**11.9**	**27.4**	**38.05**	**12.70**	**25.50**	**81.35**	**0.436**	**20.74**	**0.335**	**85.7**	**85.7**	**2.98**	**3.0**	**96.1**	**113.4**	**0.847443**	165
	Minimum =	**8.5**	**23.5**	**26.00**	**11.00**	**15.00**	**73.00**	**0.321**	**11.70**	**0.202**	**14.5**		**0.35**	**1.1**	**85.2**	**100.0**		
	Maximum =	**15.5**	**34.1**	**51.00**	**15.00**	**39.00**	**87.00**	**0.700**	**31.98**	**0.656**	**164.8**		**7.81**	**5.9**	**100.3**	**123.0**		
	Averages =	**11.9**	**27.4**	**38.05**	**12.70**	**25.50**	**81.35**	**0.451**	**20.76**	**0.361**	**85.4**		**2.95**	**3.0**	**96.1**	**113.4**		



TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 164.8 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	13.2			
Dry Density - pcf	120.7			
Diameter - inches	1.98			
Height - inches	4.45			
AT TEST				
Final Moisture - %	13.2			
Dry Density - pcf	120.7			
Calculated Diameter (in.)	1.98			
Height - inches	4.45			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	329.61			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.6			
σ_1 Failure - psi	339.61			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUIS-1
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-6, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 33 PL: 14 PI: 19 Percent -200: 83
REMARKS:

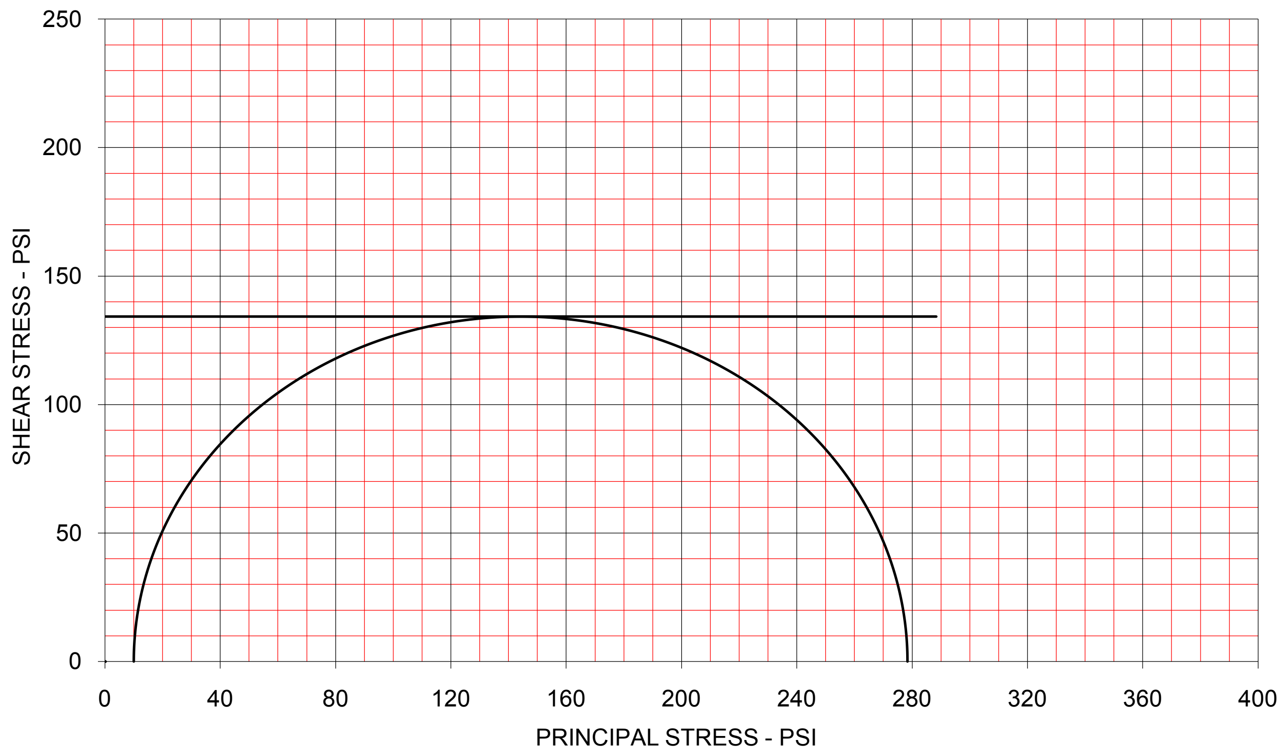
PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

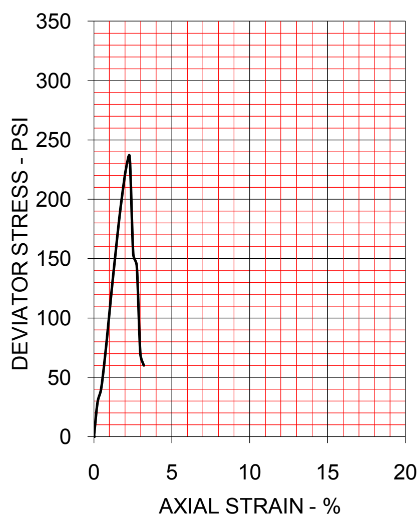
OSU - CIVE - GEOTECHNICAL PLATE: UUIS.1

UUIS-1-AA533150-B-6 (3-5).xlsx

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 134.2 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	8.5			
Dry Density - pcf	117.7			
Diameter - inches	2.11			
Height - inches	4.35			
AT TEST				
Final Moisture - %	8.5			
Dry Density - pcf	117.7			
Calculated Diameter (in.)	2.11			
Height - inches	4.35			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	268.39			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.2			
σ_1 Failure - psi	278.39			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUIS-2
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), brown
SAMPLE LOCATION: B-11-1, 3-4 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 37 PL: 12 PI: 25 Percent -200: 84
REMARKS:

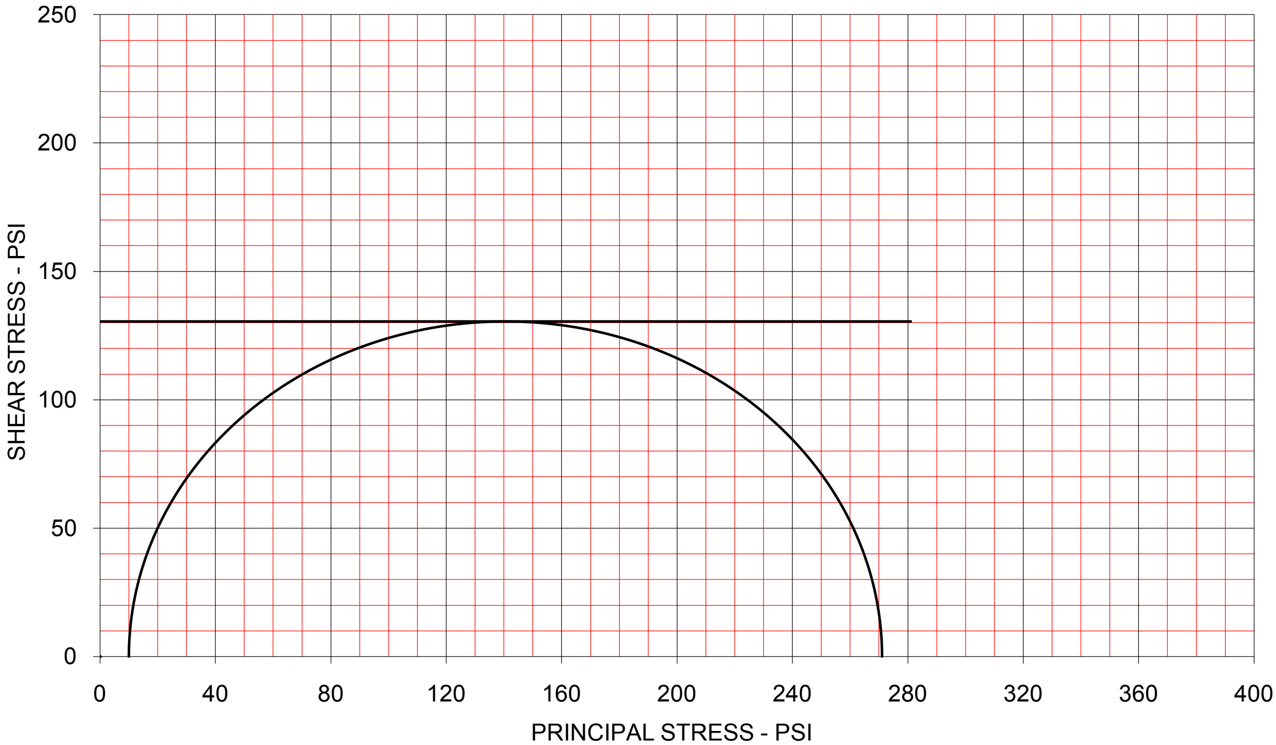
PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

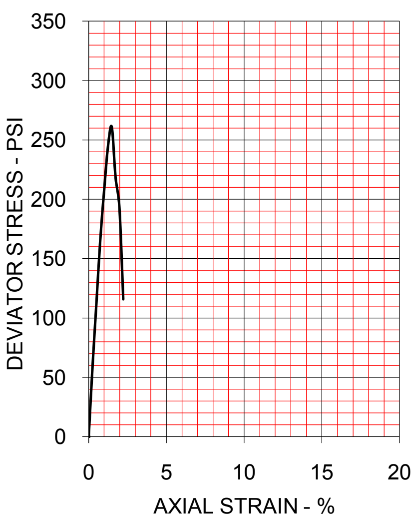
OSU - CIVE - GEOTECHNICAL PLATE: UUIS.2

UUIS-2-AA533150-B-11 (3-4)-1.xlsx

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 130.6 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	10.4			
Dry Density - pcf	117.1			
Diameter - inches	2.02			
Height - inches	4.04			
AT TEST				
Final Moisture - %	10.4			
Dry Density - pcf	117.1			
Calculated Diameter (in.)	2.02			
Height - inches	4.04			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	261.10			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	1.5			
σ_1 Failure - psi	271.10			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

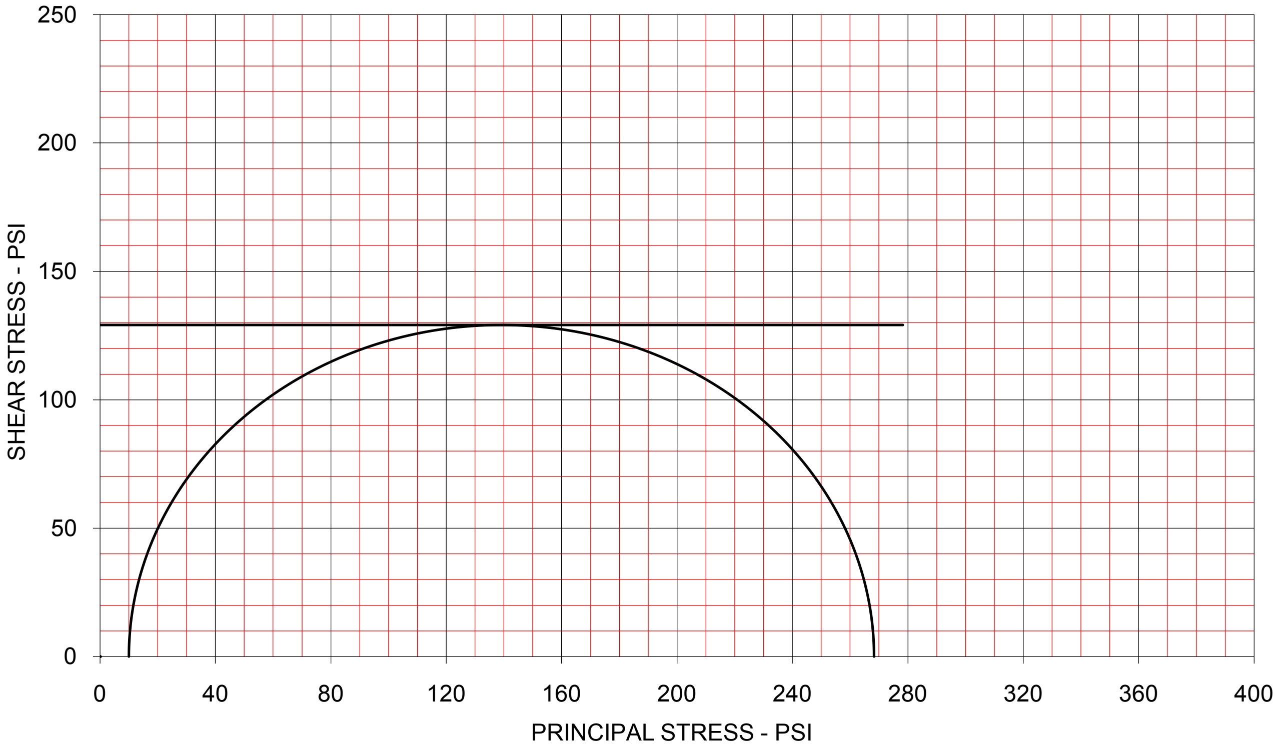
TYPE OF TEST & NO: UU Triaxial - UUIS-3
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), yellowish brown
SAMPLE LOCATION: B-11-2, 4-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 41 PL: 15 PI: 41 Percent -200: 84
REMARKS:

PROJECT INFORMATION

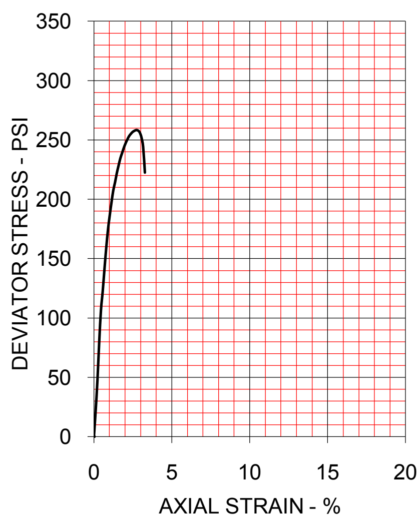
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.3

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 129.2 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	11.7			
Dry Density - pcf	110.6			
Diameter - inches	1.99			
Height - inches	4.44			
AT TEST				
Final Moisture - %	11.7			
Dry Density - pcf	110.6			
Calculated Diameter (in.)	1.99			
Height - inches	4.44			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	258.32			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.7			
σ_1 Failure - psi	268.32			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

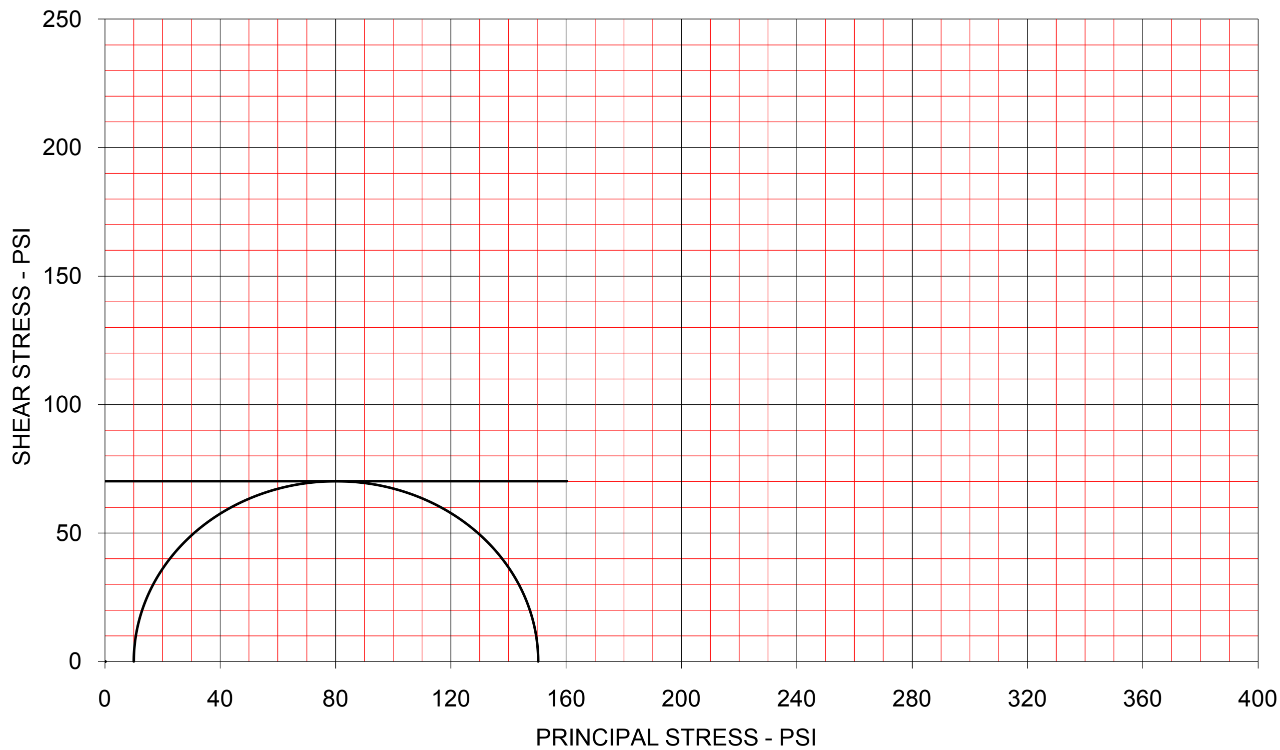
TYPE OF TEST & NO: UU Triaxial - UUIS-4
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: FAT CLAY (CH), brown
SAMPLE LOCATION: B-13, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 51 PL: 37 PI: 41 Percent -200: 77
REMARKS:

PROJECT INFORMATION

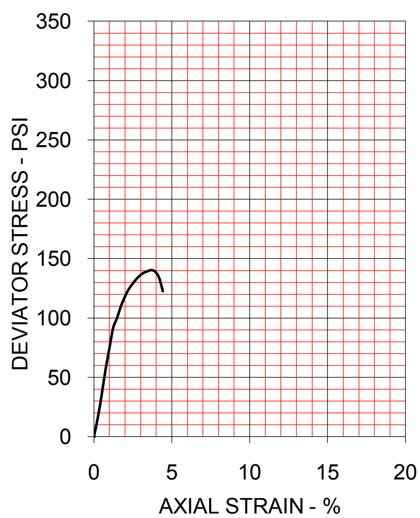
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS-4

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 70.1 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	13.6			
Dry Density - pcf	109.2			
Diameter - inches	1.93			
Height - inches	4.07			
AT TEST				
Final Moisture - %	13.6			
Dry Density - pcf	109.2			
Calculated Diameter (in.)	1.93			
Height - inches	4.07			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	140.26			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	3.7			
σ_1 Failure - psi	150.26			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

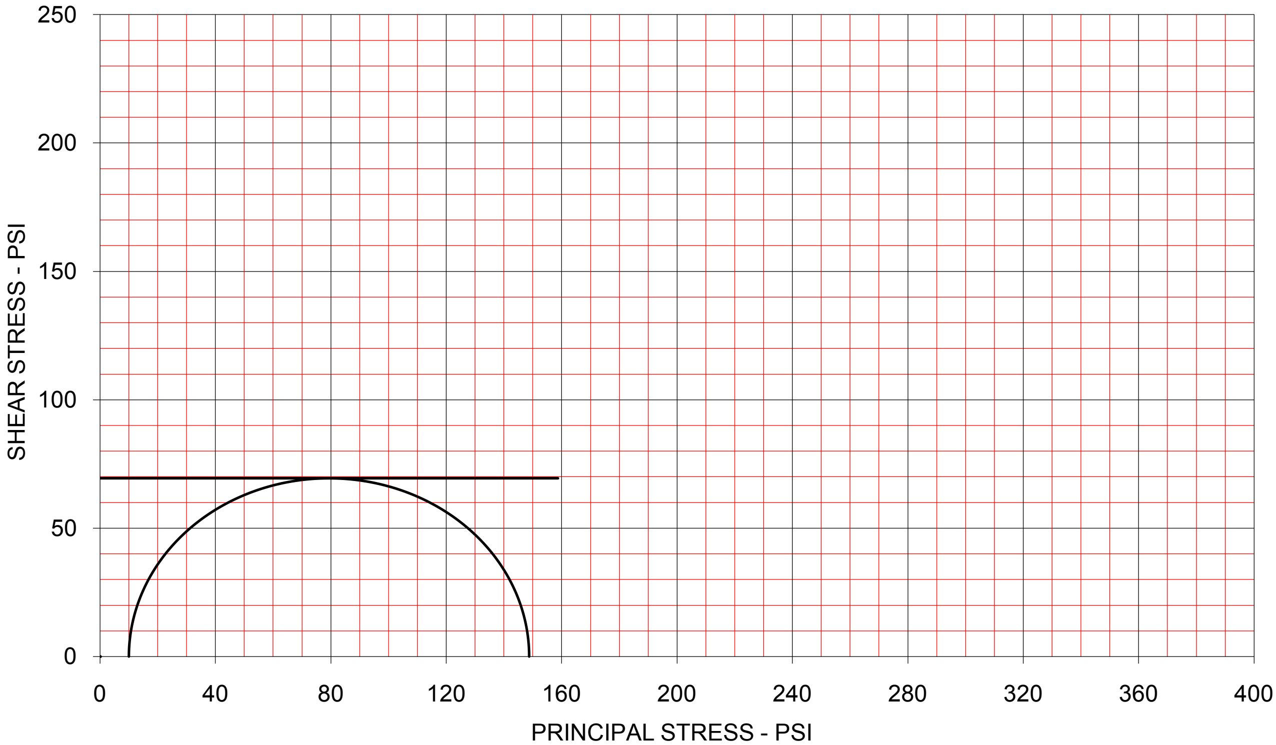
TYPE OF TEST & NO: UU Triaxial - UU-1
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-23-1, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 39 PL: 13 PI: 26 Percent -200: 73
REMARKS:

PROJECT INFORMATION

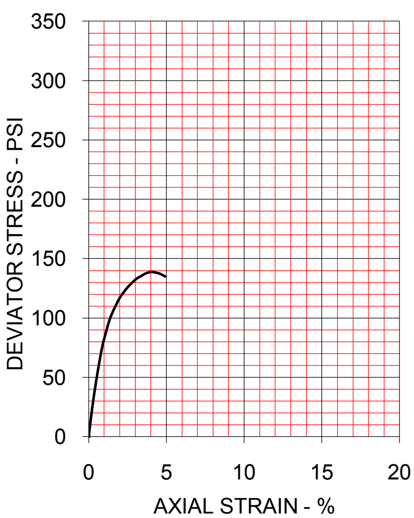
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL | PLATE: UUIS.5

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 69.4 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	12.8			
Dry Density - pcf	113.6			
Diameter - inches	2.00			
Height - inches	4.47			
AT TEST				
Final Moisture - %	12.8			
Dry Density - pcf	113.6			
Calculated Diameter (in.)	2.00			
Height - inches	4.47			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	138.76			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	4.0			
σ_1 Failure - psi	148.76			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

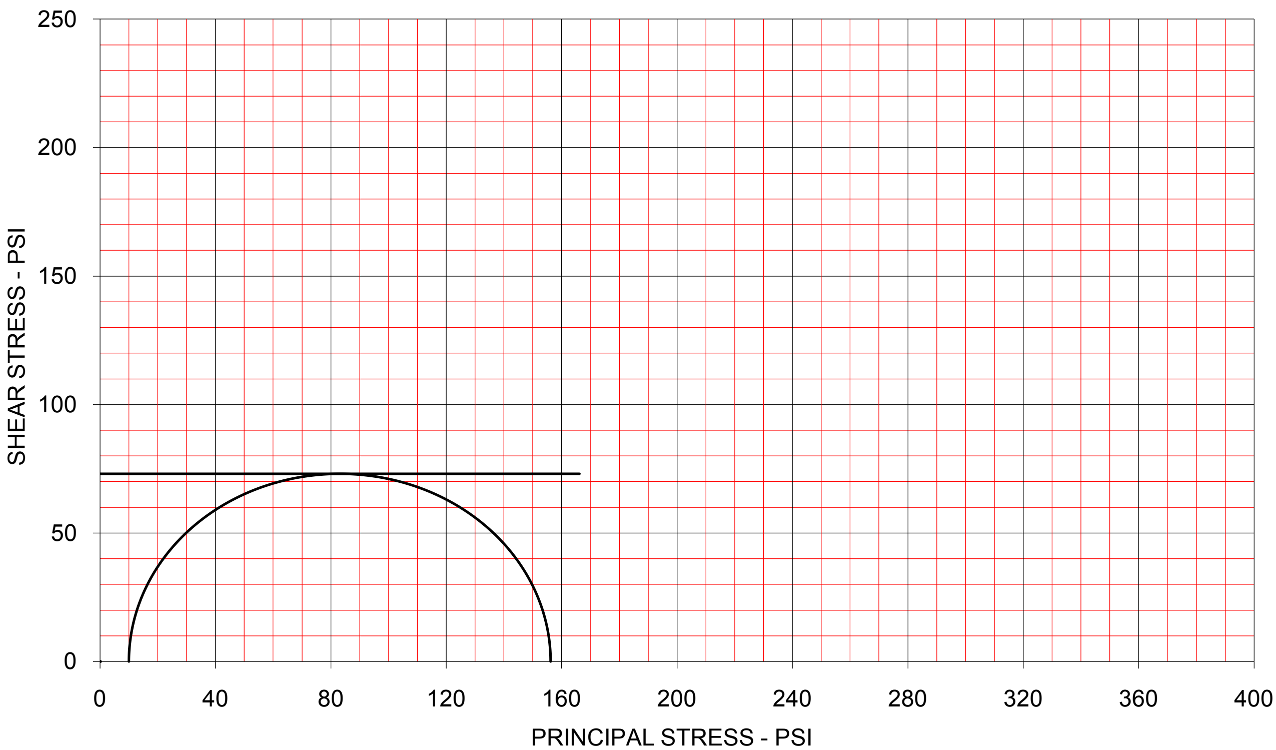
TYPE OF TEST & NO: UU Triaxial - UUIS-6
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-23-2, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 39 PL: 13 PI: 26 Percent -200: 73
REMARKS:

PROJECT INFORMATION

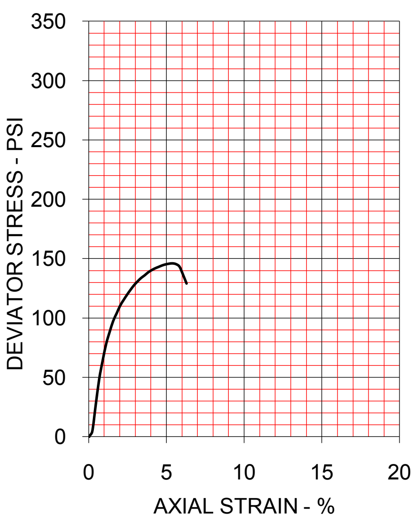
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.6

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 73.1 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	11.7			
Dry Density - pcf	114.9			
Diameter - inches	1.98			
Height - inches	4.45			
AT TEST				
Final Moisture - %	11.7			
Dry Density - pcf	114.9			
Calculated Diameter (in.)	1.98			
Height - inches	4.45			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	146.13			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.4			
σ_1 Failure - psi	156.13			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

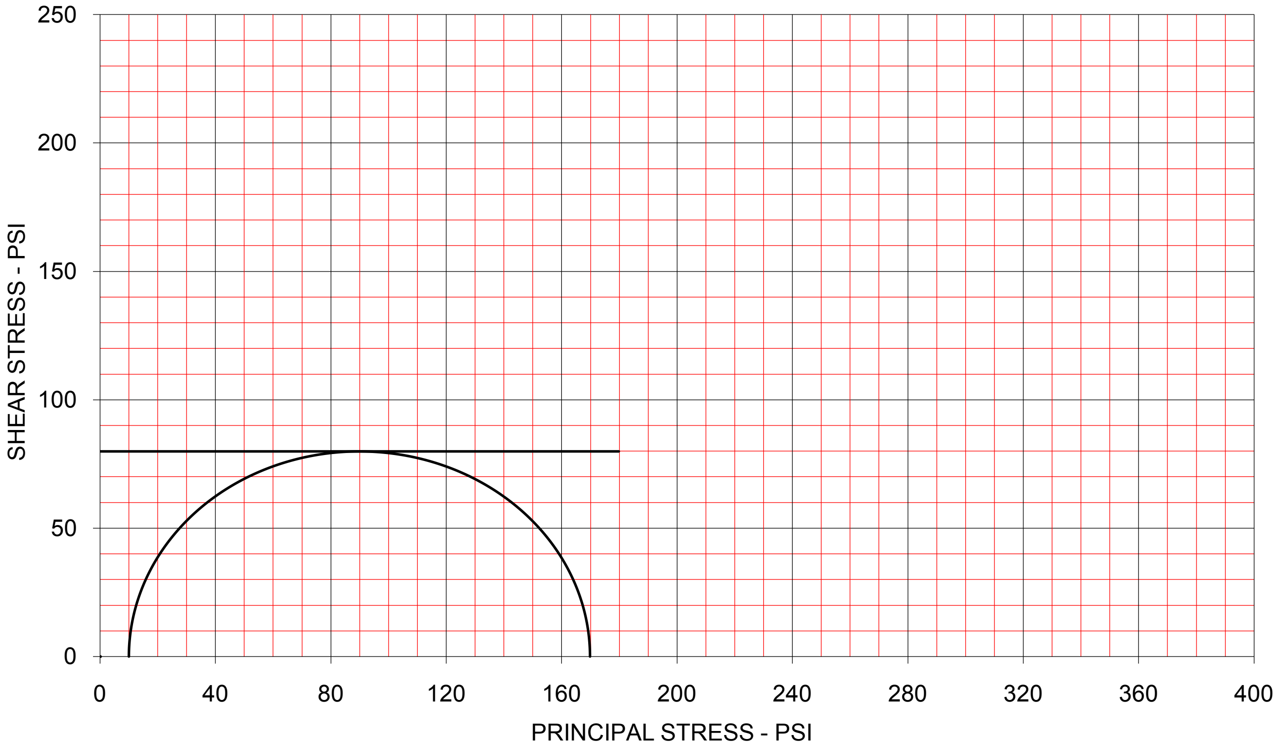
TYPE OF TEST & NO: UU Triaxial - UUIS-7
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-27, 8-9 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 35 PL: 12 PI: 23 Percent -200: 81
REMARKS:

PROJECT INFORMATION

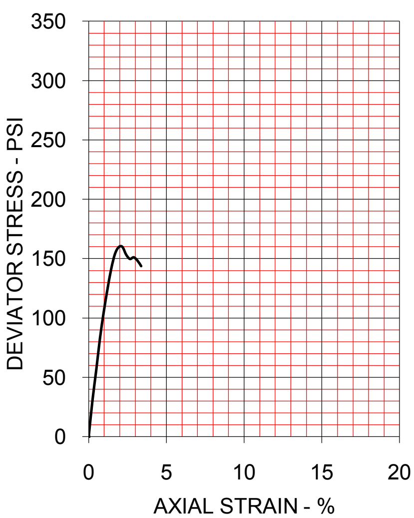
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.7

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 79.9 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	12.3			
Dry Density - pcf	108.3			
Diameter - inches	2.06			
Height - inches	4.15			
AT TEST				
Final Moisture - %	12.3			
Dry Density - pcf	108.3			
Calculated Diameter (in.)	2.06			
Height - inches	4.15			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	159.87			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.2			
σ_1 Failure - psi	169.87			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

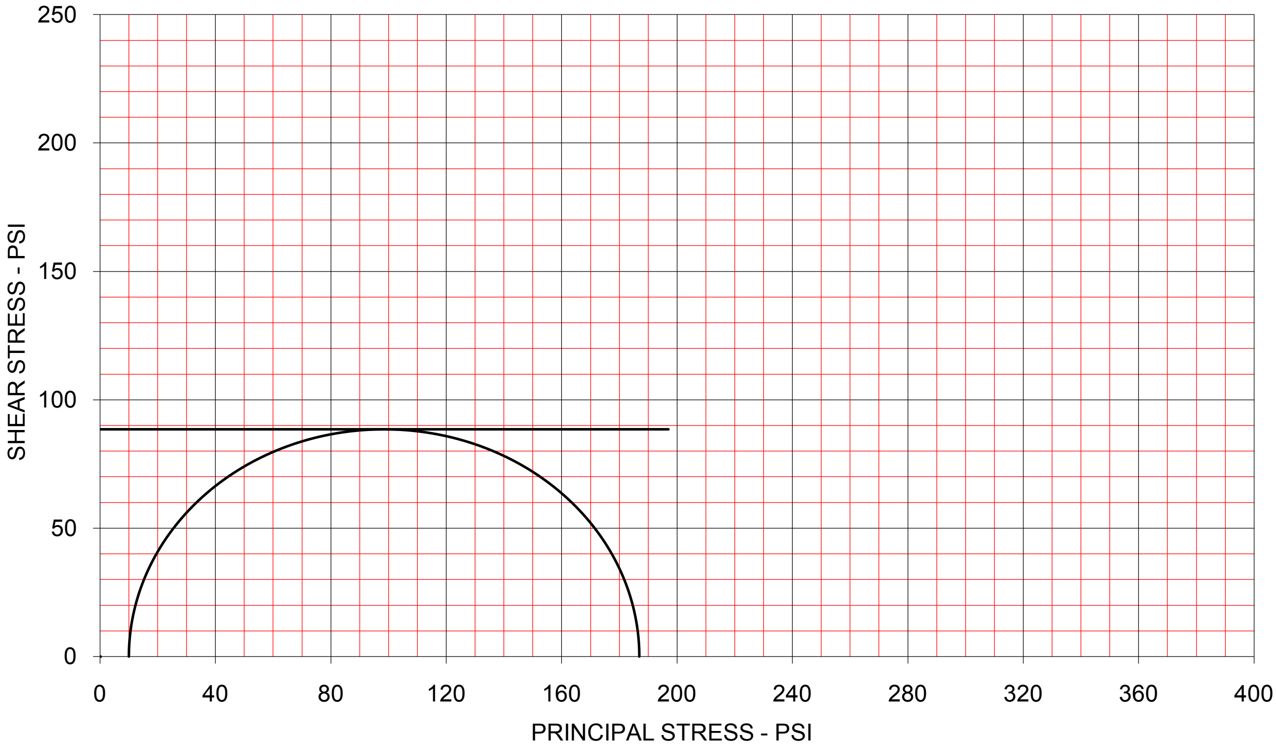
TYPE OF TEST & NO: UU Triaxial - UUIS-8
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: SANDY LEAN CLAY (CL), dark brown
SAMPLE LOCATION: B-28-1, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 26 PL: 11 PI: 15 Percent -200: 78
REMARKS:

PROJECT INFORMATION

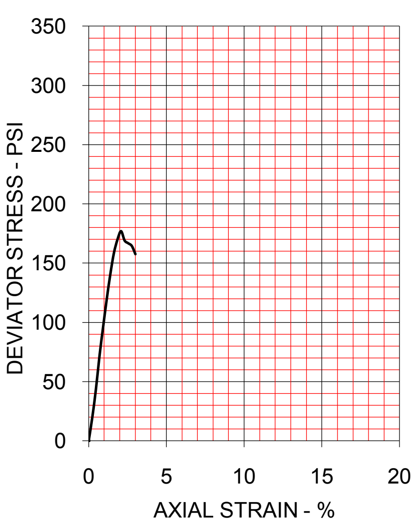
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.8

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 88.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	8.7			
Dry Density - pcf	118.7			
Diameter - inches	1.99			
Height - inches	4.32			
AT TEST				
Final Moisture - %	8.7			
Dry Density - pcf	118.7			
Calculated Diameter (in.)	1.99			
Height - inches	4.32			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	176.97			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.0			
σ_1 Failure - psi	186.97			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUIS-9
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: SANDY LEAN CLAY (CL), dark brown
SAMPLE LOCATION: B-28-2, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 26 PL: 11 PI: 15 Percent -200: 78
REMARKS:

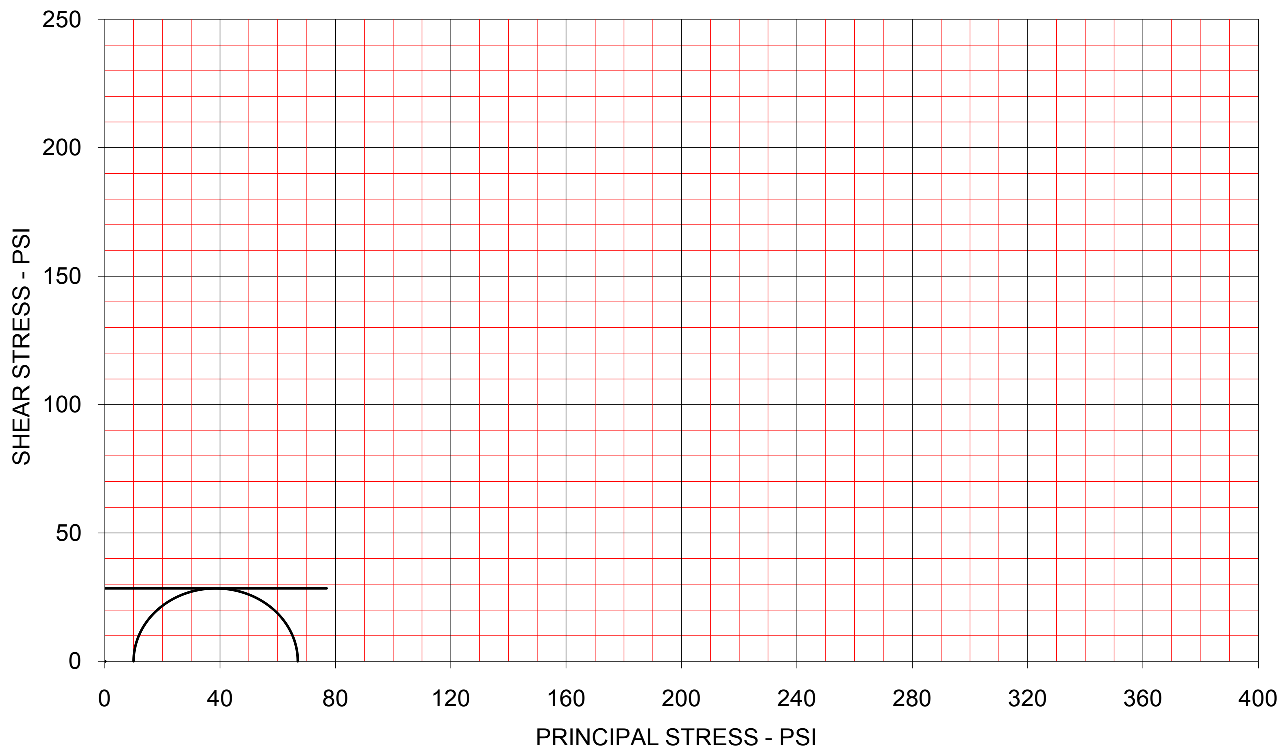
PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

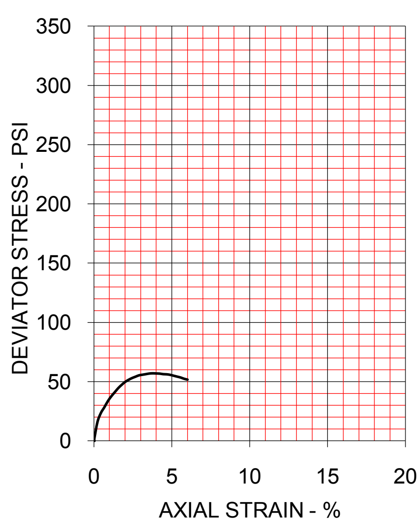
OSU - CIVE - GEOTECHNICAL PLATE: UUIS.9

UUIS-9-AA533150-B-28-2 (3-5).xlsx

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 28.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	15.2			
Dry Density - pcf	100.0			
Diameter - inches	1.97			
Height - inches	4.49			
AT TEST				
Final Moisture - %	15.2			
Dry Density - pcf	100.0			
Calculated Diameter (in.)	1.97			
Height - inches	4.49			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	56.94			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	3.8			
σ_1 Failure - psi	66.94			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

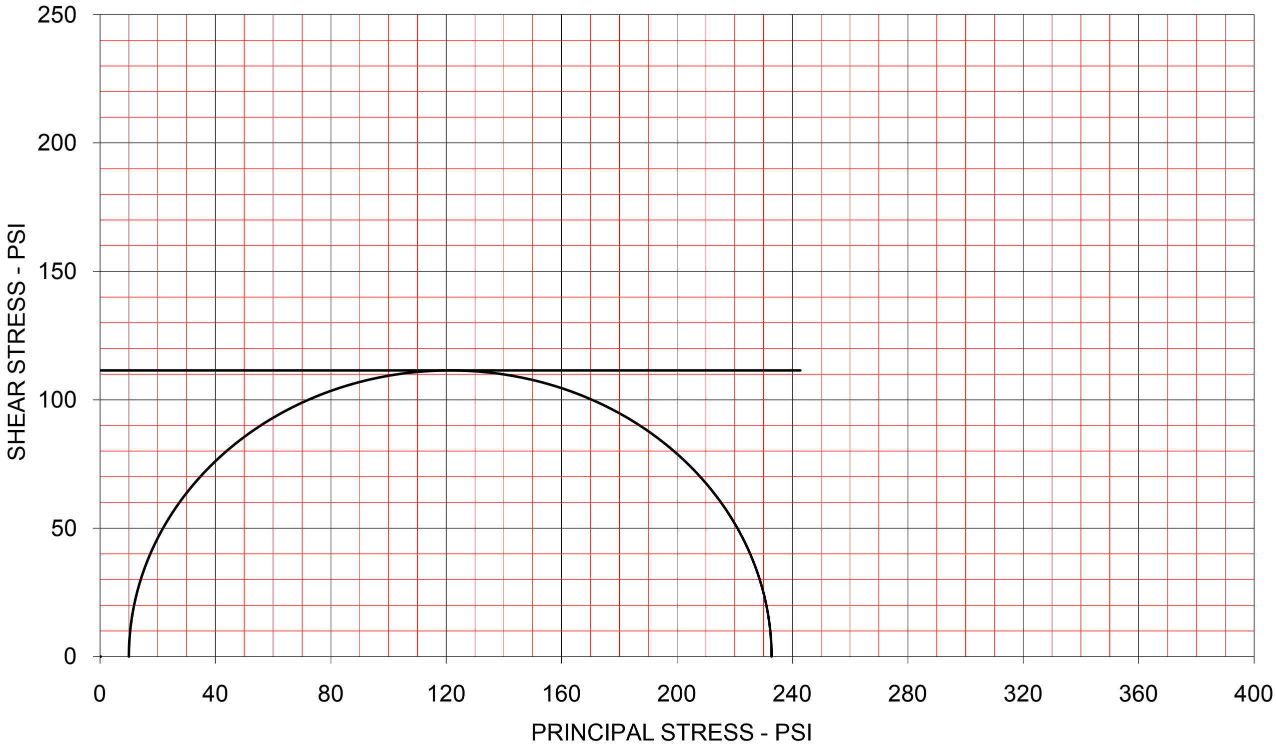
TYPE OF TEST & NO: UU Triaxial - UUIS-10
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), very dark grayish brown
SAMPLE LOCATION: B-31, 1-2 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 36 PL: 15 PI: 21 Percent -200: 87
REMARKS:

PROJECT INFORMATION

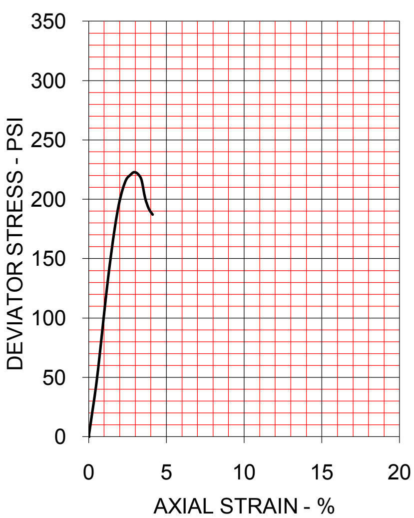
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.10

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 111.4 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	9.8			
Dry Density - pcf	123.0			
Diameter - inches	1.92			
Height - inches	4.14			
AT TEST				
Final Moisture - %	9.8			
Dry Density - pcf	123.0			
Calculated Diameter (in.)	1.92			
Height - inches	4.14			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	222.78			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.9			
σ_1 Failure - psi	232.78			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

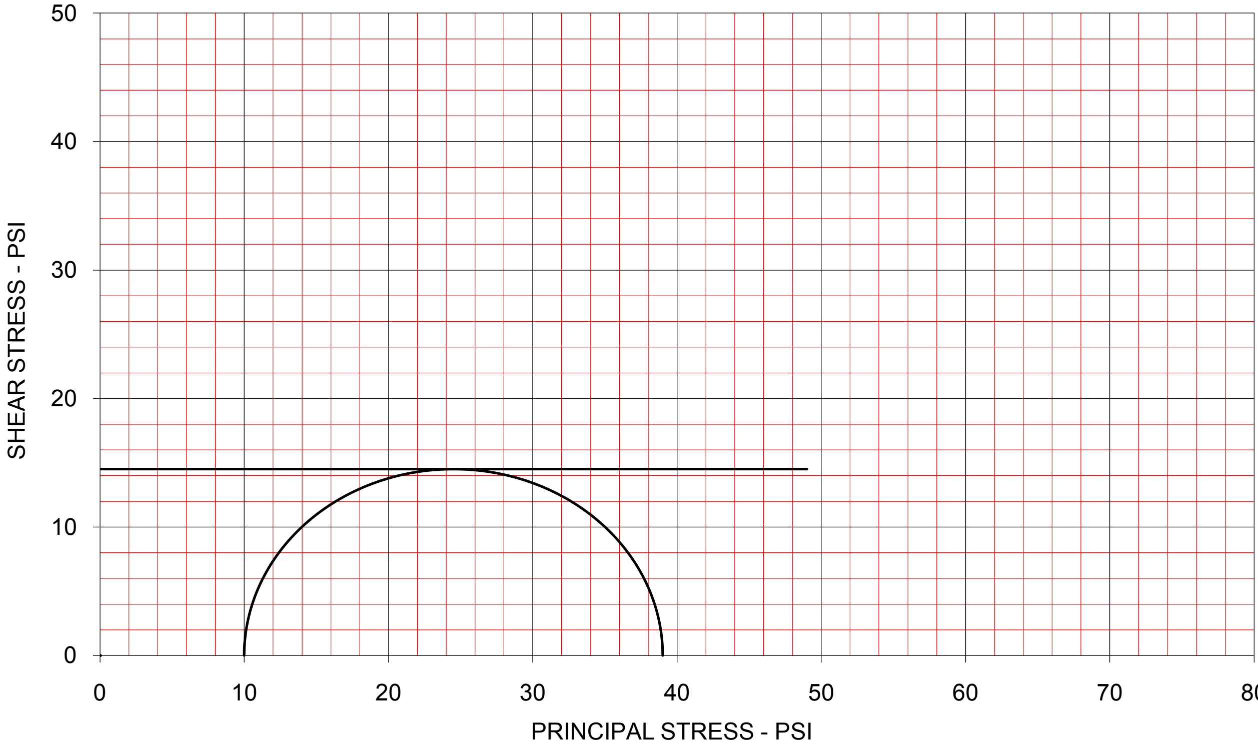
TYPE OF TEST & NO: UU Triaxial - UUIS-11
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), very dark grayish brown
SAMPLE LOCATION: B-31-2, 6-7 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 36 PL: 15 PI: 21 Percent -200: 87
REMARKS:

PROJECT INFORMATION

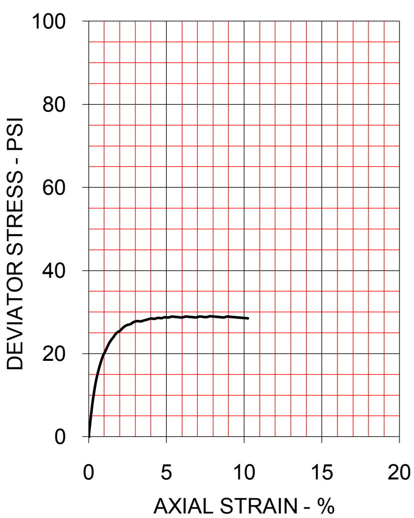
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.11

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 14.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	15.5			
Dry Density - pcf	105.2			
Diameter - inches	2.05			
Height - inches	4.49			
AT TEST				
Final Moisture - %	15.5			
Dry Density - pcf	105.2			
Calculated Diameter (in.)	2.05			
Height - inches	4.49			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	29.01			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	7.8			
σ_1 Failure - psi	39.01			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

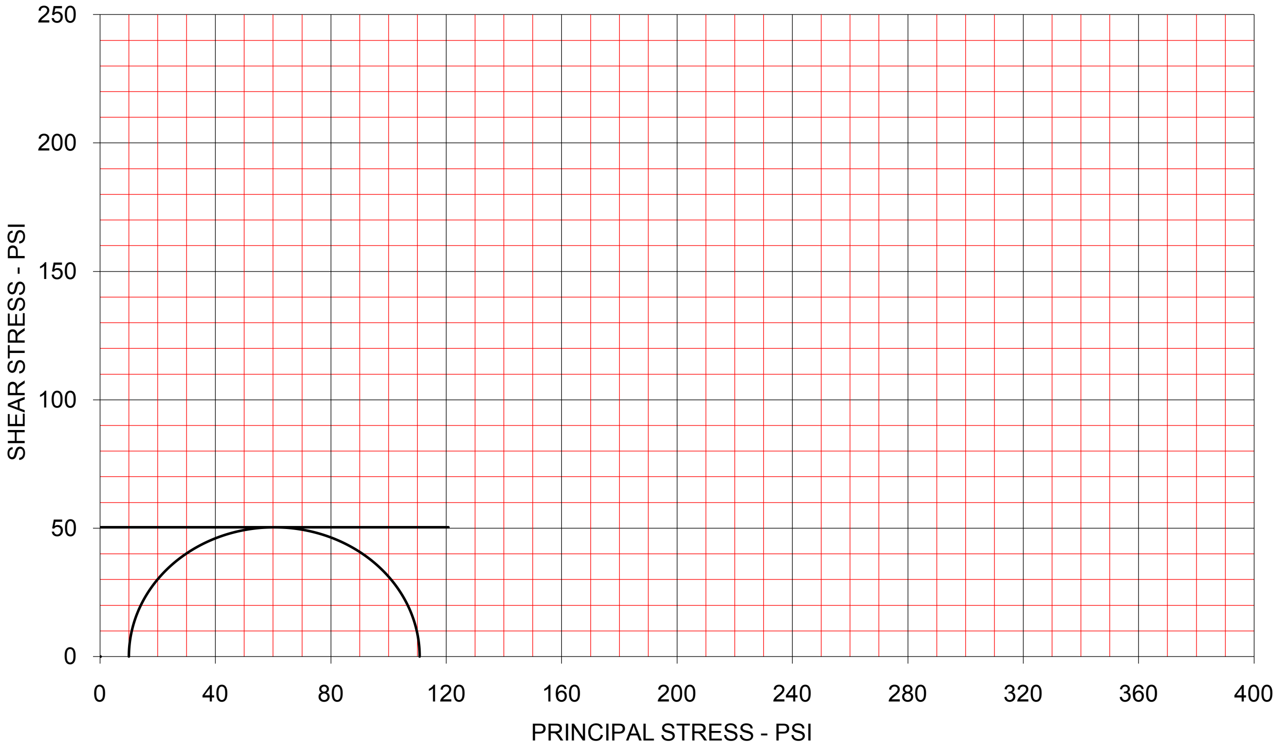
TYPE OF TEST & NO: UU Triaxial - UUIS-12
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-31, 28-29 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 30 PL: 11 PI: 19 Percent -200: 80
REMARKS:

PROJECT INFORMATION

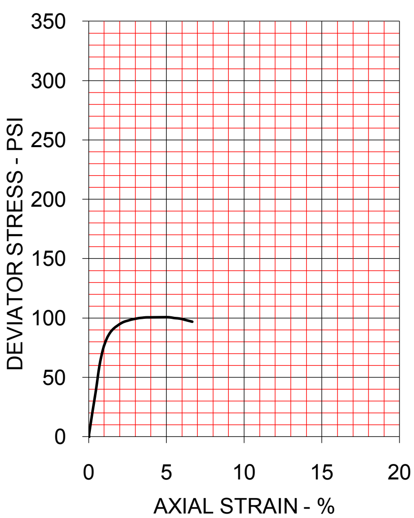
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.12

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 50.4 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	14.2			
Dry Density - pcf	114.6			
Diameter - inches	2.11			
Height - inches	4.35			
AT TEST				
Final Moisture - %	14.2			
Dry Density - pcf	114.6			
Calculated Diameter (in.)	2.11			
Height - inches	4.35			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	100.73			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.1			
σ_1 Failure - psi	110.73			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUIS-13
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-32, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 38 PL: 12 PI: 26 Percent -200: 83
REMARKS:

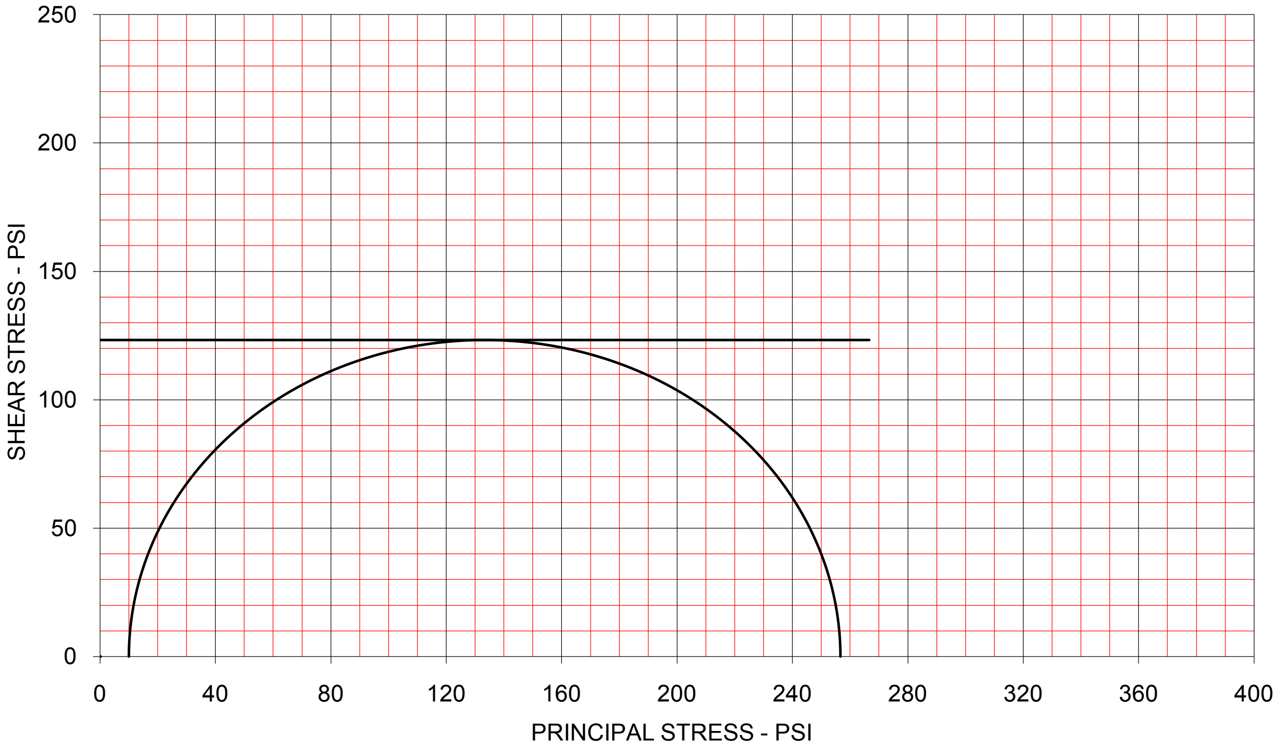
PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

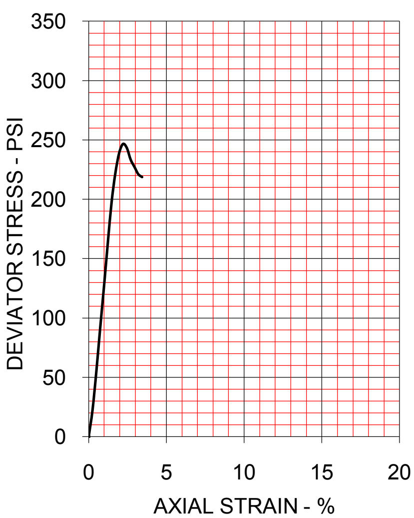
OSU - CIVE - GEOTECHNICAL PLATE: UUIS.13

UUIS-13-AA533150-B-32-1 (1-3).xlsx

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 123.3 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	13.2			
Dry Density - pcf	111.0			
Diameter - inches	2.00			
Height - inches	4.07			
AT TEST				
Final Moisture - %	13.2			
Dry Density - pcf	111.0			
Calculated Diameter (in.)	2.00			
Height - inches	4.07			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	246.64			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.2			
σ_1 Failure - psi	256.64			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

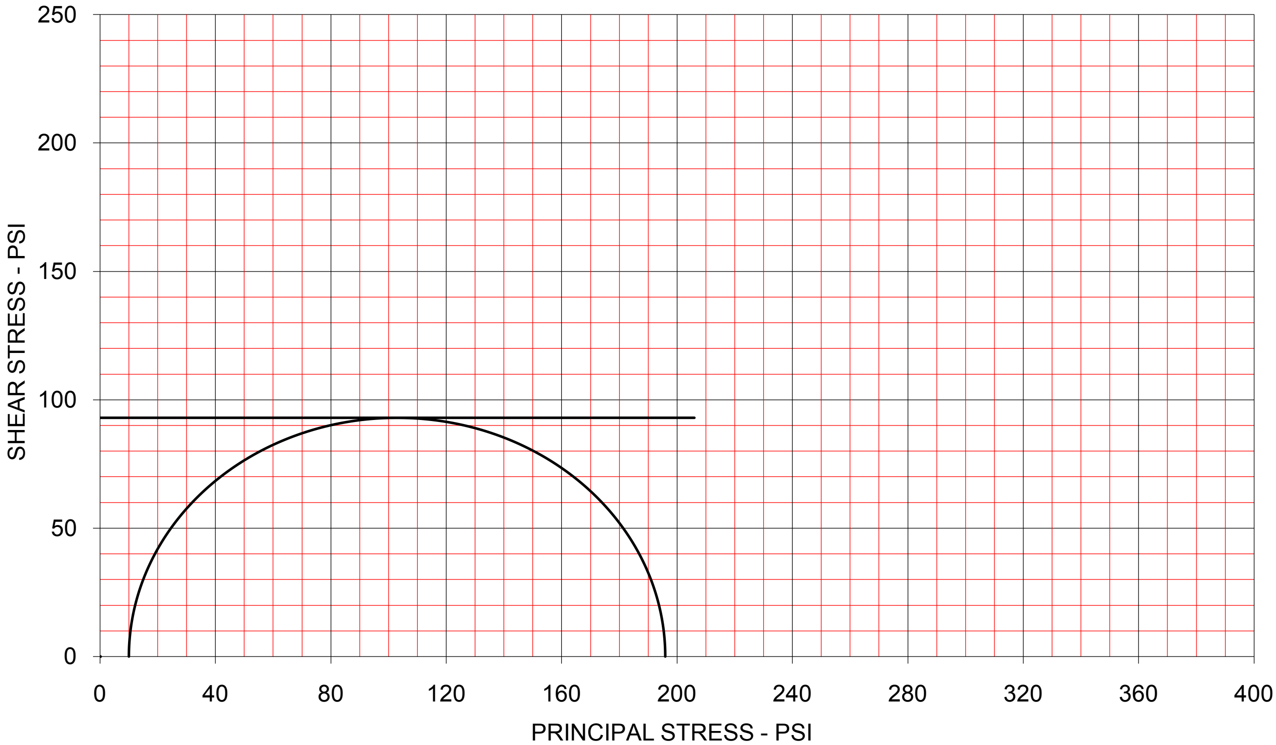
TYPE OF TEST & NO: UU Triaxial - UUIS-14
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-32, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 38 PL: 12 PI: 26 Percent -200: 83
REMARKS:

PROJECT INFORMATION

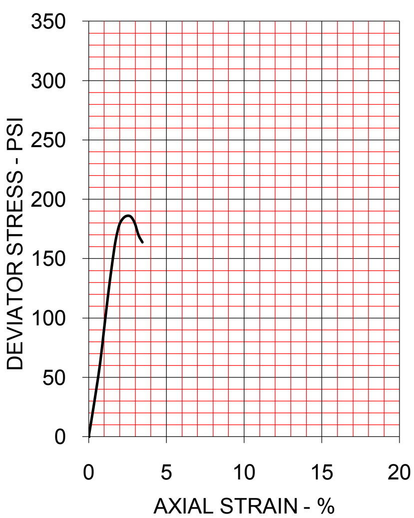
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.14

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 93.0 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	9.7			
Dry Density - pcf	119.5			
Diameter - inches	2.01			
Height - inches	4.05			
AT TEST				
Final Moisture - %	9.7			
Dry Density - pcf	119.5			
Calculated Diameter (in.)	2.01			
Height - inches	4.05			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	185.96			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.5			
σ_1 Failure - psi	195.96			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

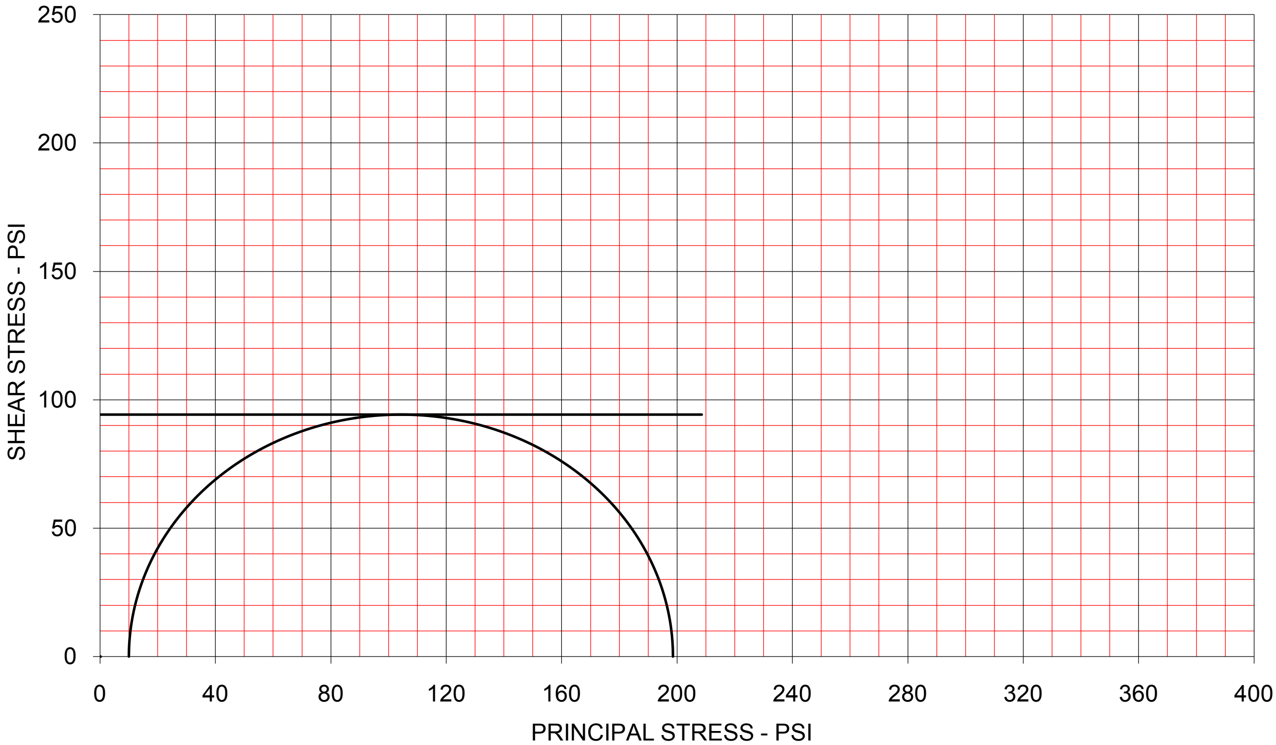
TYPE OF TEST & NO: UU Triaxial - UUIS-15
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-34, 3-4 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 39 PL: 12 PI: 27 Percent -200: 86
REMARKS:

PROJECT INFORMATION

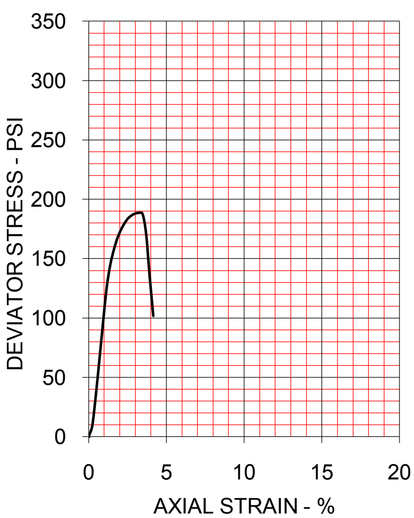
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.15

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 94.3 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	9.3			
Dry Density - pcf	116.9			
Diameter - inches	1.95			
Height - inches	4.34			
AT TEST				
Final Moisture - %	9.3			
Dry Density - pcf	116.9			
Calculated Diameter (in.)	1.95			
Height - inches	4.34			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	188.59			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	3.2			
σ_1 Failure - psi	198.59			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

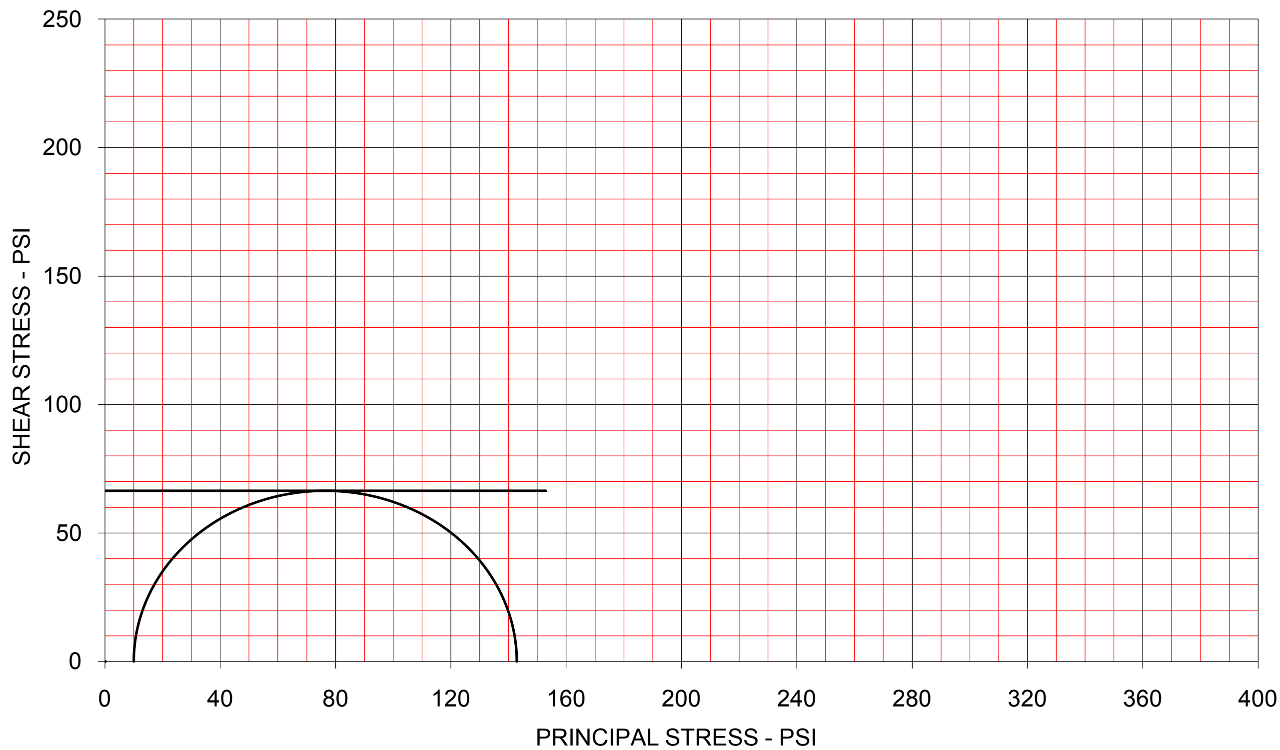
TYPE OF TEST & NO: UU Triaxial - UUIS-16
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-34, 4-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 39 PL: 12 PI: 27 Percent -200: 86
REMARKS:

PROJECT INFORMATION

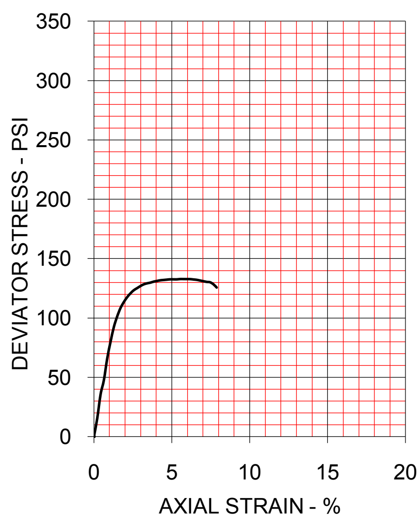
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.16

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 66.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	12.5			
Dry Density - pcf	113.3			
Diameter - inches	2.07			
Height - inches	4.69			
AT TEST				
Final Moisture - %	12.5			
Dry Density - pcf	113.3			
Calculated Diameter (in.)	2.07			
Height - inches	4.69			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	132.91			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.5			
σ_1 Failure - psi	142.91			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

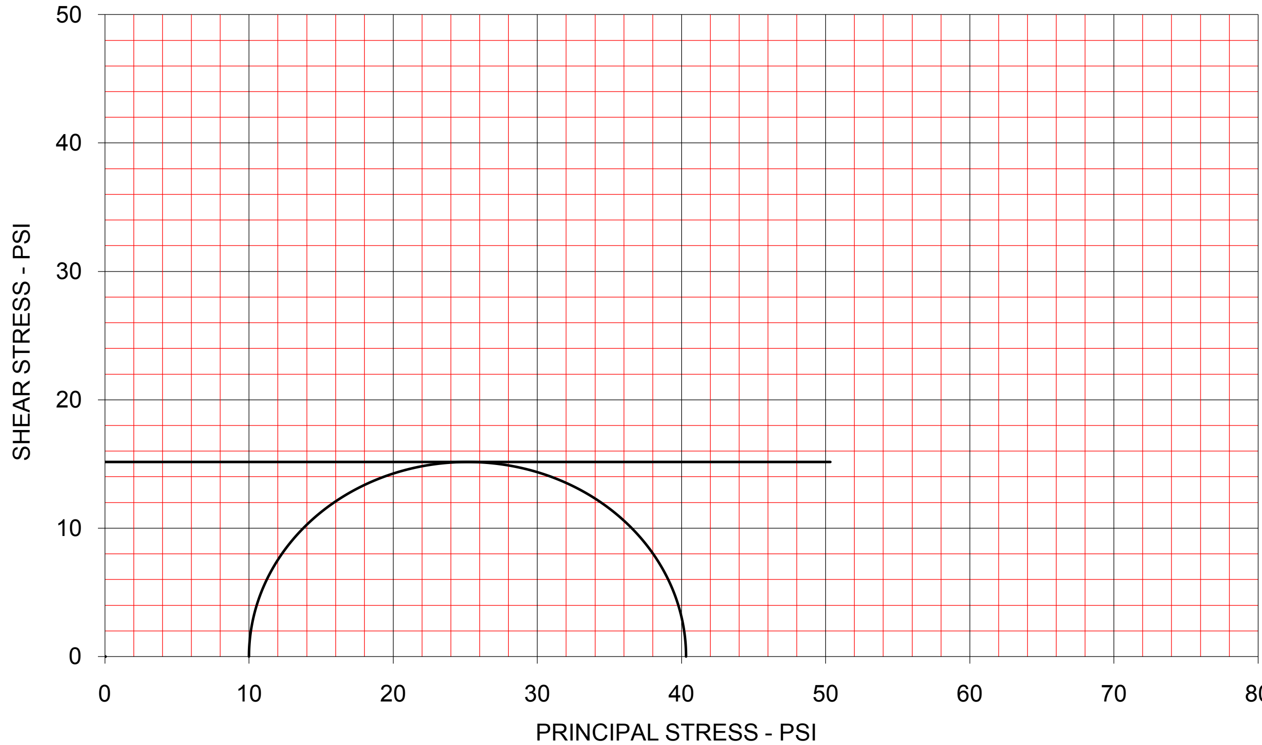
TYPE OF TEST & NO: UU Triaxial - UUIS-17
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: FAT CLAY (CH), brown
SAMPLE LOCATION: B-38, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 50 PL: 12 PI: 38 Percent -200: 82
REMARKS:

PROJECT INFORMATION

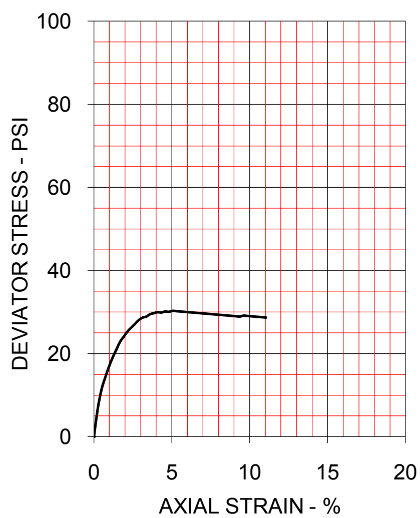
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL | PLATE: UUIS.17

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 15.2 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	12.5			
Dry Density - pcf	107.5			
Diameter - inches	1.96			
Height - inches	4.17			
AT TEST				
Final Moisture - %	12.5			
Dry Density - pcf	107.5			
Calculated Diameter (in.)	1.96			
Height - inches	4.17			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	30.32			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.0			
σ_1 Failure - psi	40.32			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

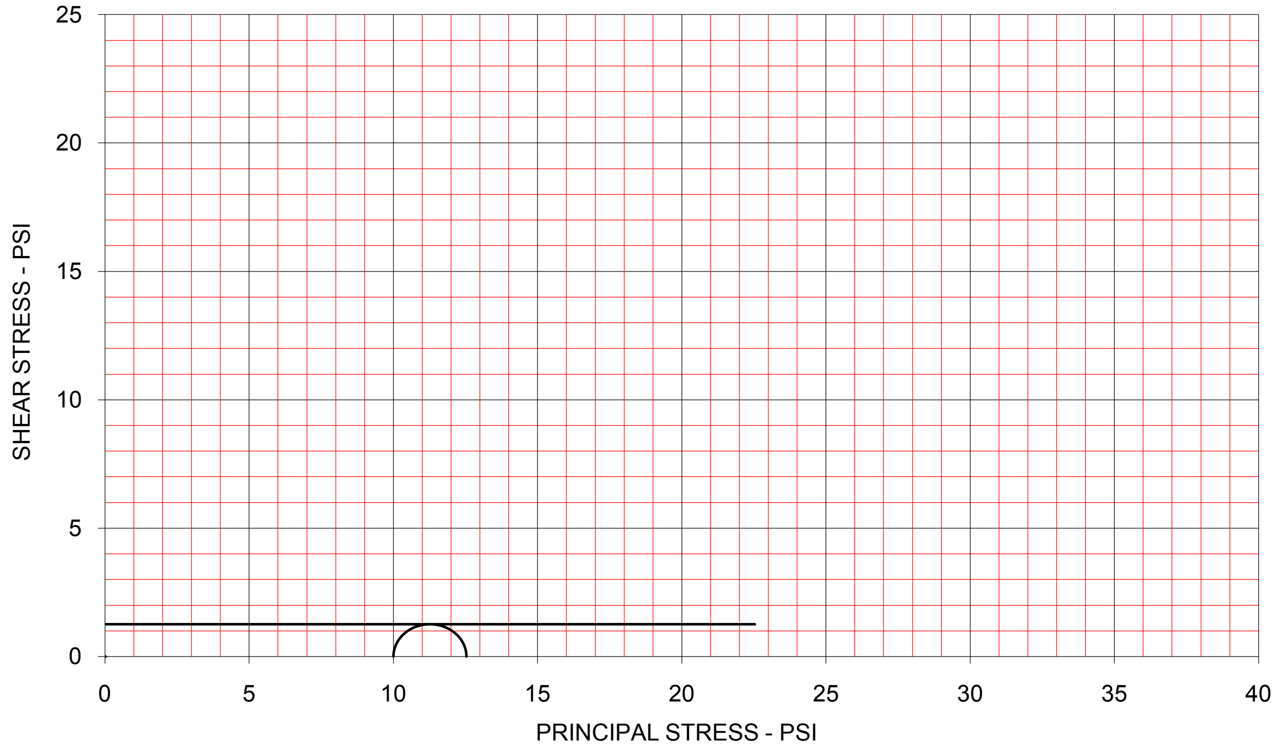
TYPE OF TEST & NO: UU Triaxial - UUIS-18
SAMPLE TYPE: SHELBY TUBE
DESCRIPTION: FAT CLAY (CH), dark grayish brown
SAMPLE LOCATION: B-38, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 51 PL: 12 PI: 39 Percent -200: 82
REMARKS:

PROJECT INFORMATION

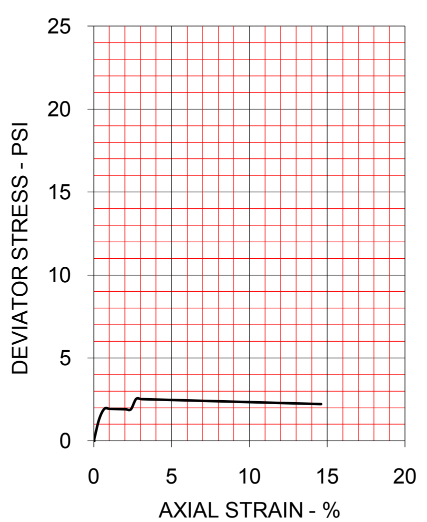
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUIS.18

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 1.3 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	34.1			
Dry Density - pcf	85.2			
Diameter - inches	1.40			
Height - inches	2.95			
AT TEST				
Final Moisture - %	34.1			
Dry Density - pcf	85.2			
Calculated Diameter (in.)	1.40			
Height - inches	2.95			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	2.53			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.6			
σ_1 Failure - psi	12.53			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUFS-1
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-6, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 33 PL: 14 PI: 19 Percent -200: 83
REMARKS:

PROJECT INFORMATION

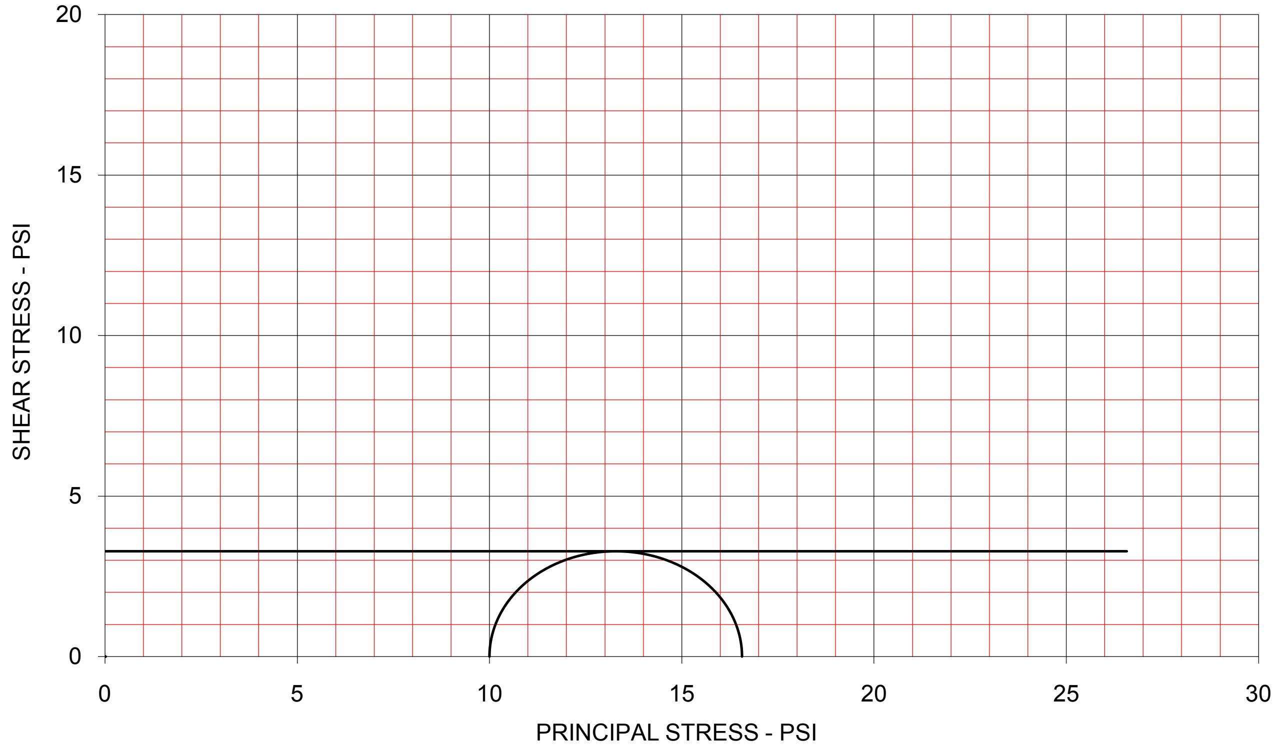
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL

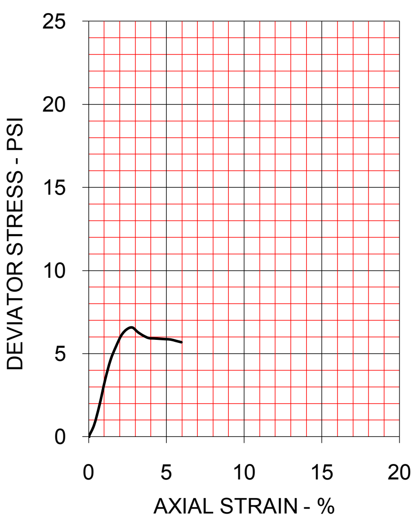
PLATE: UUF.1

UUFS-1-AA533150 -B-6 (3-5).xlsx

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 3.3 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	25.7			
Dry Density - pcf	97.3			
Diameter - inches	1.40			
Height - inches	2.85			
AT TEST				
Final Moisture - %	25.7			
Dry Density - pcf	97.3			
Calculated Diameter (in.)	1.40			
Height - inches	2.85			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	6.57			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.8			
σ_1 Failure - psi	16.57			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

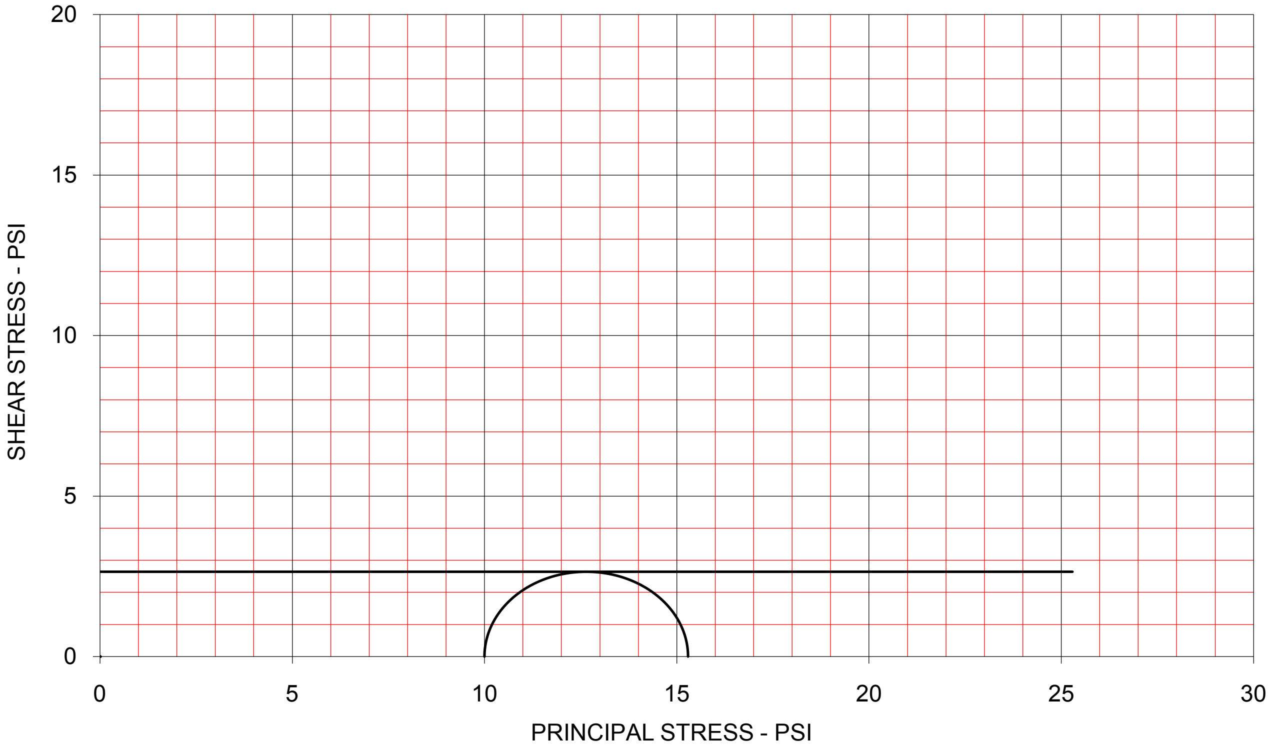
TYPE OF TEST & NO: UU Triaxial - UUFS-2
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), brown
SAMPLE LOCATION: B-11, 3-4 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 37 PL: 12 PI: 25 Percent -200: 84
REMARKS:

PROJECT INFORMATION

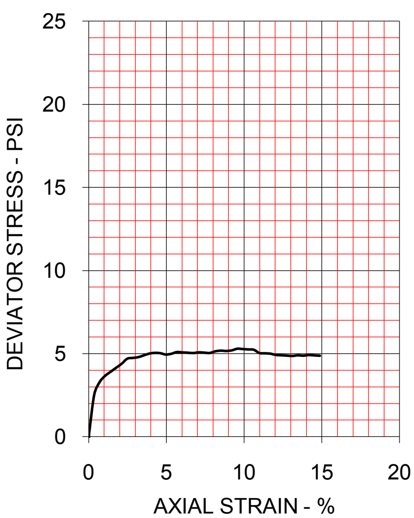
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUF.2

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 2.6 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	23.5			
Dry Density - pcf	100.1			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	23.5			
Dry Density - pcf	100.1			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	5.29			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	9.6			
σ_1 Failure - psi	15.29			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

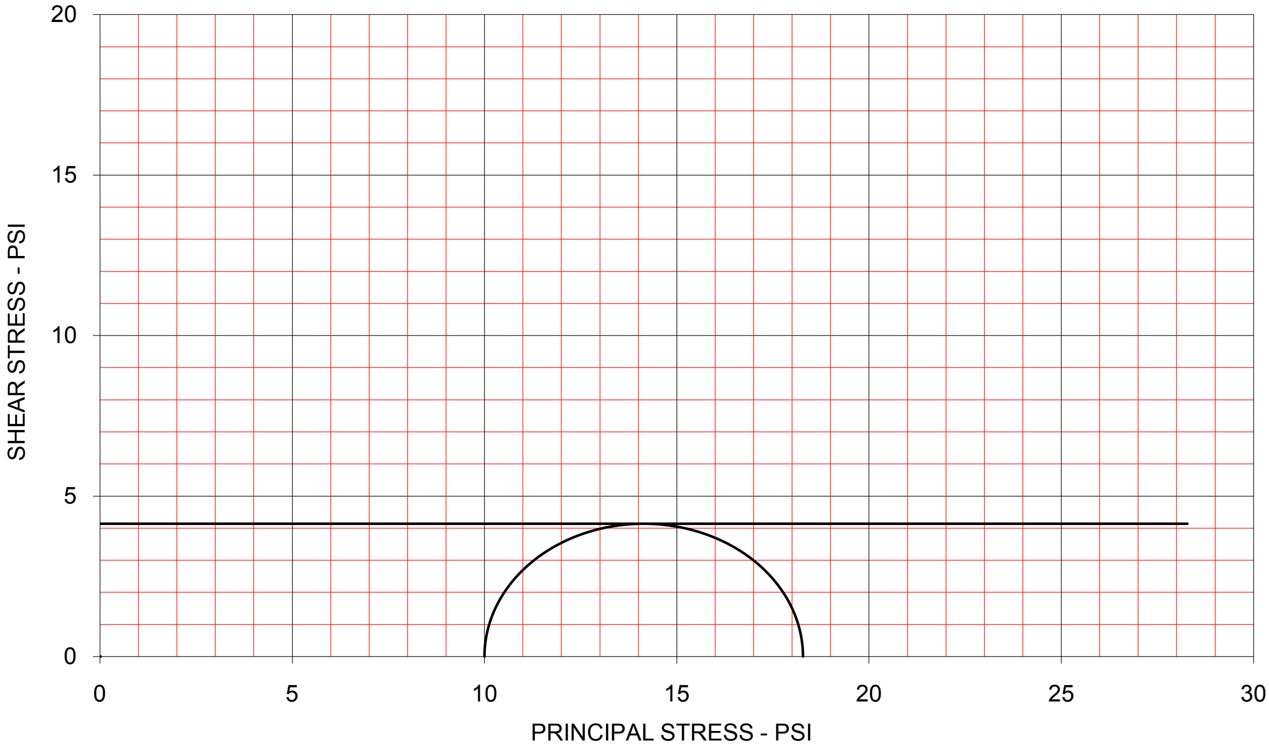
TYPE OF TEST & NO: UU Triaxial - UUFS-3
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), yellowish brown
SAMPLE LOCATION: B-11, 4 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 41 PL: 15 PI: 26 Percent -200: 84
REMARKS:

PROJECT INFORMATION

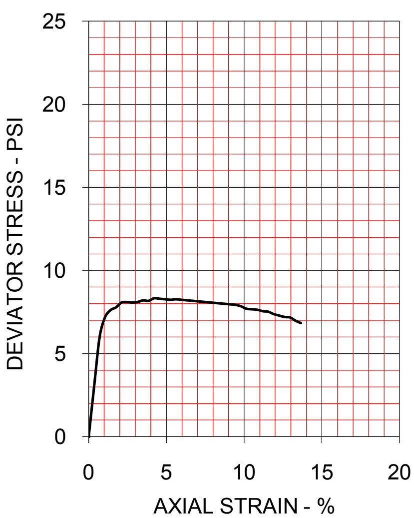
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL | PLATE: UUF.3

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 4.1 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	23.8			
Dry Density - pcf	100.3			
Diameter - inches	1.40			
Height - inches	2.86			
AT TEST				
Final Moisture - %	23.8			
Dry Density - pcf	100.3			
Calculated Diameter (in.)	1.40			
Height - inches	2.86			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	8.28			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.6			
σ_1 Failure - psi	18.28			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: FAT CLAY (CH), brown
SAMPLE LOCATION: B-13, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 51 PL: 14 PI: 37 Percent -200: 77
REMARKS:

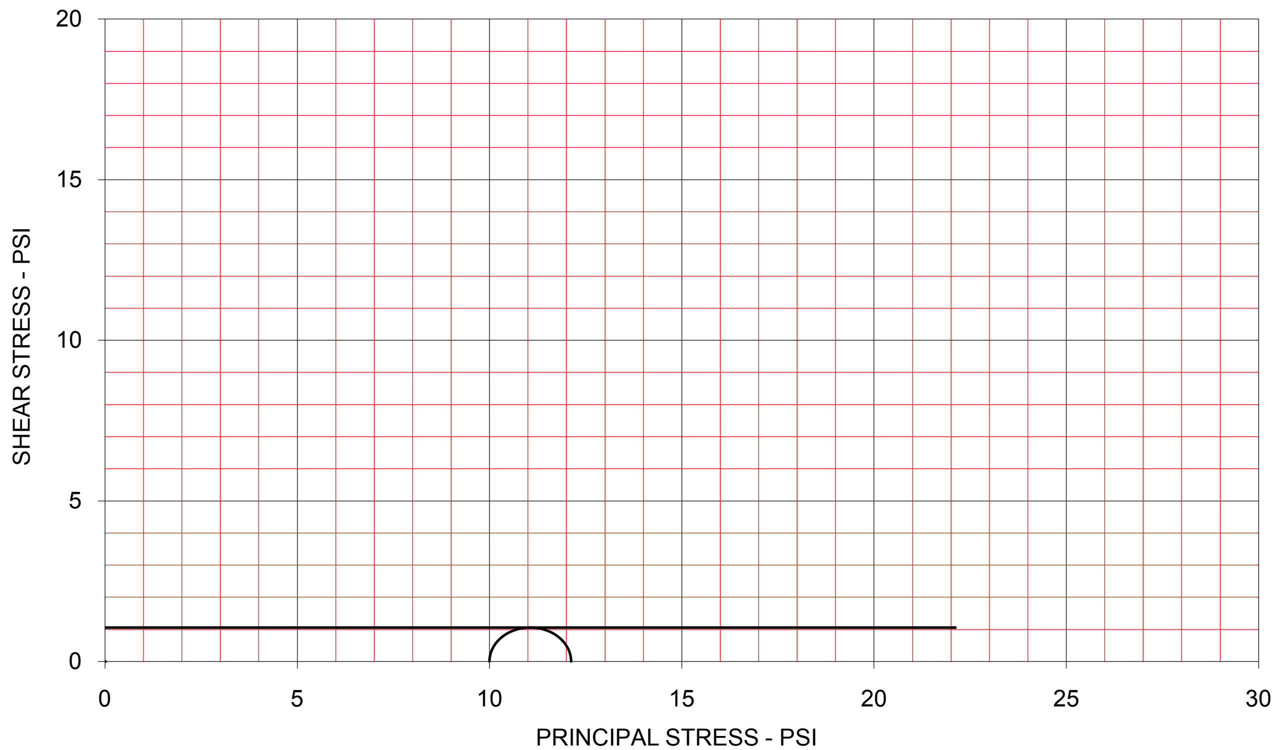
PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

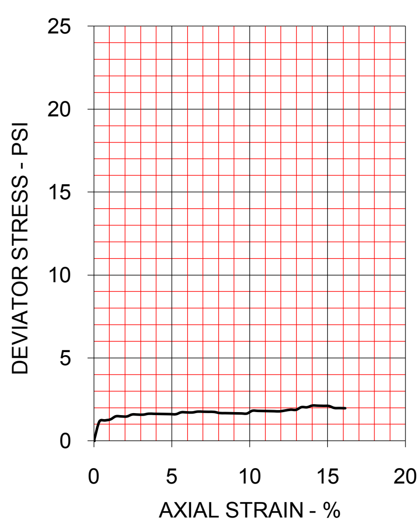
OSU - CIVE - GEOTECHNICAL | PLATE: UUF.4

UUFS-4-AA533150 -B-13 (1-3).xlsx

TRIAXIAL SHEAR TEST REPORT



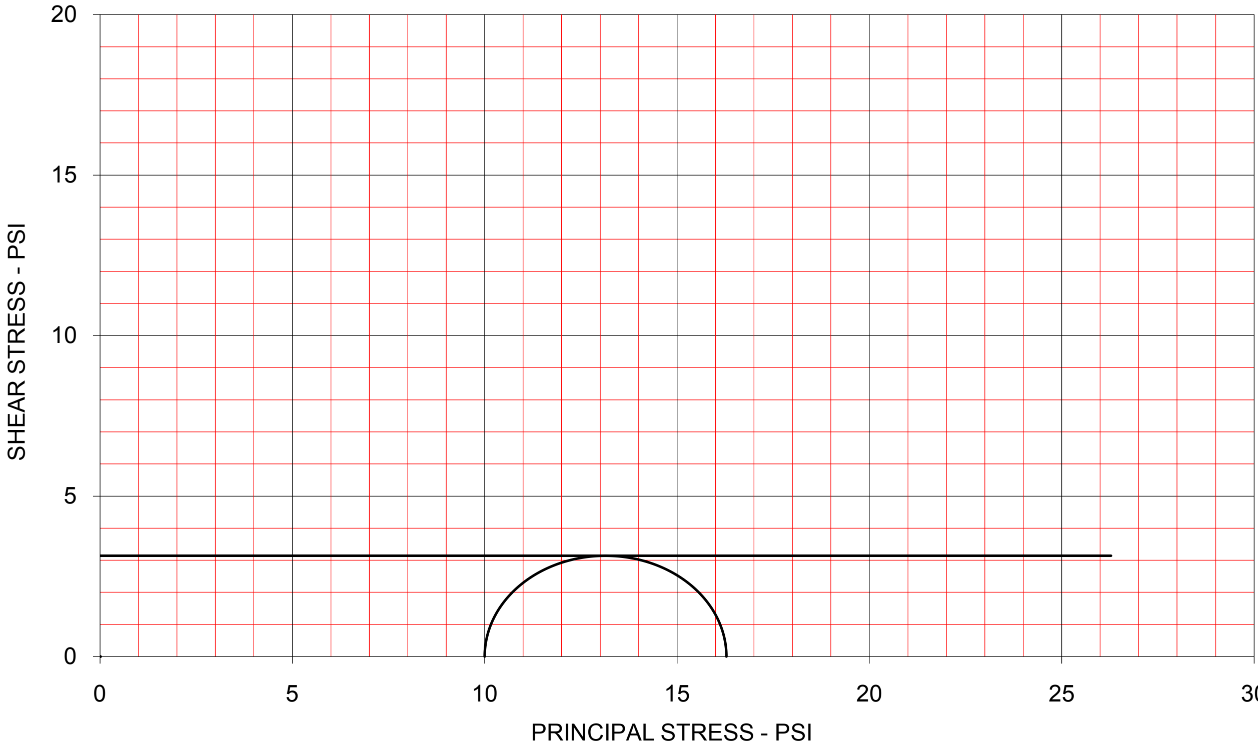
TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 1.1 psi



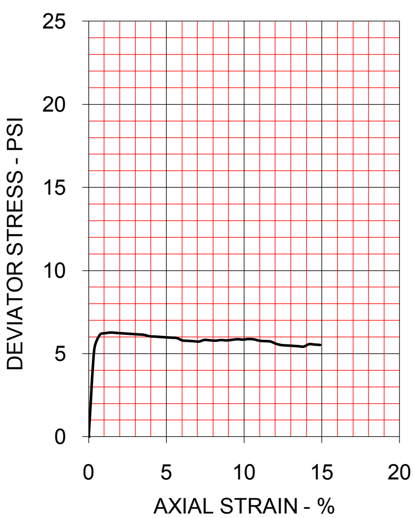
SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	27.8			
Dry Density - pcf	91.6			
Diameter - inches	1.40			
Height - inches	2.85			
AT TEST				
Final Moisture - %	27.8			
Dry Density - pcf	91.6			
Calculated Diameter (in.)	1.40			
Height - inches	2.85			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	2.12			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	14.0			
σ_1 Failure - psi	12.12			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION	PROJECT INFORMATION
TYPE OF TEST & NO: UU Triaxial - UUFS-4	PROJECT: Fully-Softened Clay Research
SAMPLE TYPE: SPNC	LOCATION: Stillwater, OK
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown	PROJECT NO: AA-5-33150
SAMPLE LOCATION: B-23, 1-3 ft	CLIENT: ODOT
ASSUMED SPECIFIC GRAVITY: 2.70	DATE: 10/20/2010
LL: 39 PL: 13 PI: 26 Percent -200: 73	***OSU - CIVE - GEOTECHNICAL***
REMARKS:	PLATE: UUF.5

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 3.1 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	26.5			
Dry Density - pcf	96.6			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	26.5			
Dry Density - pcf	96.6			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	6.28			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	1.4			
σ_1 Failure - psi	16.28			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

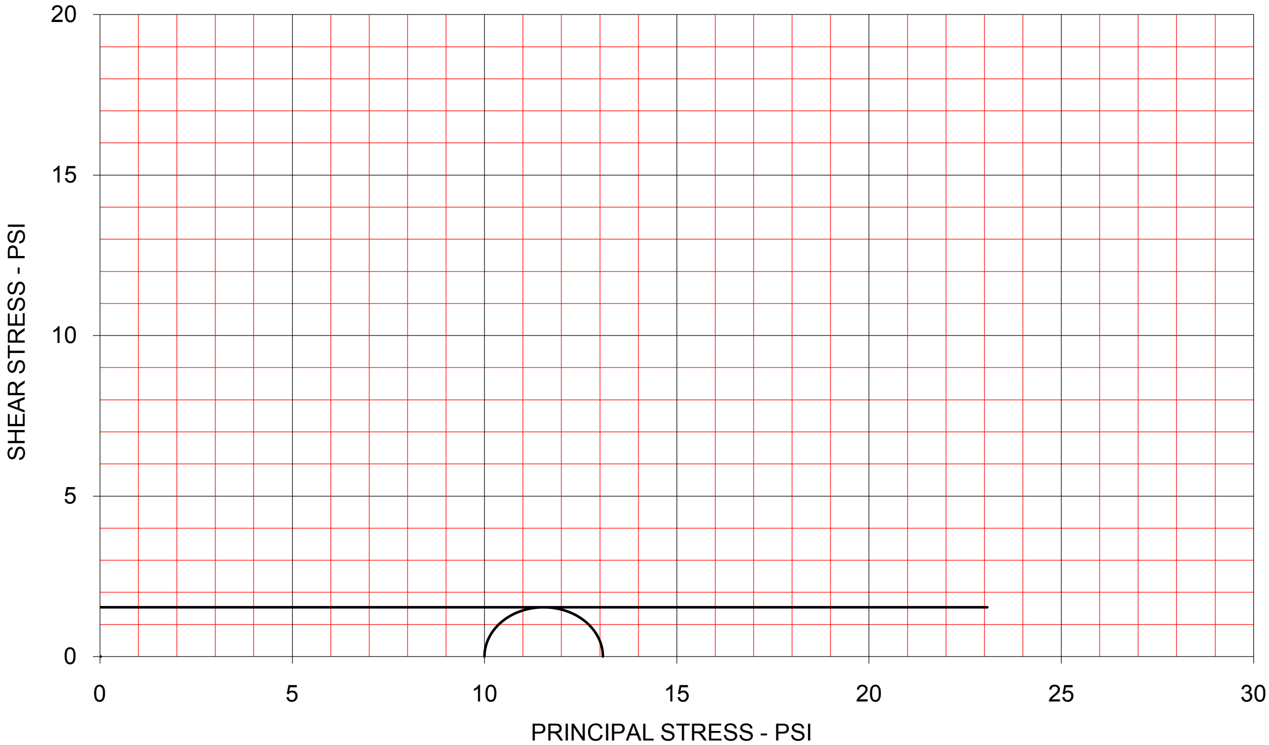
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-23, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 39 PL: 13 PI: 26 Percent -200: 73
REMARKS:

PROJECT INFORMATION

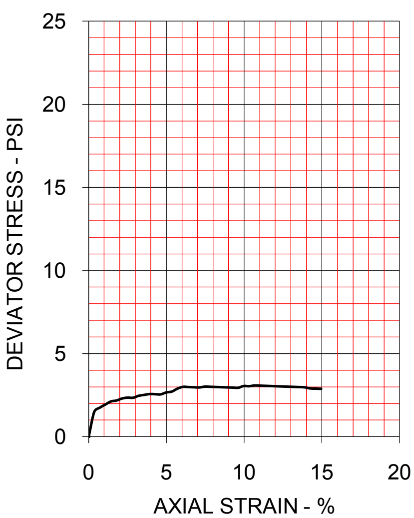
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUF.6

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 1.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	30.1			
Dry Density - pcf	94.7			
Diameter - inches	1.40			
Height - inches	2.81			
AT TEST				
Final Moisture - %	30.1			
Dry Density - pcf	94.7			
Calculated Diameter (in.)	1.40			
Height - inches	2.81			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	3.08			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	10.7			
σ_1 Failure - psi	13.08			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

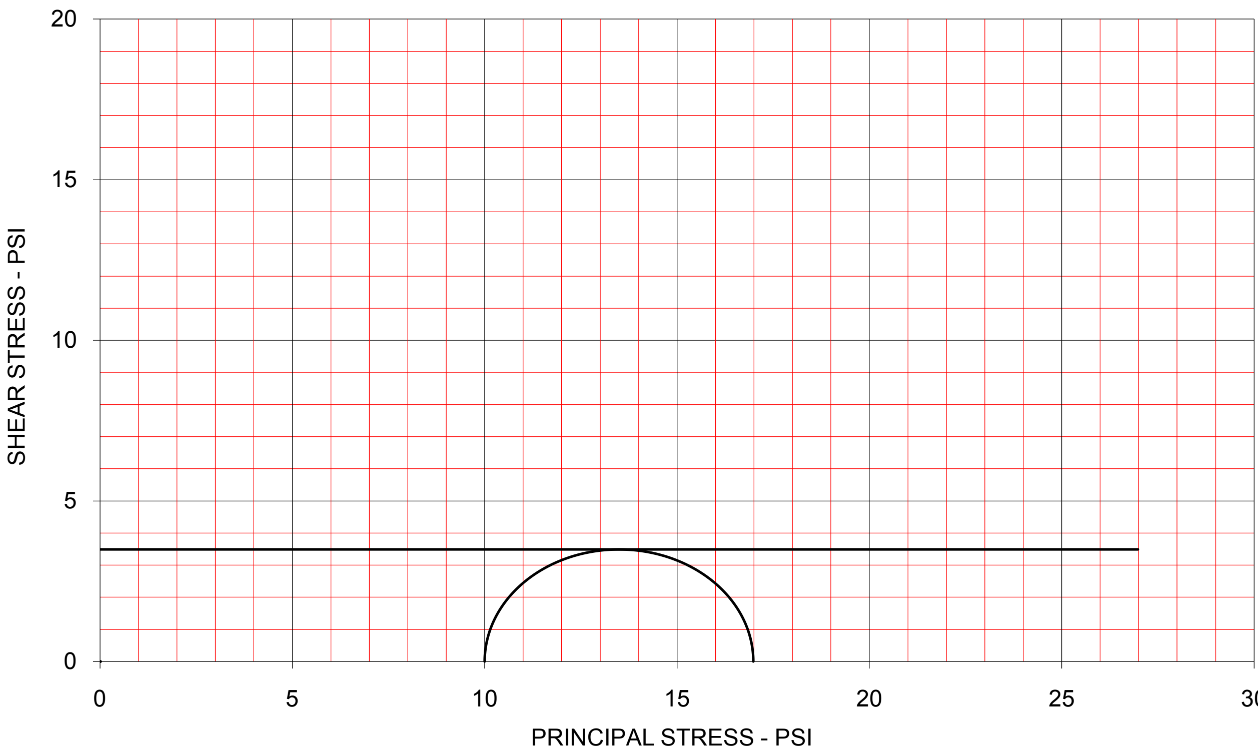
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-27, 8-9 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 35 PL: 12 PI: 23 Percent -200: 81
REMARKS:

PROJECT INFORMATION

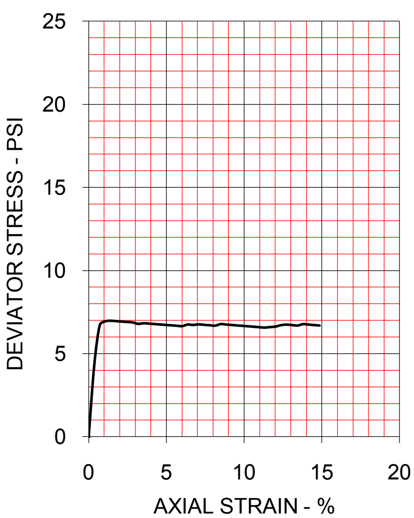
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUF.7

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 3.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	23.9			
Dry Density - pcf	98.1			
Diameter - inches	1.40			
Height - inches	2.83			
AT TEST				
Final Moisture - %	23.9			
Dry Density - pcf	98.1			
Calculated Diameter (in.)	1.40			
Height - inches	2.83			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	6.98			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	1.4			
σ_1 Failure - psi	16.98			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

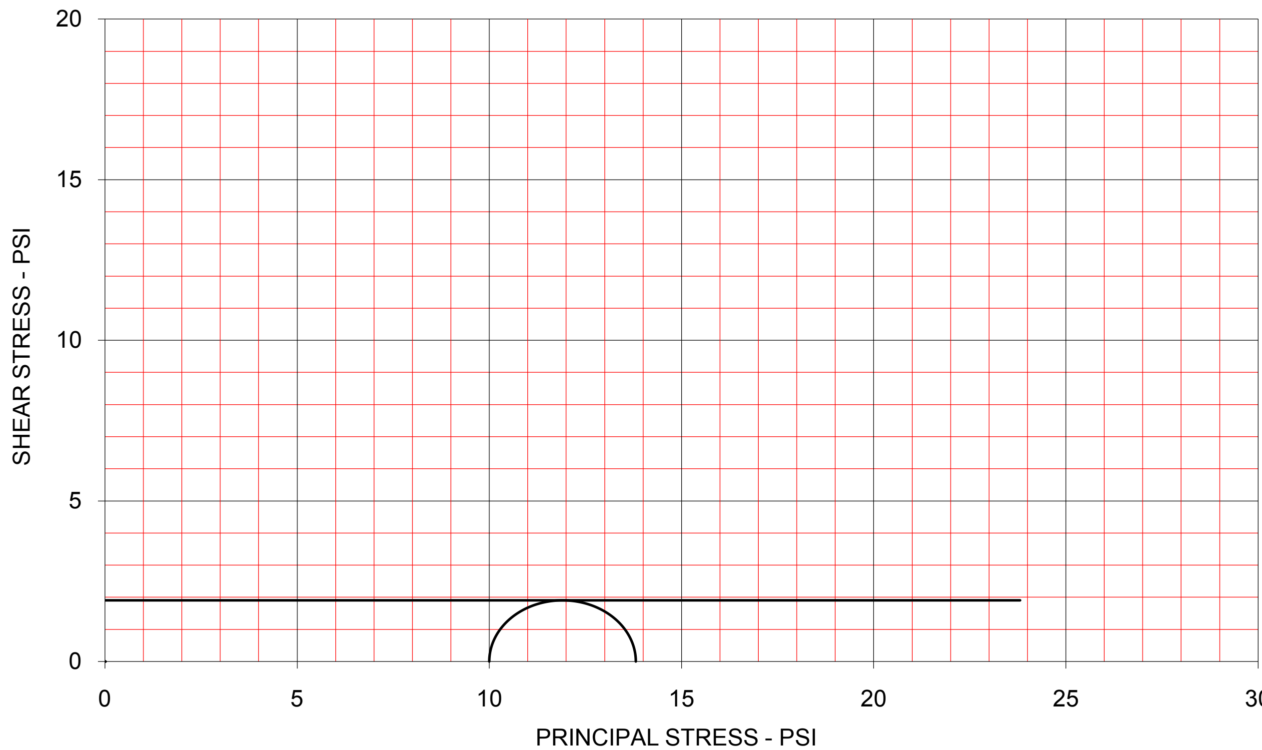
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: SANDY LEAN CLAY (CL), dark brown
SAMPLE LOCATION: B-28, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 26 PL: 11 PI: 15 Percent -200: 78
REMARKS:

PROJECT INFORMATION

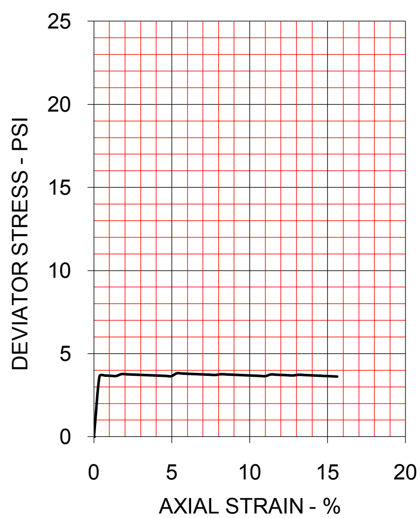
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUF.8

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 1.9 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	25.8			
Dry Density - pcf	98.4			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	25.8			
Dry Density - pcf	98.4			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	3.81			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	5.3			
σ_1 Failure - psi	13.81			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

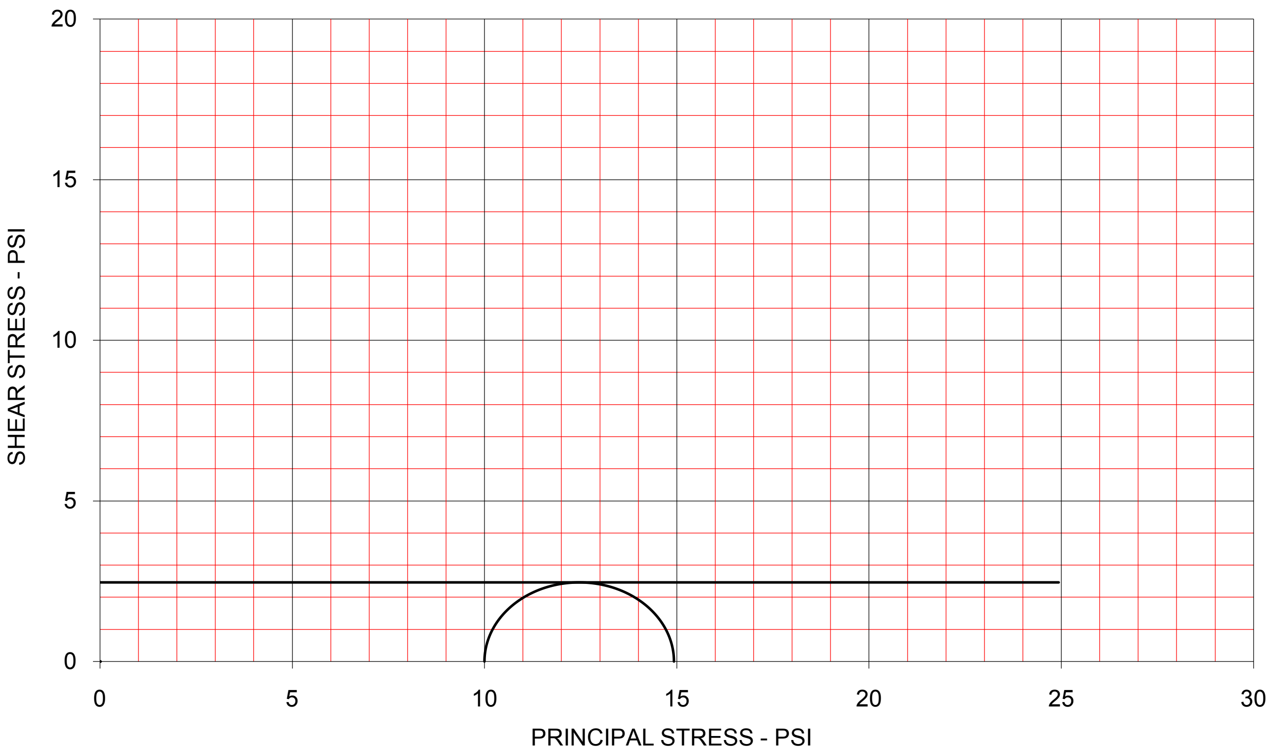
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: SANDY LEAN CLAY (CL), dark brown
SAMPLE LOCATION: B-28, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 26 PL: 11 PI: 15 Percent -200: 78
REMARKS:

PROJECT INFORMATION

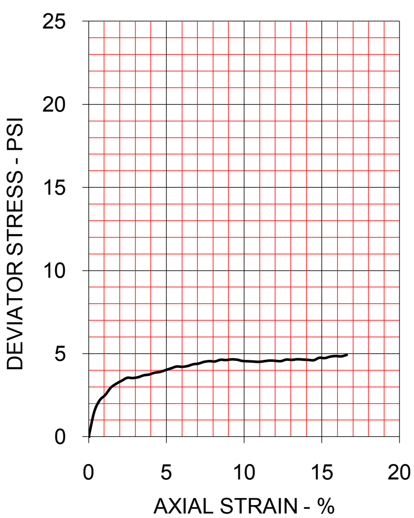
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE: UUF.9

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 2.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	28.2			
Dry Density - pcf	93.9			
Diameter - inches	1.40			
Height - inches	2.83			
AT TEST				
Final Moisture - %	28.2			
Dry Density - pcf	93.9			
Calculated Diameter (in.)	1.40			
Height - inches	2.83			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	4.93			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	16.6			
σ_1 Failure - psi	14.93			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

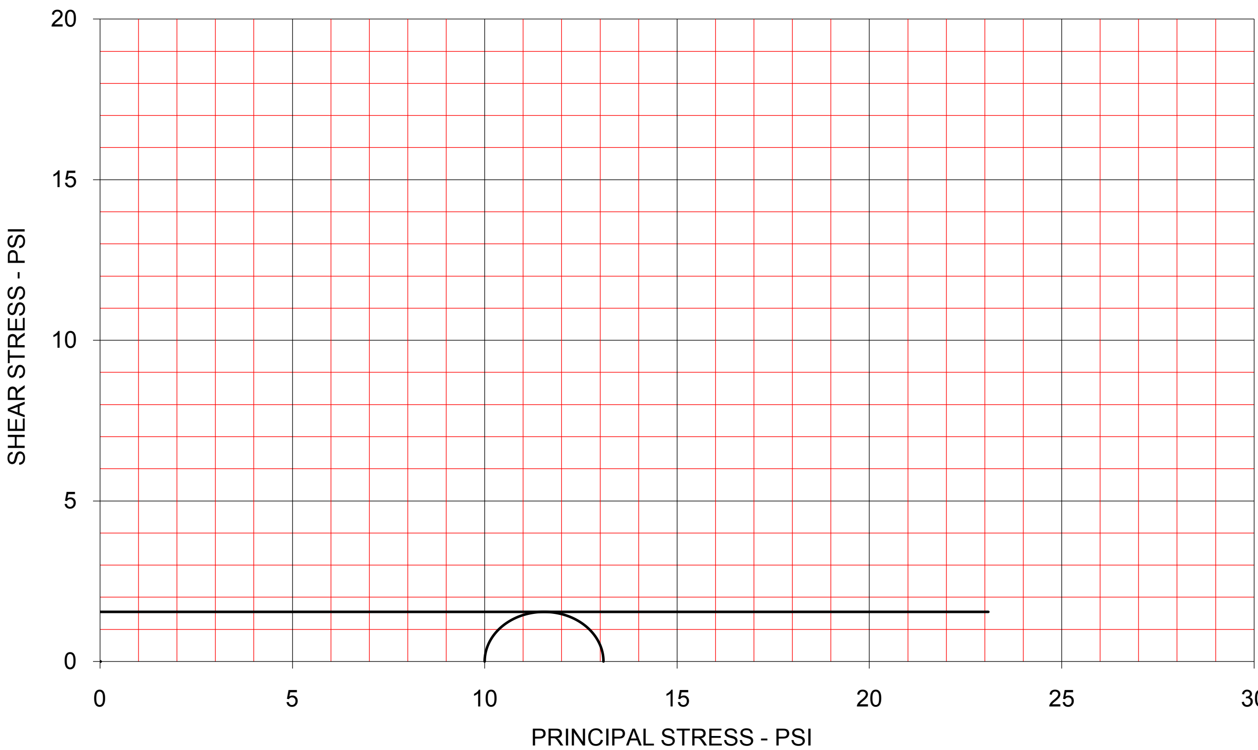
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), very dark grayish brown
SAMPLE LOCATION: B-31, 1-2 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 36 PL: 15 PI: 21 Percent -200: 87
REMARKS:

PROJECT INFORMATION

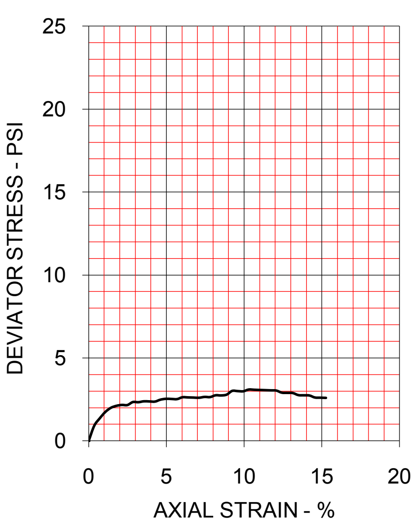
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE:UUF.10

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 1.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	33.9			
Dry Density - pcf	91.8			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	33.9			
Dry Density - pcf	91.8			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	3.09			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	10.3			
σ_1 Failure - psi	13.09			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

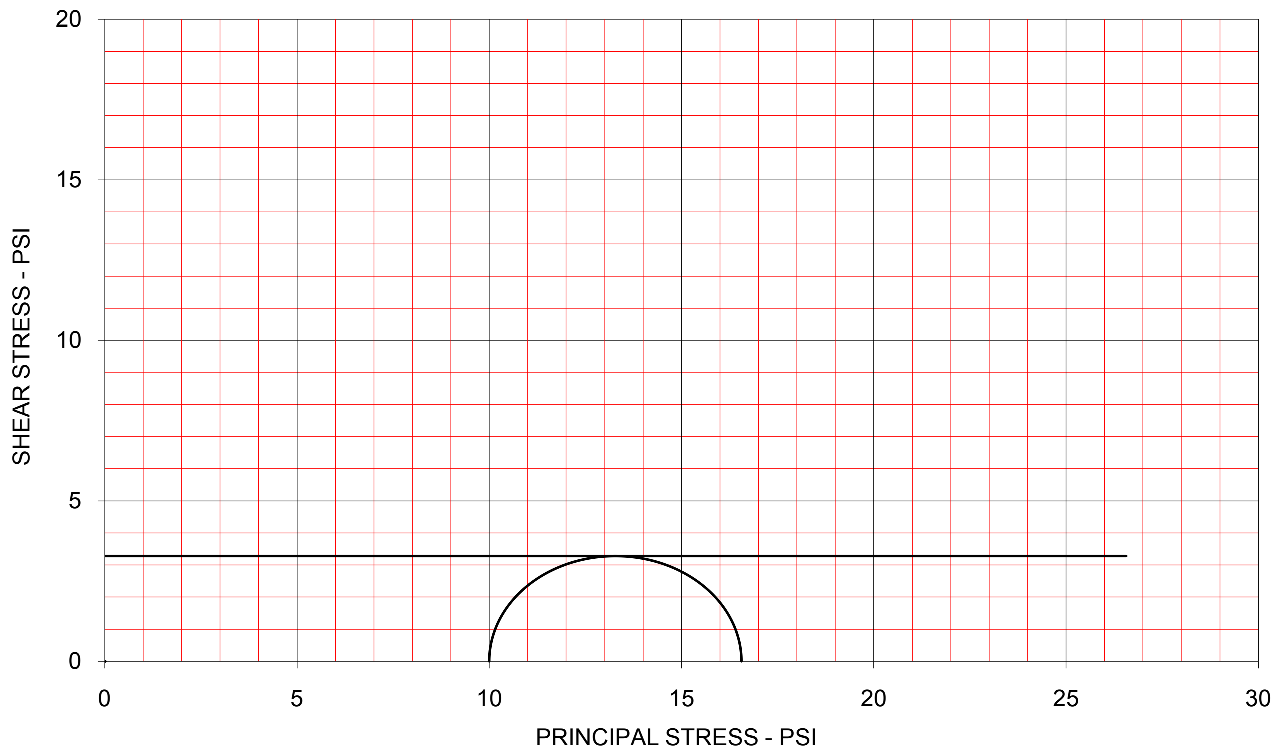
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), very dark grayish brown
SAMPLE LOCATION: B-31, 6-7 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 36 PL: 15 PI: 21 Percent -200: 87
REMARKS:

PROJECT INFORMATION

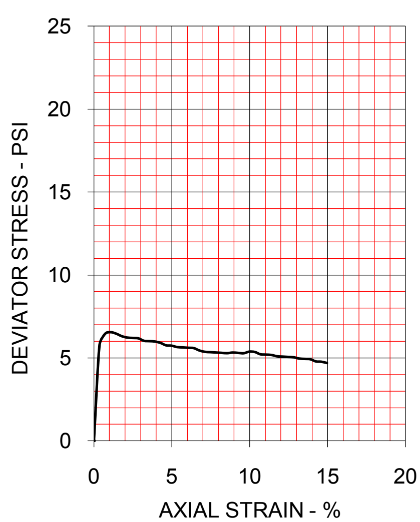
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL | PLATE:UUF.11

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 3.3 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	24.7			
Dry Density - pcf	97.5			
Diameter - inches	1.40			
Height - inches	2.81			
AT TEST				
Final Moisture - %	24.7			
Dry Density - pcf	97.5			
Calculated Diameter (in.)	1.40			
Height - inches	2.81			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	6.56			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	1.1			
σ_1 Failure - psi	16.56			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

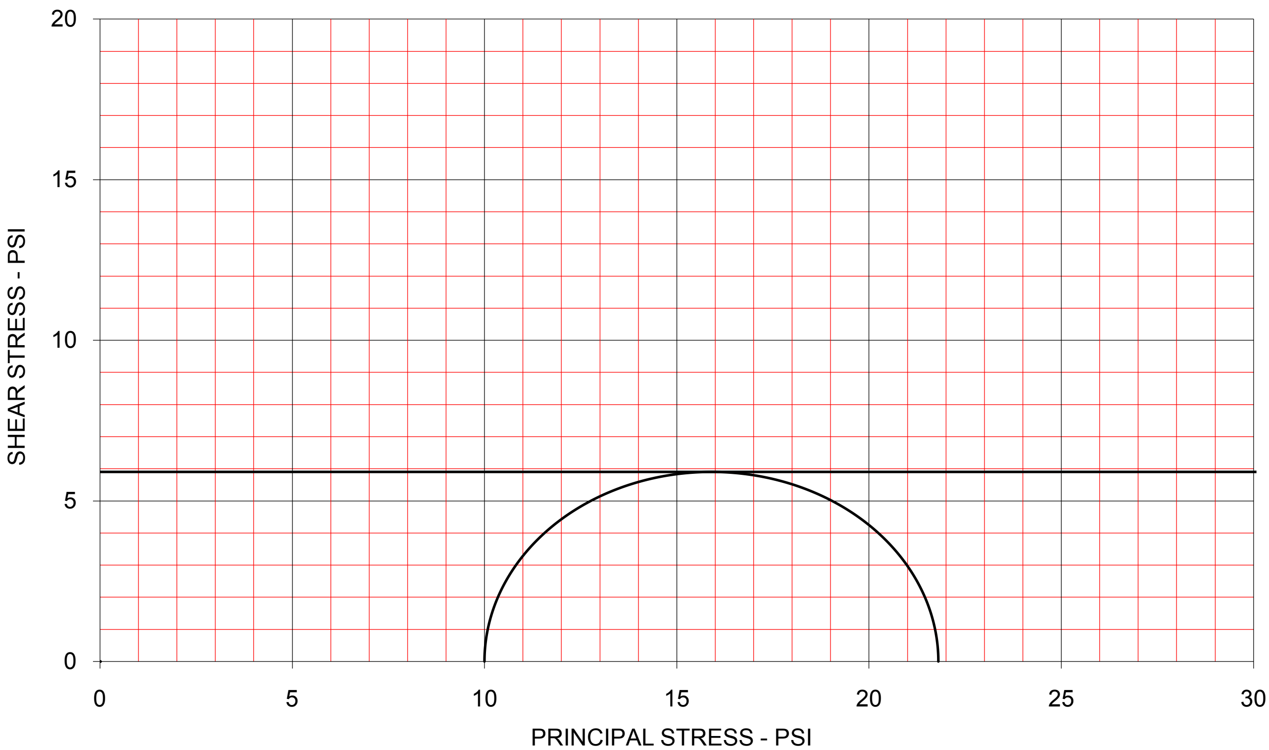
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-31, 28-29 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 30 PL: 11 PI: 19 Percent -200: 80
REMARKS:

PROJECT INFORMATION

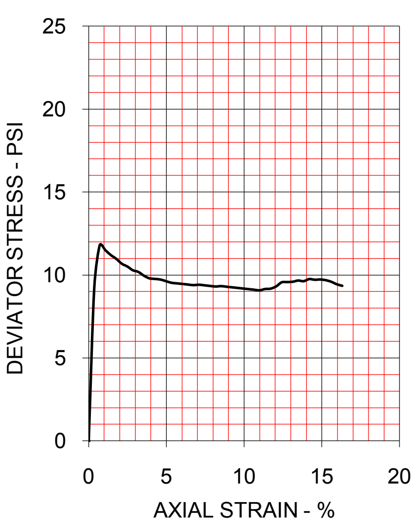
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE:UUF.12

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 5.9 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	25.6			
Dry Density - pcf	98.6			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	25.6			
Dry Density - pcf	98.6			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	11.80			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	0.7			
σ_1 Failure - psi	21.80			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

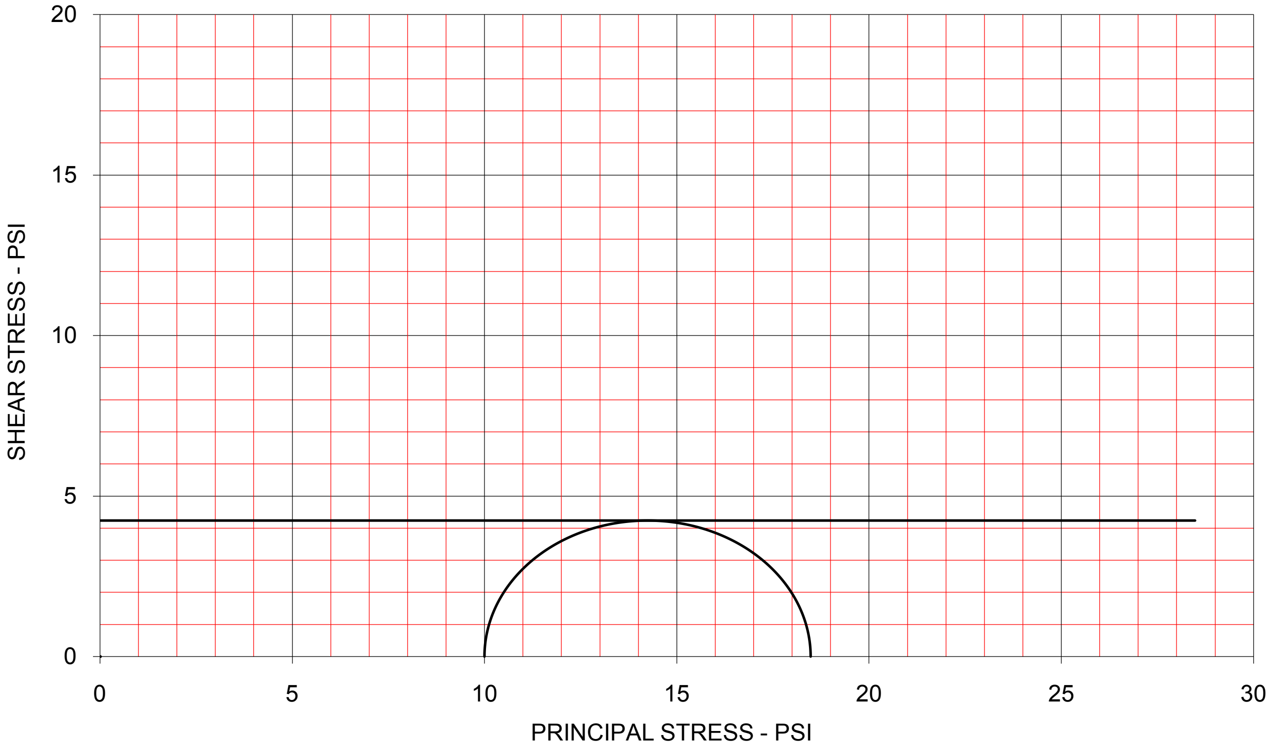
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-32, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 38 PL: 12 PI: 26 Percent -200: 83
REMARKS:

PROJECT INFORMATION

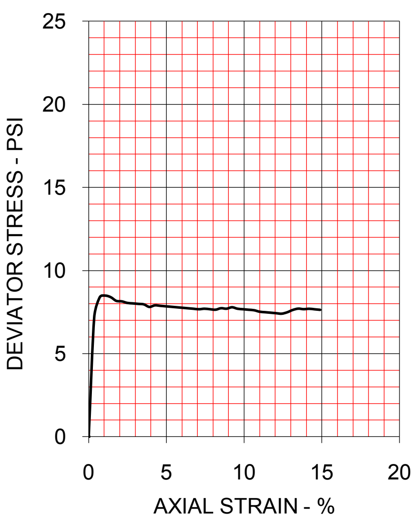
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE:UUF.13

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 4.2 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	25.3			
Dry Density - pcf	99.8			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	25.3			
Dry Density - pcf	99.8			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	8.48			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	1.1			
σ_1 Failure - psi	18.48			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

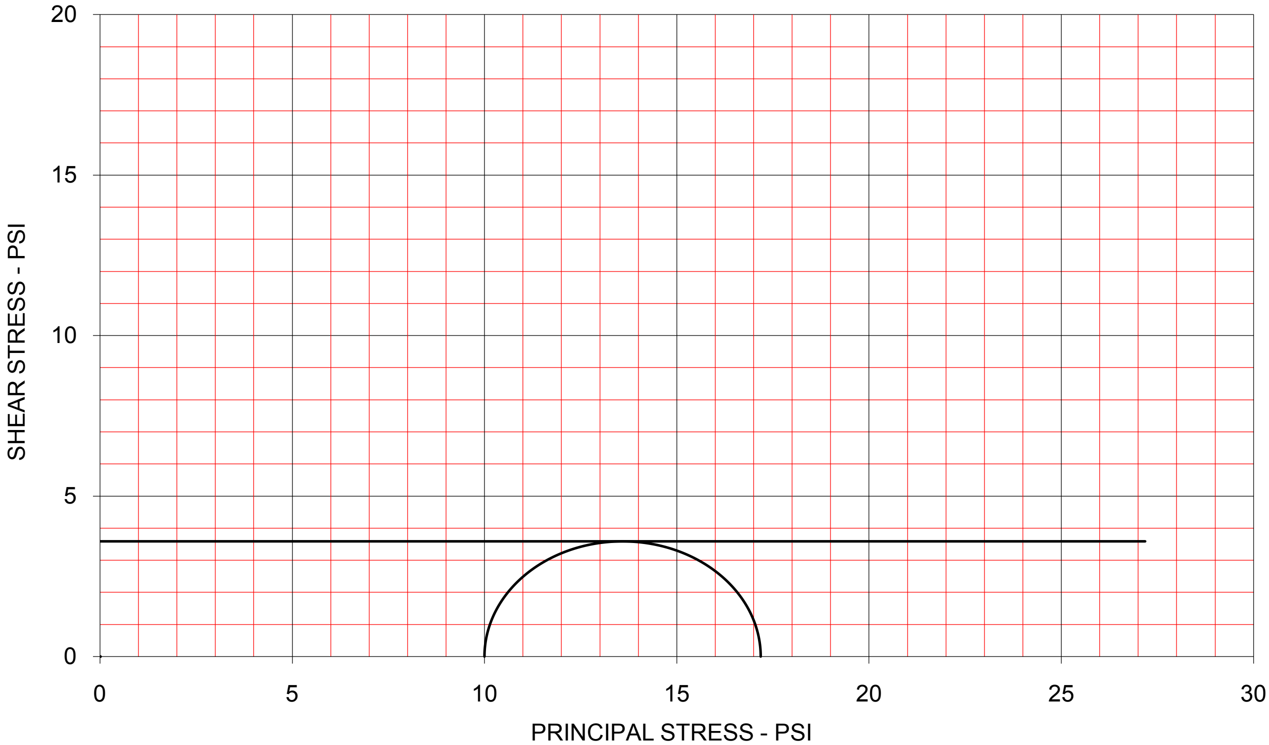
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-32, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 38 PL: 12 PI: 26 Percent -200: 83
REMARKS:

PROJECT INFORMATION

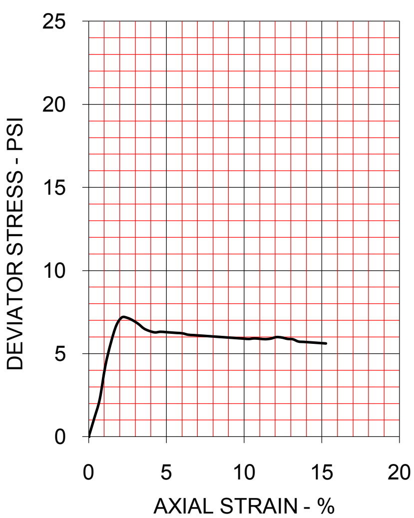
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE:UUF.14

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 3.6 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	26.7			
Dry Density - pcf	98.0			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	26.7			
Dry Density - pcf	98.0			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	7.18			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	2.1			
σ_1 Failure - psi	17.18			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

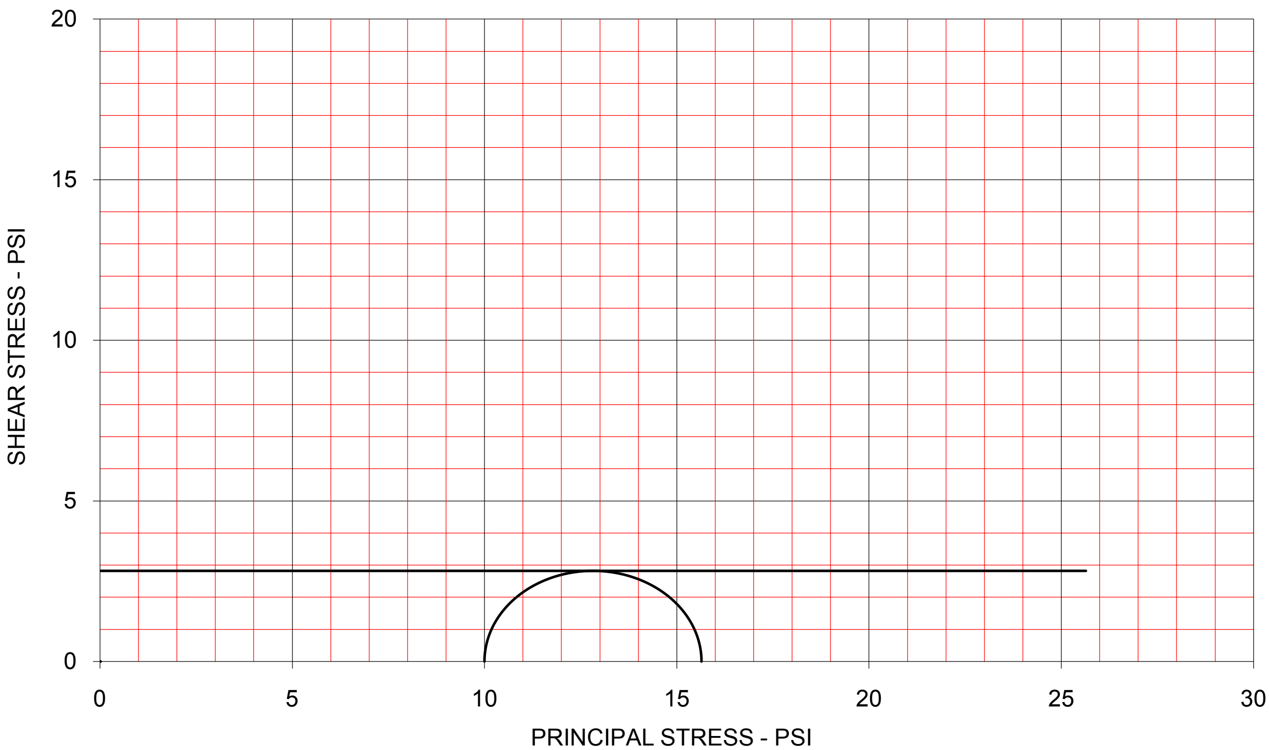
TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: LEAN CLAY (CL), dark yellowish brown
SAMPLE LOCATION: B-34, 3-4 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 39 PL: 12 PI: 27 Percent -200: 86
REMARKS:

PROJECT INFORMATION

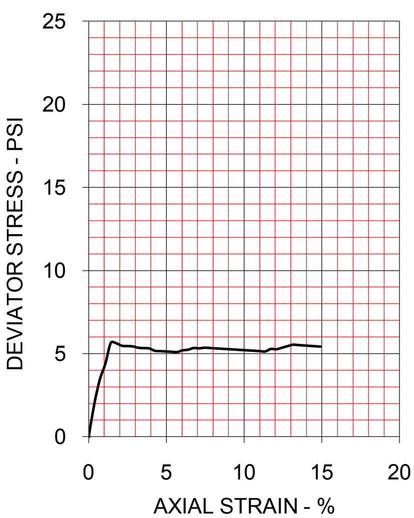
PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE:UUF.15

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ =	0.0 deg	c =	2.8 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	24.8			
Dry Density - pcf	97.9			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	24.8			
Dry Density - pcf	97.9			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	5.64			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	1.4			
σ_1 Failure - psi	15.64			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUFS-4

SAMPLE TYPE: SPNC

DESCRIPTION: LEAN CLAY (CL), dark brown

SAMPLE LOCATION: B-34, 4-5 ft

ASSUMED SPECIFIC GRAVITY: 2.70

LL: 39 PL: 12 PI: 27 Percent -200: 86

REMARKS:

PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research

LOCATION: Stillwater, OK

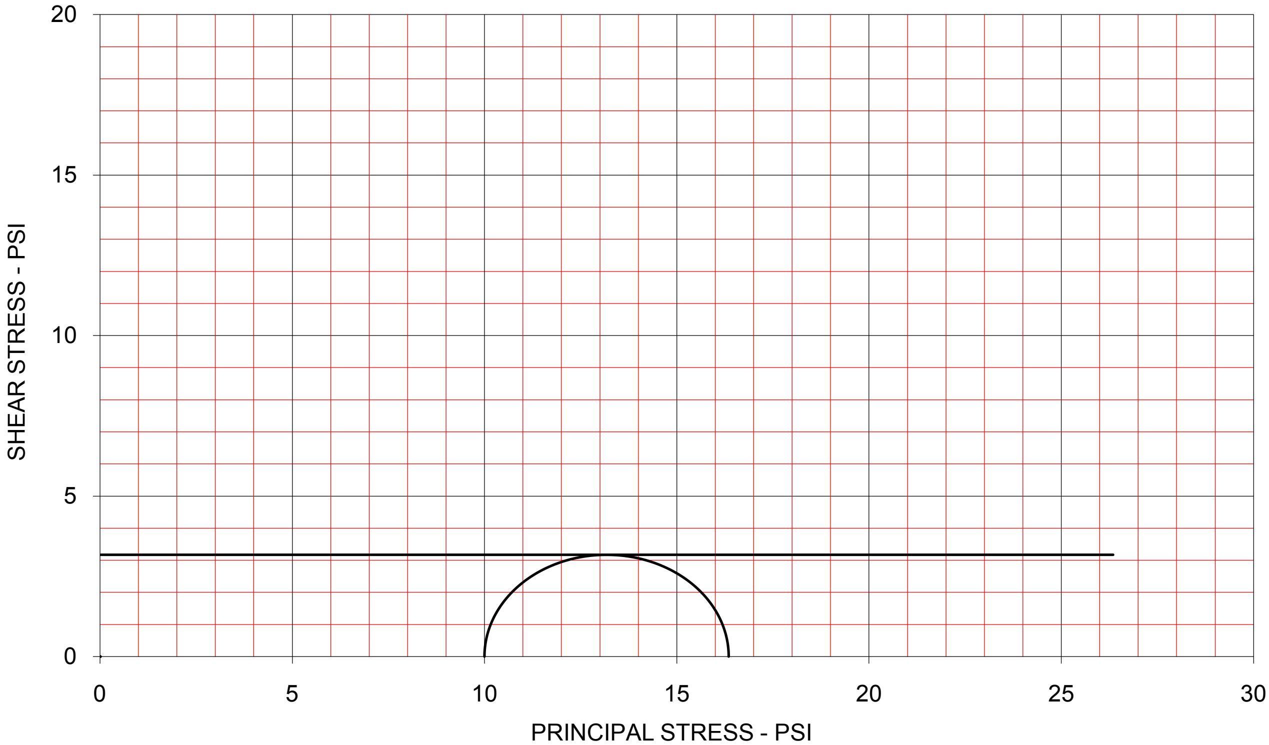
PROJECT NO: AA-5-33150

CLIENT: ODOT

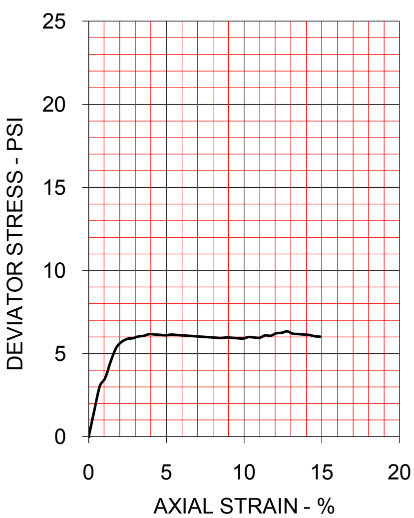
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE:UUF.16

TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	ϕ = 0.0 deg	c = 3.2 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	32.1			
Dry Density - pcf	93.4			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	32.1			
Dry Density - pcf	93.4			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	6.35			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	12.8			
σ_1 Failure - psi	16.35			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: FAT CLAY (CH), brown
SAMPLE LOCATION: B-38, 1-3 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 50 PL: 12 PI: 38 Percent -200: 82
REMARKS:

PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

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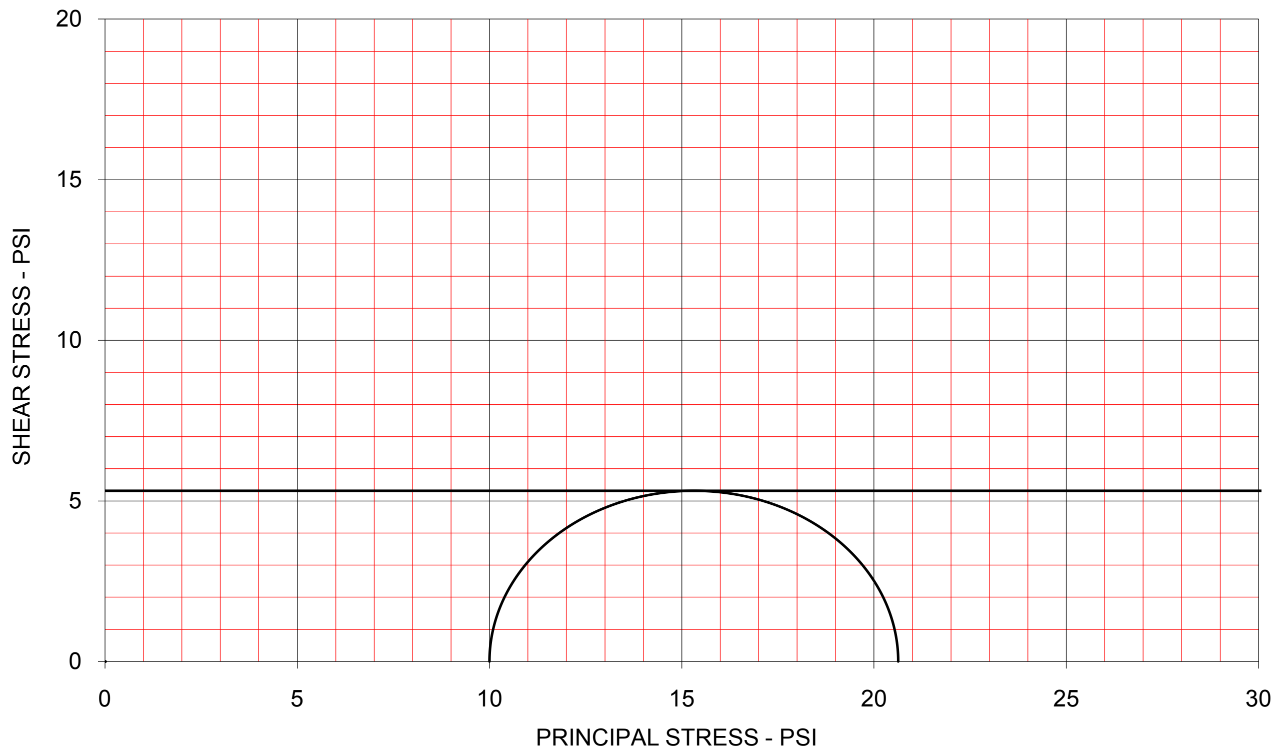
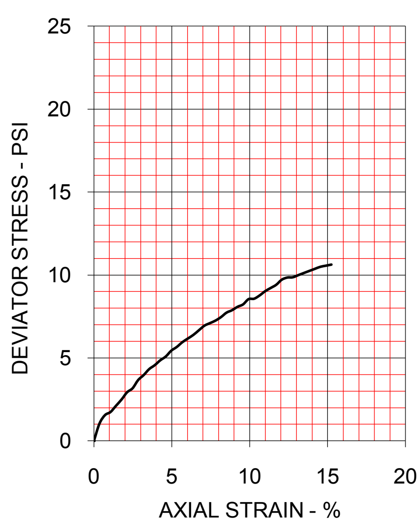
TRIAXIAL SHEAR TEST REPORT



TOTAL STRESS PARAMETERS	φ = 0.0 deg	c = 5.3 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	28.7			
Dry Density - pcf	96.1			
Diameter - inches	1.40			
Height - inches	2.82			
AT TEST				
Final Moisture - %	28.7			
Dry Density - pcf	96.1			
Calculated Diameter (in.)	1.40			
Height - inches	2.82			
Effect. Cell Pressure - psi	10.0			
Failure Stress - psi	10.63			
Total Pore Pressure - psi	10.0			
Strain Rate - inches/min.	0.03000			
Failure Strain - %	15.3			
σ_1 Failure - psi	20.63			
σ_3 Failure - psi	10.00			

TEST DESCRIPTION

TYPE OF TEST & NO: UU Triaxial - UUFS-4
SAMPLE TYPE: SPNC
DESCRIPTION: FAT CLAY (CH), dark grayish brown
SAMPLE LOCATION: B-38, 3-5 ft
ASSUMED SPECIFIC GRAVITY: 2.70
LL: 51 PL: 12 PI: 39 Percent -200: 82
REMARKS:

PROJECT INFORMATION

PROJECT: Fully-Softened Clay Research
LOCATION: Stillwater, OK
PROJECT NO: AA-5-33150
CLIENT: ODOT
DATE: 10/20/2010

OSU - CIVE - GEOTECHNICAL PLATE:UUF.18