Progress Report 3

(For the Period Covering 03/09/2010 to 06/08/2010)

Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading

FDOT Contract No. BDK75 977-21

UF Contract No. 82153

FDOT Project Manager:	Rick Renna, P.E.
UF Principal Investigator:	Dr. David Bloomquist, Ph.D., P.E.
Co-Principal Investigator:	Dr. Timothy J. McGrath, Ph.D., P.E.
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Date of Submittal: July 1, 2010

1. Work Accomplished This Quarter

   This quarter, preparation work continued on the FDOT Soil Box to complete it for the proposed testing program. This involved numerous tasks, ranging from ordering new materials and machining parts for the project, to doing research on a number of different testing techniques. Specifically, the following was accomplished this quarter:

   a. Nuclear density tests were performed to ensure proper compaction of the soil being added to the Soil Box.

   b. Review of existing triaxial test data for the A-2-4 soil being used.

   c. New triaxial tests were performed at lower confining pressures and lower standard proctor densities.

   d. The Soil Box was partially filled and one M294 HDPE pipe installed.

   e. The M294 HDPE pipes for the first test were pre-deflected.

   f. Earth pressure load cells were assigned a naming convention to be able to more easily identify each cell, its location, and its corresponding pressure reading.

   g. The Soil Box was prepared for the first test.

   h. Earth pressure readings were taken on seven separate occasions during this quarter.

   i. Calculations were performed to determine the amount of water needed to fully saturate the soil in the Soil Box.

   j. A watering trial was performed outside of the University of Florida Coastal Lab to determine the duration of watering needed to fully saturate the soil.

   k. Watering was performed to saturate the soil as best as possible.

   l. Load plates were painted.

   m. French drain was installed on the South end of the Soil Box.

   n. Selection of instrumentation equipment to accurately record horizontal movement of laser used to measure pipe deflection.

   o. Work continued on the laser mounting system.

   p. Numerous visits to the Lab to photograph newly delivered materials, newly machined parts, and project progress in general.

q. Literature review.

A discussion of the completed activities follows.

a. Nuclear density tests were performed to ensure proper compaction of the soil being added to the Soil Box.

Nuclear density tests were performed by FDOT Technicians from the State Materials Office (SMO) on the soil being added to the Soil Box. These tests were done on four separate occasions: March 22, April 28, April 29, and May 3, 2010. Each of these dates corresponds to a lift of soil that had been added to the Soil Box. The test done on March 22 assessed the compaction in the first lift of soil which was 1 foot thick. Subsequently, two lifts each with a thickness of two feet were added to the Soil Box. The tests performed on April 28 and April 29 checked the respective compaction levels. Finally, two and a half feet of soil was added. The compaction of this final lift was assessed on May 3.

The location of all the nuclear density tests that were performed can be found on Pages C-17 and C-18 of *Appendix A: Supplemental AutoCAD Drawings*. The results of the nuclear density tests can be seen in *Appendix B: Nuclear Density Test Results*.

From the nuclear density test data, the average moisture content of the soil in the Soil Box was calculated as three percent. This will be discussed further in Section i.

b. Review of existing triaxial test data for the A-2-4 soil being used.

Existing triaxial test results were provided by Mr. Daniel Pitocchi, the Soils and Foundation Lab Manager at the SMO. The results can be found in *Appendix C: Triaxial Test Results for Sample 23421*, *Appendix D: Triaxial Test Results for Sample 23422*, and *Appendix E: Triaxial Test Results for Sample 23423*. The data shown in these three Appendices corresponds to the soil being tested at 100 percent standard proctor density. Each sample, 23421, 23422, and 23423, was tested at 7, 14, and 21 psi confining pressures.

c. New triaxial tests were performed at lower confining pressures and lower standard proctor densities.

To be able to view the test soil's response under conditions similar to those existing in the Soil Box, new triaxial tests were performed. Specifically, new testing parameters included lowering the confining pressure to a level that could be maintained reliably, and testing at lower standard densities. Some of these results can be found in *Appendix F: Triaxial Test Results for Sample with 90% Standard Density*. This particular sample was compacted at 90 percent standard density and tested at 3 and 5 psi confining pressures. At the time of this progress report's submission, two other samples compacted and 80 and 85 percent standard densities, respectively, were being tested. Those results will be included in Progress Report 4.

d. The Soil Box was partially filled and one M294 HDPE pipe installed.

The Soil Box was partially set up for the purposes of the industry visit which took place on Tuesday, March 16, 2010. This partial set up included the 12 inch thick layer of compacted soil at the bottom of the Soil Box, as well as the installation of an M294 HDPE pipe in the North end of the box. As can be seen in the figures below, the 12 inch thick layer was compacted uniformly and the rubber membrane sealing system was installed over the interface between the pipe end and the Soil Box wall.

Figure 1: 12 inch thick layer of soil at bottom of Soil Box.

Figure 2: M294 HDPE pipe installed in North end of Soil Box.

Figure 3: Sealing system between pipe end and Soil Box wall.

e. The M294 HDPE pipes for the first test were pre-deflected.

Shortly after the industry visit of March 16, it was decided to pre-deflect the flexible pipe materials to approximately five percent deflection along the length of the pipe. This aspect of the testing aims to further simulate field conditions during pipe installation. This pre-deflection of the pipes was made possible with the use of manual turnbuckles, shown below in Figure 4. Four percent pre-deflection, or 1.44 inches, was achieved for the 36 inch diameter M294 HDPE pipes.

Because this decision was made after one of the pipes had already been installed in the Soil Box, the pipe was removed, pre-deflected, and then reinstalled. In order to maintain the deflected shape, the turnbuckles will remain in place until the test is begun. It is expected that the load from the lift bags will exert enough pressure on the pipes so that the turnbuckles are released, allowing for their safe removal through the portholes.

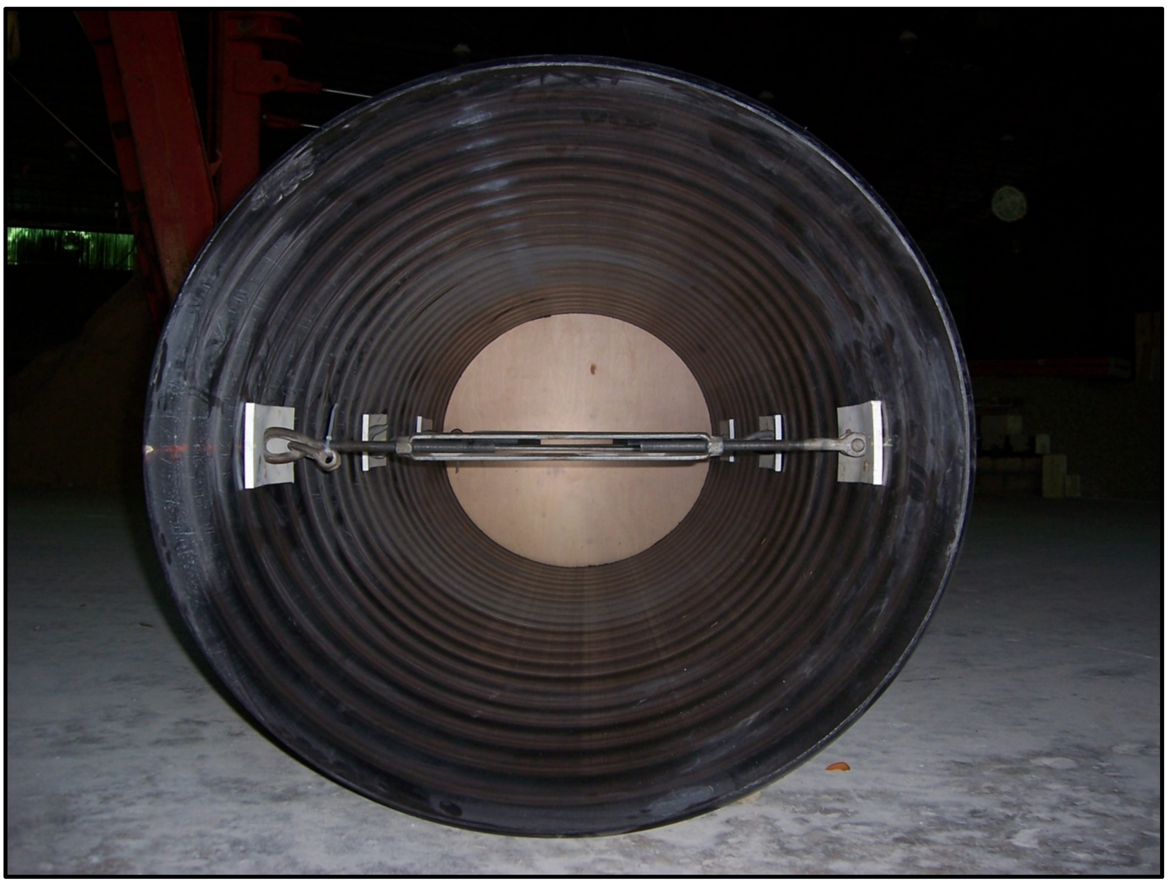


Figure 4: Pre-deflected M294 HDPE pipe with turnbuckles.

f. Earth pressure load cells were assigned a naming convention to be able to more easily identify each cell, its location, and its corresponding pressure reading.

A vital part of the tests being performed is being able to accurately record and analyze all the data that is being output by the various pieces of instrumentation. There are a total of 16 earth pressure cells being used during one test, and readings are collected about every 30 seconds. It is very important to see which reading corresponds to what location in the Soil Box.

The naming convention shown below in Table 1 was chosen as the most efficient method of being able to see which numbers correspond to what area. Each name is made up of three characters, the first two being letters and the last being a number. The first character refers to whether the pressure cell is in the South half or the North half of the Soil Box. The second character identifies the depth location of the cell relative to the pipe; namely bottom, side, or top. The third and last character identifies each pressure cell based on its position in the East-West directions. The pressure cells are numbered starting at 1, from the East to the West. Both the cells on the top and on the bottom therefore range from 1 to 3, while those cells on the side range from 1 to 2.

SB1	South Bottom 1
SB2	South Bottom 2
SB3	South Bottom 3
SS1	South Side 1
SS2	South Side 2
ST1	South Top 1
ST2	South Top 2
ST3	South Top 3
NB1	North Bottom 1
NB2	North Bottom 2
NB3	North Bottom 3
NS1	North Side 1
NS2	North Side 2
NT1	North Top 1
NT2	North Top 2
NT3	North Top 3

Table 1: Earth pressure cell naming convention.

The location of all the pressure cells and their respective names can be found on Pages C-19 through C-21 of *Appendix A: Supplemental AutoCAD Drawings*.

g. The Soil Box was prepared for the first test.

This particular task was accomplished in a number of stages. The bottom 12 inch thick layer of compacted fill was already in place. The next step was to properly route all the instrumentation wiring through the center porthole, as was discussed in Progress Report 2. See Figures 5 and 6 below for the completed instrumentation wiring.

Figure 5: Completed routing of instrumentation wiring with sealant (view from inside).

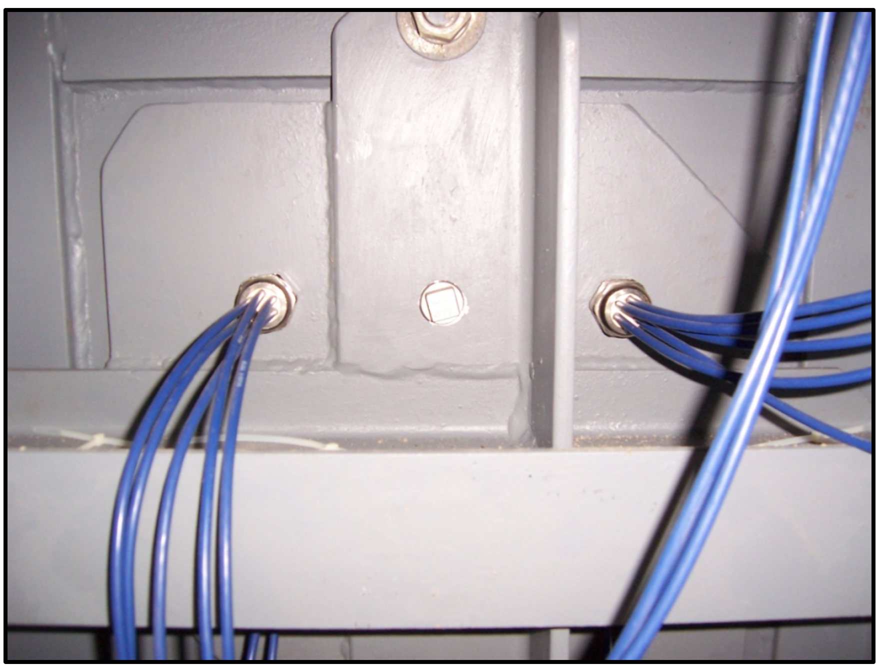


Figure 6: Completed routing of instrumentation wiring (view from outside).

The M294 HDPE pipes will be loaded during the first test. Figure 7 below shows how the pipes are lowered into the Soil Box. Both pipes were pre-deflected to four percent along the ten foot length, or about 1.44 inches. After the pipes were lowered, the rubber membrane sealing system was installed over the four open joints. This was done using the same procedure as seen above in Figure 3. Additional views of the pipe/wall interface prior to and immediately after the installation of the sealing system can be seen in Figures 8 and 9, respectively, below.

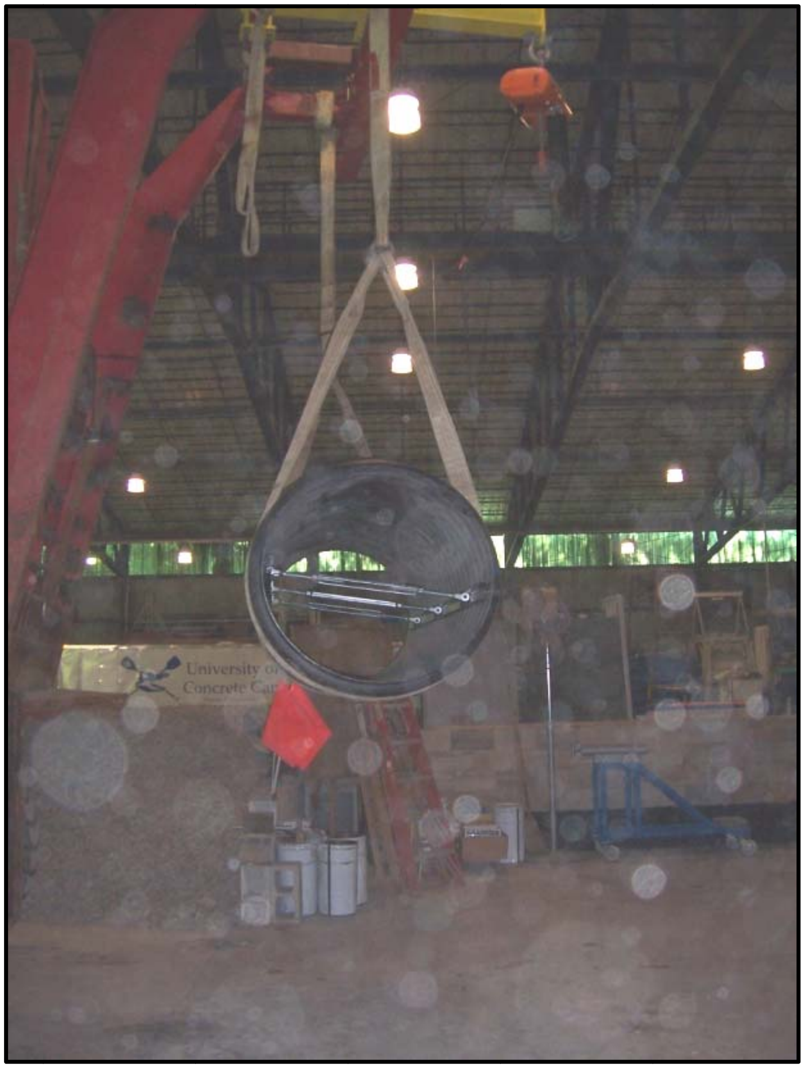


Figure 7: M294 HDPE pipe being lowered into Soil Box.

Figure 8: Pipe/wall interface prior to sealing.

Figure 9: Installed rubber membrane sealing system.

Immediately following the installation of both pipes, soil began to be loaded into the box. This was done in three separate lifts, as previously described in Section a. This was accomplished with the use of a front end loader dumping soil into a concrete bucket. The concrete bucket was then hoisted over the Soil Box, and its contents emptied. This process can be seen in the figures below.

Figure 10: Dumping of soil into concrete bucket.

Figure 11: Full concrete bucket hoisted over Soil Box.

Figure 12: Concrete bucket emptied over Soil Box.

The next step in the process, which took place in conjunction with filling, was to properly place the earth pressure cells. The cells needed to be located according to the specifications outlined in the Appendix of Progress Report 2.

Figure 13: Placement of SS2 pressure cell.

Figure 14: View of SS1 (left) and SS2 (right) pressure cells.

Figure 15: Placement of NT3 pressure cell.

Finally, after the last lift of soil was added to the Soil Box, the soil was leveled uniformly. See Figure 16 below. Once again, careful attention was paid to ensure that the soil was not compacted anymore than required. This was verified by the nuclear density tests performed on May 3.

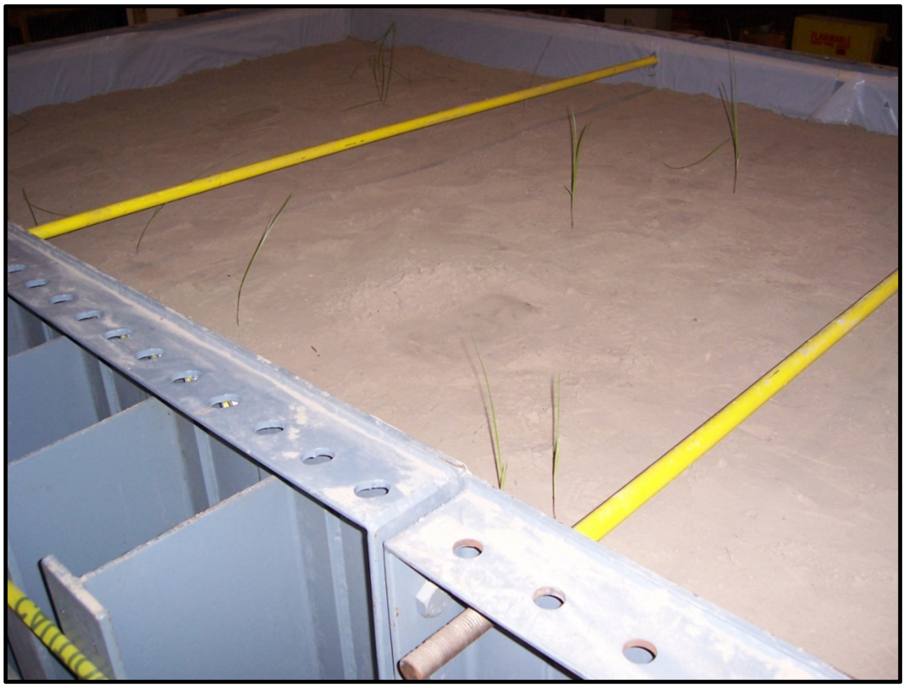


Figure 16: Soil profile following addition of final soil lift and completion of leveling.

h. Earth pressure readings were taken on seven separate occasions during this quarter.

There are three separate sets of data that were collected during this quarter. The first set includes data recorded prior to soil saturation. The second set is for data recorded during the soil saturation period. Finally, the third set reflects the data recorded after the soil saturation process had been completed. The average of each of the three sets, for each individual cell, is presented in Table 2 below. Unfortunately, the SS2 cell began to malfunction after installation. The readings recorded for that cell were deemed unreliable.

As can be seen by the table, pressures are greater with increasing depth. Likewise, pressures increase from the first set of data, to the second, to the third. This follows the assumption that the pressures would increase as the soil was saturated. For a quick reference of the specific cell locations, please refer to Pages C-19 through C-21 of *Appendix A: Supplemental AutoCAD Drawings*.

Pressure Cell Identifier	Pressure Cell Name	Average Pressure Prior To Saturation (psi)	Average Pressure During Saturation (psi)	Average Pressure After Saturation (psi)	Approximate Depth Of Pressure Cell (feet)
SB1	South Bottom 1	2.31	2.67	3.00	7.5
SB2	South Bottom 2	3.59	3.67	3.04	7.5
SB3	South Bottom 3	1.28	1.56	1.90	7.5
SS1	South Side 1	2.68	3.00	3.83	5.5
SS2 (Bad Cell)	South Side 2	-	-	-	5.5
ST1	South Top 1	1.29	1.38	1.38	2.5
ST2	South Top 2	0.33	0.40	0.41	1.25
ST3	South Top 3	1.67	1.85	1.99	2.5
NB1	North Bottom 1	3.29	3.79	4.41	7.5
NB2	North Bottom 2	3.03	3.50	4.18	7.5
NB3	North Bottom 3	3.02	3.43	3.43	7.5
NS1	North Side 1	1.35	1.69	2.00	5.5
NS2	North Side 2	1.75	2.13	2.20	5.5
NT1	North Top 1	0.37	0.40	0.42	1.25
NT2	North Top 2	1.64	1.95	2.00	2.5
NT3	North Top 3	0.69	0.73	0.72	1.25

Table 2: Initial pressure cell readings before, during, and after saturation.

i. Calculations were performed to determine the amount of water needed to fully saturate the soil in the Soil Box.

One of the important parts of the testing procedure was to fully saturate the soil. As discussed in Section a, the soil added to the Soil Box had a moisture content of around three percent. Using soil phase diagram relationships and an average of the actual dry unit weights obtained from the triaxial test results, it was calculated that approximately 3,200 gallons of water would be needed to fully saturate the soil. This number was based on two assumptions: that the Soil Box was filled completely with soil and that the soil could be fully saturated. As can be seen in the figures above, there are about six inches of freeboard near the top of the box. Also, it would be near impossible to fully saturate the soil, unless all the soil was maintained in an airtight configuration and flooded. That was not a likely consideration. The method of soil saturation is discussed in Sections j and k. The saturation calculations can be seen in *Appendix G: Soil Saturation Calculations*.

j. A watering trial was performed outside of the University of Florida Coastal Lab to determine the duration of watering needed to fully saturate the soil.

To be able to accurately record exactly how much water was being added to the Soil Box, a trial was performed outside of the UF Coastal Lab. The footprint of the Soil Box was measured out and outlined with orange chalk. A lawn sprinkler was then connected to the water supply, and the pressure regulated until the water fell within the chalk boundary. This pressure was then held constant while the sprinkler was held over a bucket of known volume. The time required to fill the bucket to three gallons was one minute and 55 seconds. The above steps can be seen in the figures below.

Figure 17: Footprint of Soil Box outlined with orange chalk.

Figure 18: Water pressure being regulated for water to stay within the footprint.

Figure 19: Filling of bucket at constant pressure.

Figure 20: Stopwatch used to record the amount of time needed to fill the bucket.

It would have taken approximately 34 hours to fill the Soil Box with 3200 gallons, maintaining the low pressure necessary to stay within the footprint. The lawn sprinkler represented the best way to uniformly distribute the water over such a long period of time. The calculations for the time required for saturation are likewise found in *Appendix G: Soil Saturation Calculations*.

k. Watering was performed to saturate the soil as best as possible.

Because full saturation could not be attained and because the Soil Box was not completely filled, water was added to the Soil Box for about half of the 34 hours, or about 18 hours. This was done over the course of three days. Figure 21 below shows the sprinkler setup in the Soil Box towards the end of the watering process. In the middle of the photo, water can be seen beginning to form puddles.

Figure 21: Sprinkler setup inside Soil Box with water beginning to form puddles.

l. Load plates were painted.

This task was more for aesthetics, but nonetheless was part of the work done during the quarter.

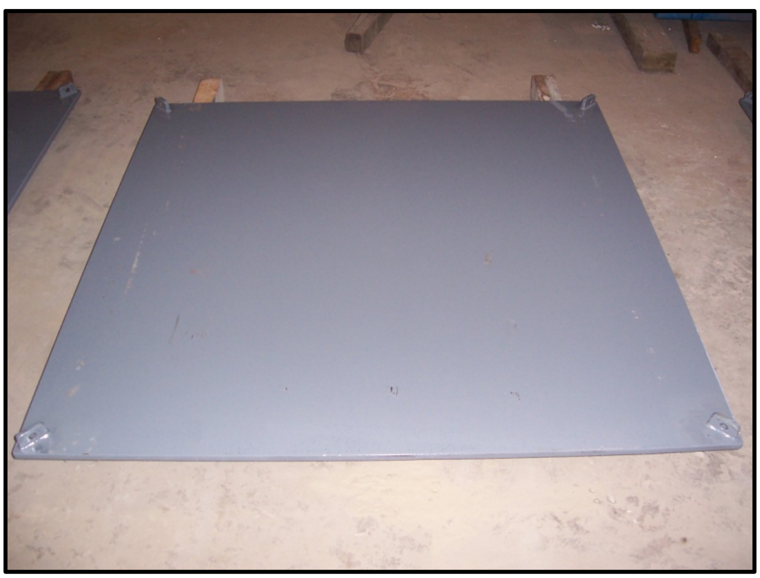


Figure 22: Painted load plate.

m. French drain was installed on the South end of the Soil Box.

This particular task was needed for drainage purposes once the soil was saturated. The French drain is located along the South end of the Soil Box. A porous membrane allows only water to penetrate into the drain. This prevents soil from clogging the drain. The drainage spout can be seen in Figure 23 below.

Figure 23: French drain release valve.

n. Selection of instrumentation equipment to accurately record horizontal movement of laser used to measure pipe deflection.

This particular subject was discussed in Task p of Progress Report 2. It was ultimately decided that a string potentiometer would be used to measure the horizontal translation of the laser as the laser moves along the track system it will be mounted on. As anticipated, the string potentiometer will output to the same piece of equipment as the other instrumentation, simplifying the data acquisition process.

o. Work continued on the laser mounting system.

This task has become somewhat more difficult than was anticipated at the end of the second quarter. This issue is discussed in Section 2 below.

p. Numerous visits to the Lab to photograph newly delivered materials, newly machined parts, and project progress in general.

Each week, pictures are taken of all the new steps that have progressed. This process will continue throughout the duration of the project.

q. Literature review.

The following articles have been collected and are being reviewed. Literature review will continue throughout the duration of the project.

Abolmaali, Ali. "Experimental Verification of CUES Laser Profiler Deformation Analysis Results." Arlington, TX: University of Texas, 2008. Print.

Moser, A.P. Buried Pipe Design. Second Edition. New York, NY: McGraw-Hill, 2001. Print.

Motahari, Ardavan, and Jorge Forteza. "Accuracy of Laser Profiling of Flexible Pipes Using CUES System." Arlington, TX: University of Texas, 2008. Print.

Palmer, Michael. "Results of Full-Scale Test on 16-inch HDPE Pipe." 2005. Web. 25 Jan 2010.

2. Activities Planned for Next Quarter

The first test has yet to be performed. It is anticipated that a full test will begin during the next quarter. The delay is mainly due to the unexpected setbacks with the laser system and deflection measurement. Paramount to the design of this system is the necessity of accuracy. This includes the same starting point for all tests taking place so that the measurement method does not change from test to test. The system involves fixed supports on either side of the Soil Box, for both pipes. A track will be attached to these supports, and the laser mounted on the track. The four quadrants of the pipe: top, bottom, and sides, can then be measured for deflection. A dial measurement device is also being developed to confirm the results obtained from the laser measurements.

The remaining triaxial test data will be obtained from the FDOT SMO for the A-2-4 soil that will be used for this project. This was previously discussed in Section c.

An instrumentation room will be sealed off on the Northeast corner of the Soil Box. This room will protect all of the data acquisition equipment from any hazards that might be presented during testing. The load plates, lift bags, air control equipment, and top of the Soil Box are all planned to be installed during the next quarter. This is in preparation for the first test.

3. Activities Beyond the Next Quarter

Once a successful test has taken place, the process becomes somewhat repetitious. The idea has been to make sure that everything is standardized prior to the running of any tests. This way, testing methods do not change from one test to another.

4. Summary of Requested Modifications

No changes or modifications are requested.

5. Project Schedule

A table of tasks to be completed with current status is provided on the next page.

FLORIDA DEPARTMENT OF TRANSPORTATION
RESEARCH CENTER

PROJECT SCHEDULE

Project Title	Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading				
FDOT Project No.	To be Determined	FY	2009	Month	Jun
Research Agency	University of Florida				
Principal Investigator	Dr. David Bloomquist, Dr. Tim McGrath				

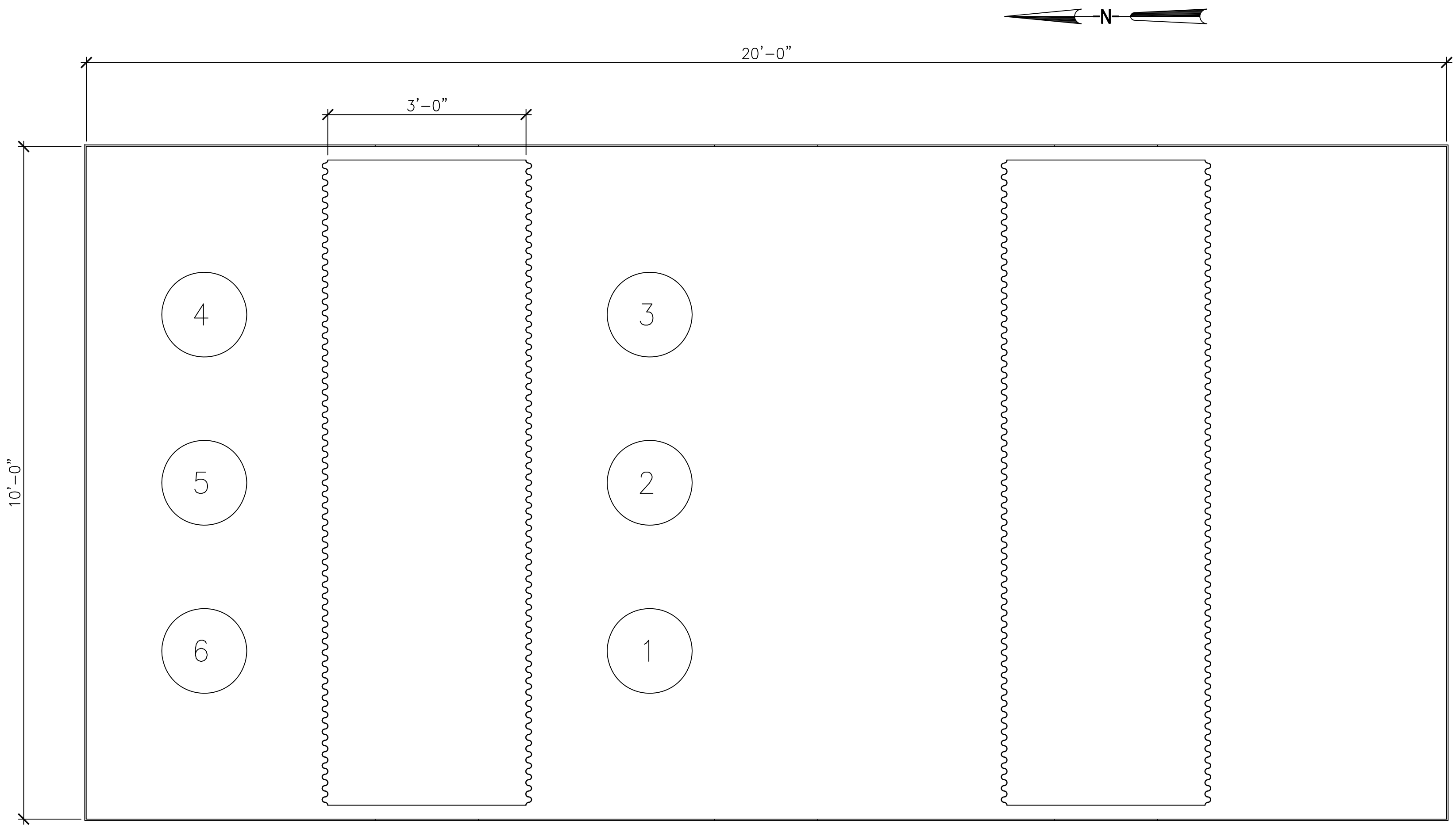
RESEARCH TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	ESTIMATED % COMPLETION
Task 1	■																								5
Install Visqueen Sheeting/Purchase Lift Bags																									
Task 2a		■																							7
Install Bedding Material/Earth Pressure Cells																									
Task 3a			■																						4
Install Two 36" HDPE Pipes/Backfill/Flooding																									
Task 4a				■																					10
Fill Box/Install Pressure Cells/Lift Bags																									
Task 5	■	■																							4
Conduct Triaxial/1D Compression Tests																									
Task 6	■	■																							3
Finalize Design/Construction of LVDT Profiler																									
Task 7					■	■																			6
Conduct Staged Load Tests on Dual 36" HDPE Pipe																									
Task 8A							■	■	■	■	■														10
Repeat Tests on Single Pipes w/ Trench Boxes																									
Task 8B												■	■												8
Repeat Test Series on 36" Corrugated Steel Pipe																									
Task 8C														■	■										8
Repeat Test Series on 36" Corrugated Aluminum Pipe																									
Task 8D																■	■								8
Repeat Test Series on 36" PVC Pipe																									
Task 8E																		■	■						8
Repeat Test Series on 24" HDPE Pipe																									
Task 8F																				■	■				8
Repeat Test Series on 24" Corrugated Steel Pipe																									
Task 9						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		10
Perform FEM modeling																									
Task 10						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1
Preparation of Final Report																									
																									100%
Overall % Complete Projected	4%	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	85%	90%	95%	100%	
Overall % Complete Actual	4%	7%	11%	!4%																					

FIG. A -- OVERALL PROJECT SCHEDULE

Appendix

Appendix A

Supplemental AutoCAD Drawings



SOIL BOX PLAN VIEW
LOCATION OF NUCLEAR DENSITY
TESTS PERFORMED ON 03-22-2010

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP–KP	
PROJECT #:	BDK75 977–21	DATE:	06–01–2010
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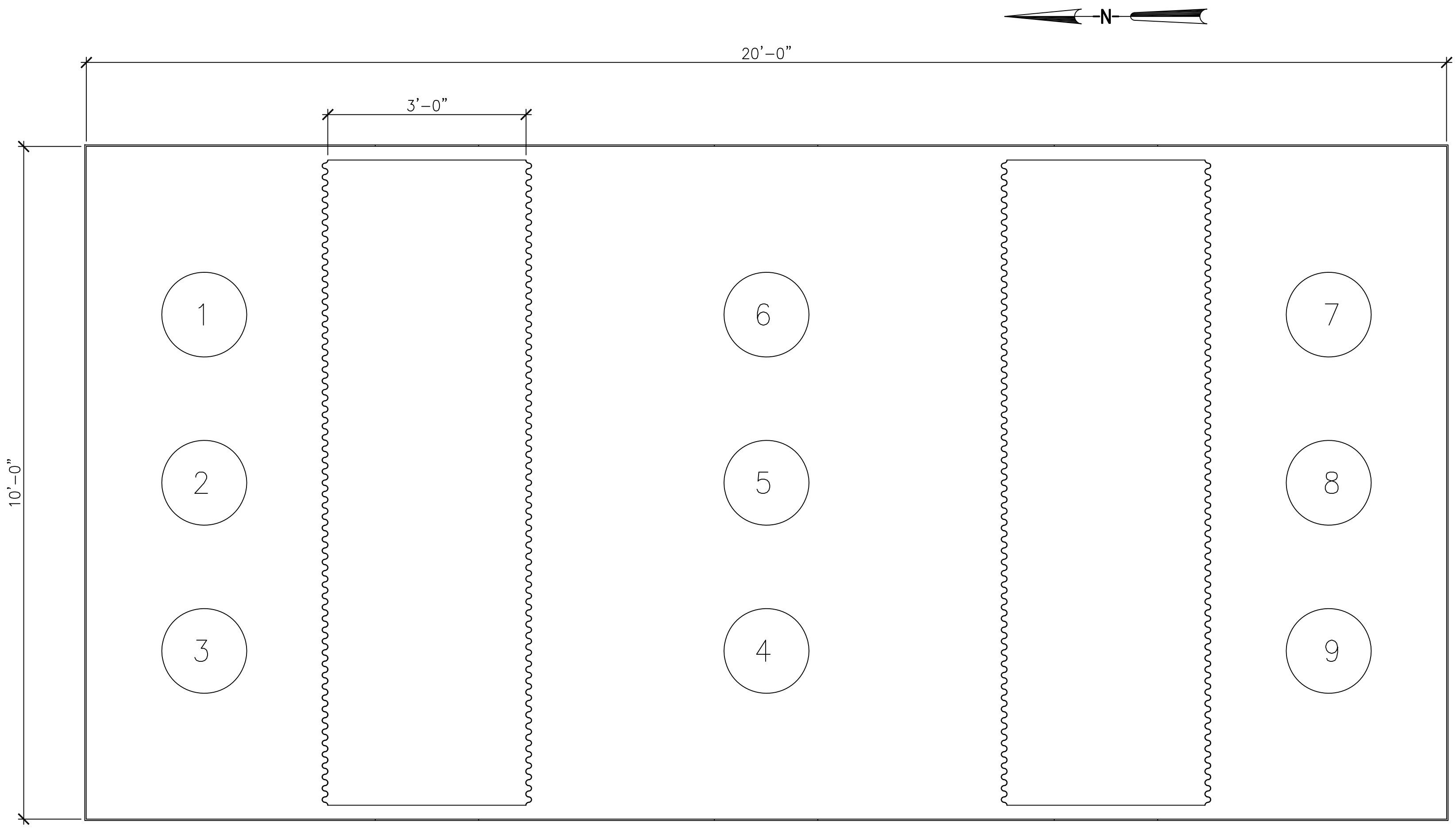

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SOIL BOX PLAN VIEW
LOCATION OF NUCLEAR DENSITY
TESTS PERFORMED ON
04-28-2010, 04-29-2010, & 05-03-2010

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	06-01-2010
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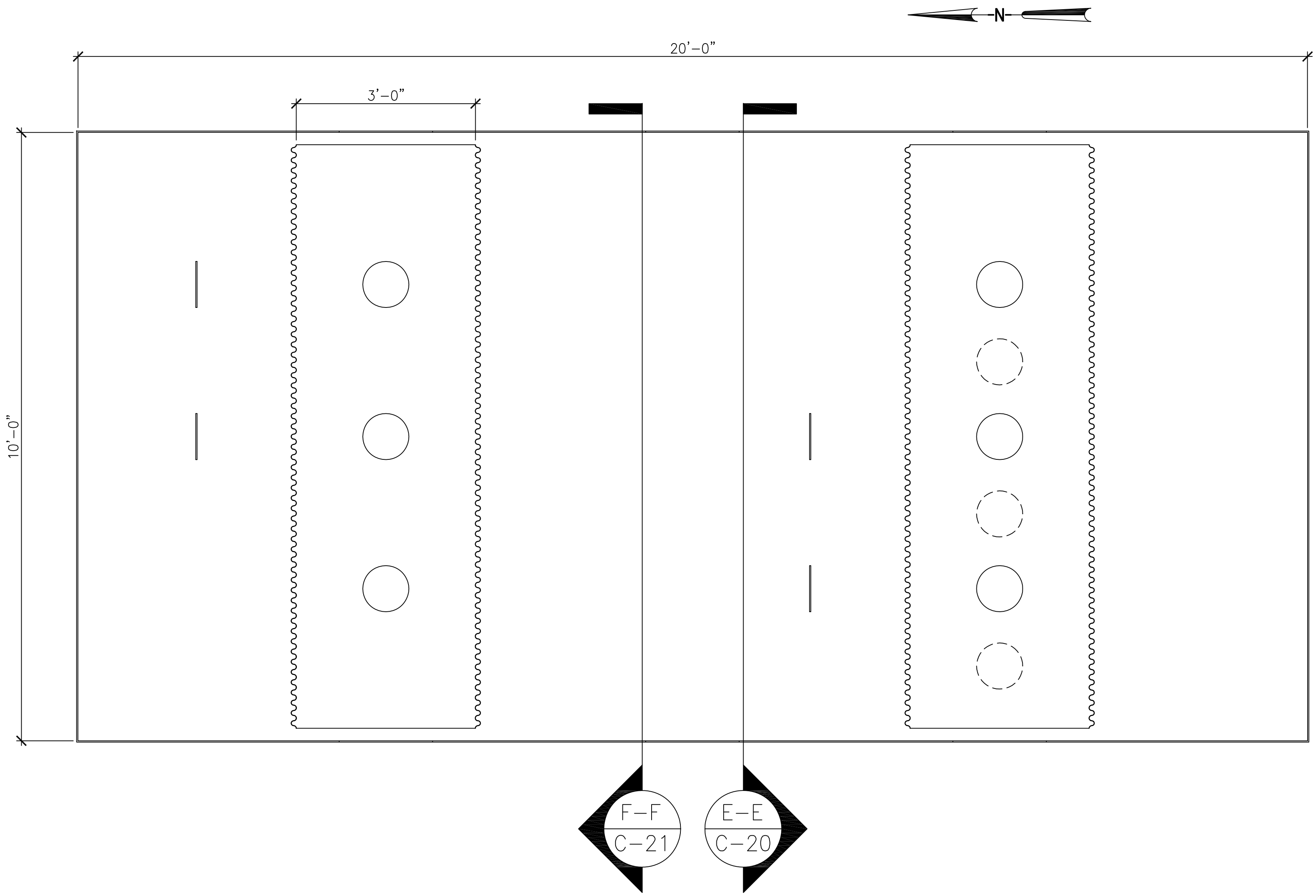

SOIL BOX PLAN VIEW
WITH 36 INCH DIAMETER PIPES

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	06-01-2010
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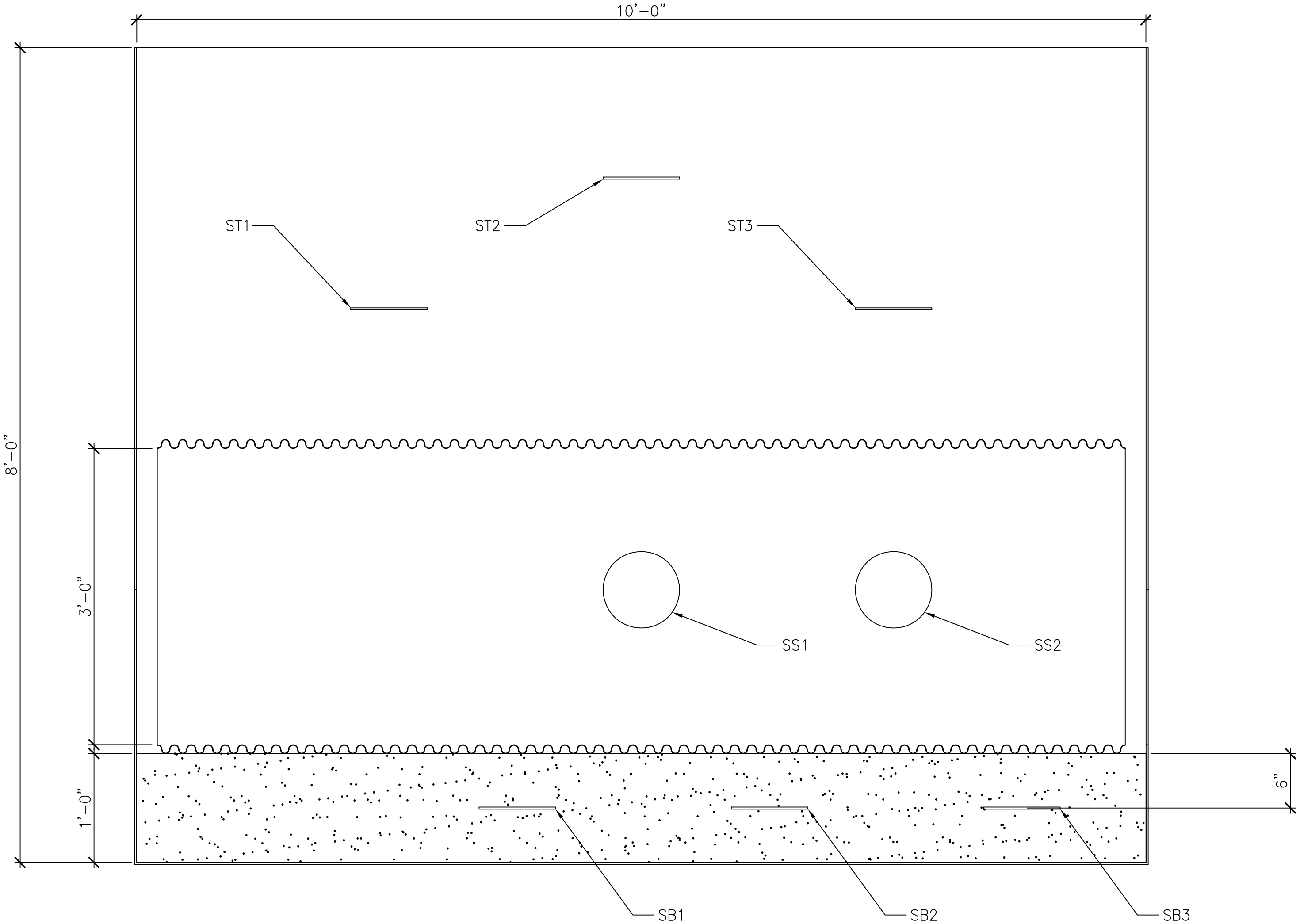

SOIL BOX PROFILE VIEW
SECTION E-E

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
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PROJECT #:	BDK75 977–21	DATE:	06–01–2010
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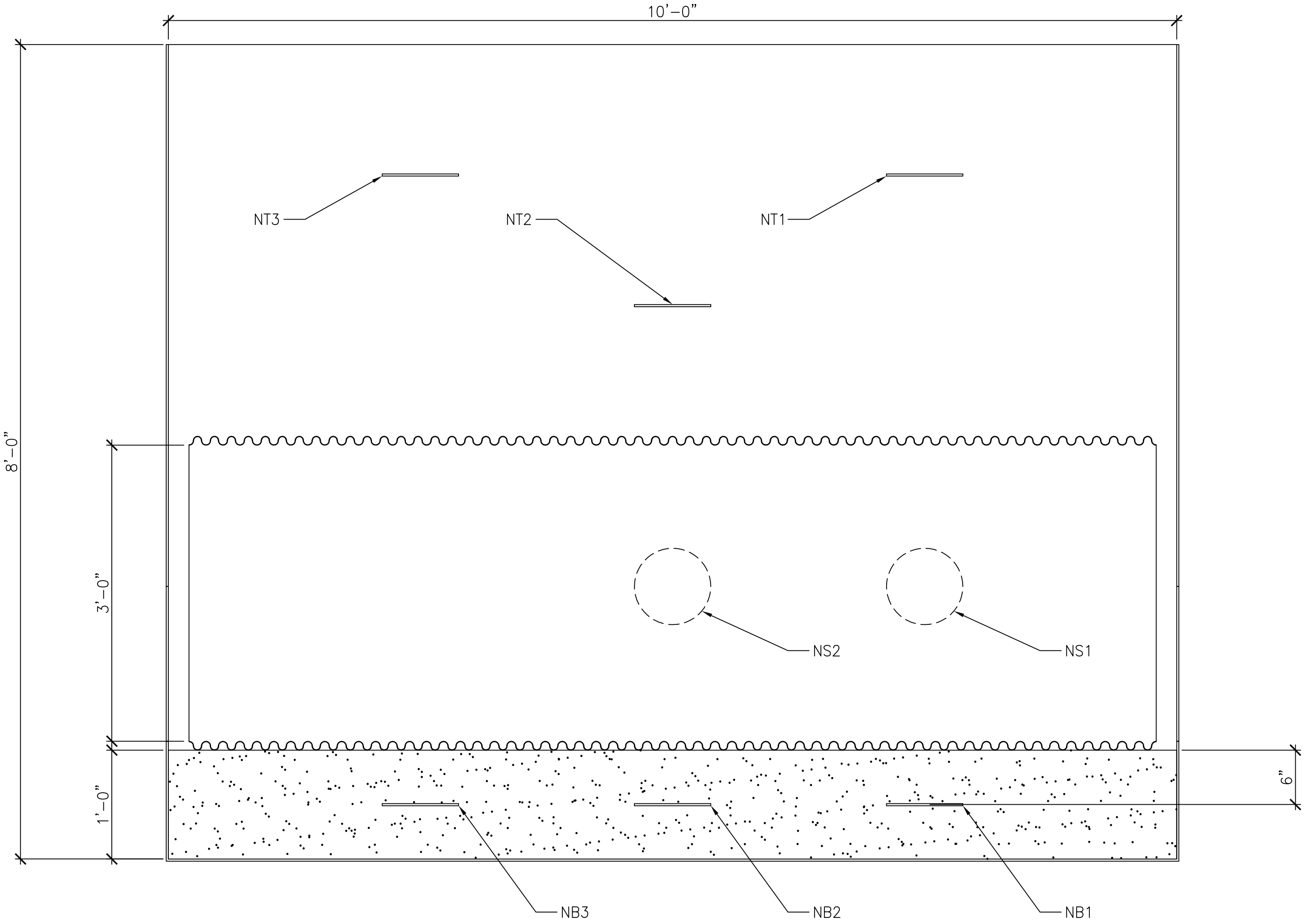

SOIL BOX PROFILE VIEW
SECTION F-F

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP–KP	
PROJECT #:	BDK75 977–21	DATE:	06–01–2010
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Appendix B

Nuclear Density Test Results

Nuclear Density Tests (Standard Proctor)				
Date Performed	Location #	Wet Density (pcf)	Dry Density (pcf)	% Moisture
March 22, 2010 (Bottom 12" Compacted Layer)	1	104.7	101.7	2.9
	2	103.5	100.8	2.6
	3	104.8	101.8	2.9
	4	105.5	102.7	2.7
	5	106.1	103.4	2.5
	6	103.8	100.9	2.8
April 28. 2010 (After Addition of 2' of Soil)	1	96.6	93.5	3.2
	2	97.7	94.8	3.0
	3	96.7	94.6	2.2
	4	100.3	97.0	3.3
	5	97.1	95.0	2.2
	6	100.2	97.2	3.0
	7	98.0	95.6	2.4
	8	99.2	96.0	3.2
	9	99.0	95.7	3.3
April 29, 2010 (After Addition of 2' of Soil)	1	98.2	95.4	2.9
	2	99.6	96.8	2.8
	3	96.7	94.6	2.2
	4	99.4	96.7	2.7
	5	100.3	98.4	1.9
	6	104.1	100.6	3.4
	7	95.7	93.2	2.6
	8	98.8	95.1	3.7
	9	95.8	93.1	2.8
May 3, 2010 (After Addition of 2.5' of Soil)	1	100.7	98.6	2.1
	2	101.6	99.1	2.5
	3	99.8	97.1	2.7
	4	100.6	97.8	2.8
	5	101.3	98.8	2.5
	6	98.5	95.8	2.7
	7	99.6	97.2	2.4
	8	97.1	94.3	2.9
	9	100.4	97.6	2.8

Appendix C

Triaxial Test Results for

Sample 23421

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23421 - 7 psi
Date:	10/14/2008
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**145.06**
Mass of 2 ps, 2fp, 1 mem + sample (g)	
Mass of sample (g)	1248.72
Mass of sample (lbs)	2.75

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2090**	**0.5220**
2	**6.2180**	**0.5220**
3	**6.2250**	**0.5210**
Average	6.217	0.522
Average Height minus pore stones and filter paper	5.6957	

Diameter (in)	
Top	**2.912**
Middle	**2.912**
Bottom	**2.912**
Average (minus membrane)	2.888
Area (in^2)	6.5506

	Initial	Final
Tare	**77.51**	**307.40**
Wet	**366.59**	**1476.10**
Dry	**333.98**	**1288.31**
moisture (%)	12.7	19.1

Optimum Dry Density, pcf	**109.4**
Optimum Moisture, %	**12.8**
Target Density, pcf	109.4
Actual Dry Density, pcf	113.1
Percentage of Optimum	**103.4**

Actual Volume, ft^3	0.0216
Volume Start of Test, cm3	611.4064
Volume After Consol, cm3	605.0894

Shear Failure Sketch	B value	
	u1 =	65.5
	u2 =	74.7
	Δs =	10
	B =	0.92

Height before saturation (in)	**0.2792**
Height after saturation (in)	**0.2954**
Δ Hs (in)	0.016
Height after consolidation (in)	**0.3005**
Δ Height after sat. and consol. (in)	0.0213
Average height ΔHc+ΔHs (in)	5.6744
Vo (in^3)	37.3103
ΔVs (in^3)	0.3184
ΔVc (cm^3)	**1.1000**
(in^3)	0.0671
ΔV_T (in^3)	0.3855
Ac (in^2)	6.5073
Volume after consolidation, Vc, (cm^3)	605.0894
Confining Pressure (psi)	**7**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23421 - 14 psi
Date:	10/14/2008
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**137.71**
Mass of 2 ps, 2fp, 1 mem + sample (g)	
Mass of sample (g)	1209.51
Mass of sample (lbs)	2.67

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2090**	**0.5280**
2	**6.2205**	**0.5250**
3	**6.2125**	**0.5220**
Average	6.214	0.525
Average Height minus pore stones and filter paper	5.6890	

Diameter (in)	
Top	**2.916**
Middle	**2.917**
Bottom	**2.915**
Average (minus membrane)	2.892
Area (in^2)	6.5688

	Initial	Final
Tare	**77.51**	**307.40**
Wet	**366.59**	**1476.10**
Dry	**333.98**	**1288.31**
moisture (%)	12.7	19.1

Optimum Dry Density, pcf	**109.4**
Optimum Moisture, %	**12.8**
Target Density, pcf	109.4
Actual Dry Density, pcf	109.4
Percentage of Optimum	**100.0**

Actual Volume, ft^3	0.0216
Volume Start of Test, cm3	612.3836
Volume After Consol, cm3	600.4843

Shear Failure Sketch	B value	
	u1 =	65.8
	u2 =	74.8
	Δs =	10
	B =	0.9

Height before saturation (in)	**0.3998**
Height after saturation (in)	**0.4255**
Δ Hs (in)	0.026
Height after consolidation (in)	**0.4284**
Δ Height after sat. and consol. (in)	0.0286
Average height ΔHc+ΔHs (in)	5.6604
Vo (in^3)	37.3699
ΔVs (in^3)	0.5065
ΔVc (cm^3)	**3.6000**
(in^3)	0.2197
ΔV_T (in^3)	0.7261
Ac (in^2)	6.4737
Volume after consolidation, Vc, (cm^3)	600.4843
Confining Pressure (psi)	**14**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23421 - 21 psi
Date:	10/14/2008
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**141.56**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1356.06**
Mass of sample (g)	1214.50
Mass of sample (lbs)	2.68

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2450**	**0.5295**
2	**6.2740**	**0.5250**
3	**6.2535**	**0.5265**
Average	6.258	0.527
Average Height minus pore stones and filter paper	5.7305	

Diameter (in)	
Top	**2.914**
Middle	**2.915**
Bottom	**2.914**
Average (minus membrane)	2.890
Area (in^2)	6.5612

	Initial	Final
Tare	**77.51**	**431.90**
Wet	**366.59**	**1726.30**
Dry	**333.98**	**1521.06**
moisture (%)	12.7	18.8

Optimum Dry Density, pcf	**109.4**
Optimum Moisture, %	**12.8**
Target Density, pcf	109.4
Actual Dry Density, pcf	109.2
Percentage of Optimum	**99.8**

Actual Volume, ft^3	0.0218
Volume Start of Test, cm3	616.1400
Volume After Consol, cm3	613.6595

Shear Failure Sketch	B value	
	u1 =	65.8
	u2 =	75.1
	Δs =	10
	B =	0.93

Height before saturation (in)	**0.4058**
Height after saturation (in)	**0.4107**
Δ Hs (in)	0.005
Height after consolidation (in)	**0.4199**
Δ Height after sat. and consol. (in)	0.014
Average height ΔHc+ΔHs (in)	5.7164
Vo (in^3)	37.5992
ΔVs (in^3)	0.0965
ΔVc (cm^3)	**0.9000**
(in^3)	0.0549
ΔV_T (in^3)	0.1514
Ac (in^2)	6.5509
Volume after consolidation, Vc, (cm^3)	613.6595
Confining Pressure (psi)	**21**

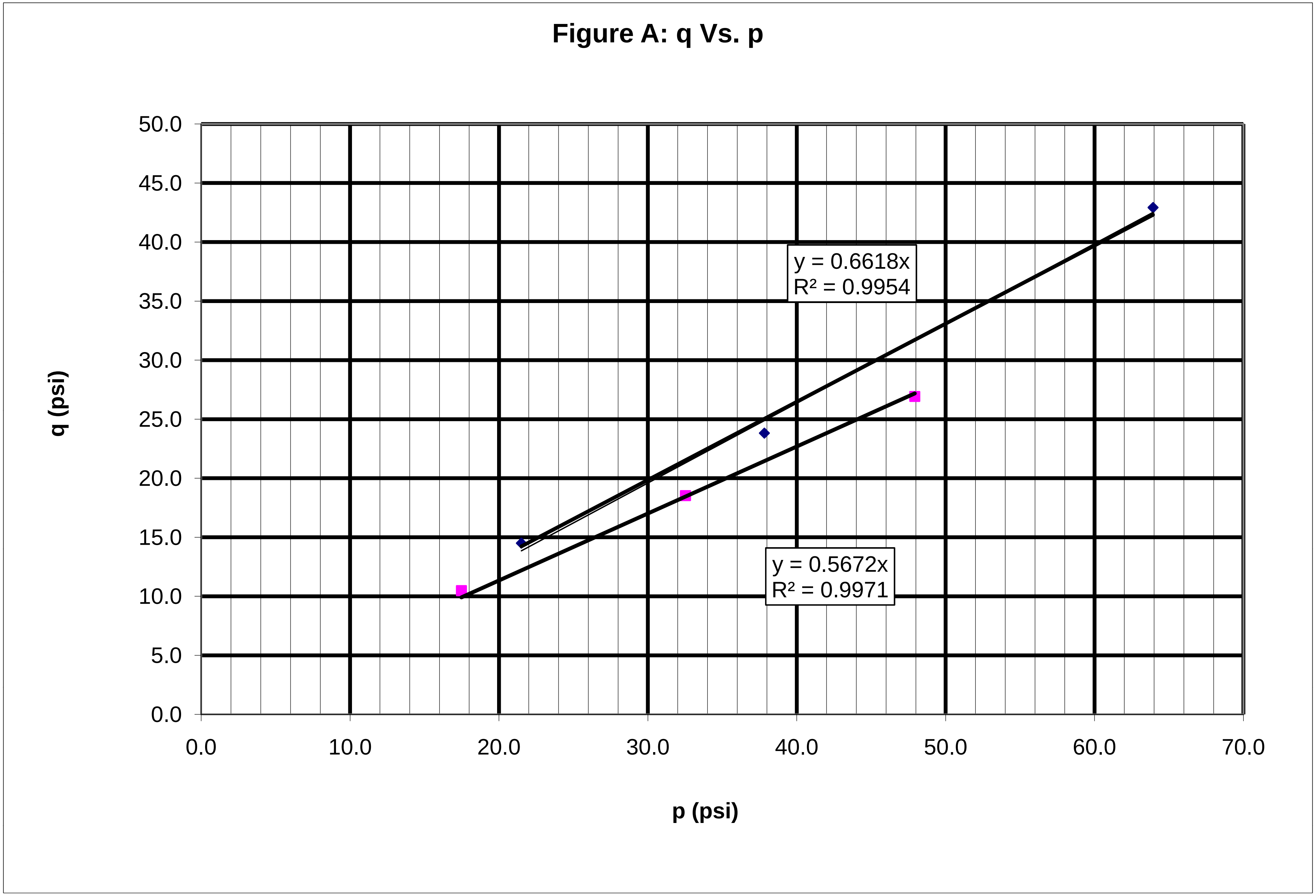


Figure A: q Vs. p
q (psi)
p (psi)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
y = 0.6618x
R² = 0.9954
y = 0.5672x
R² = 0.9971

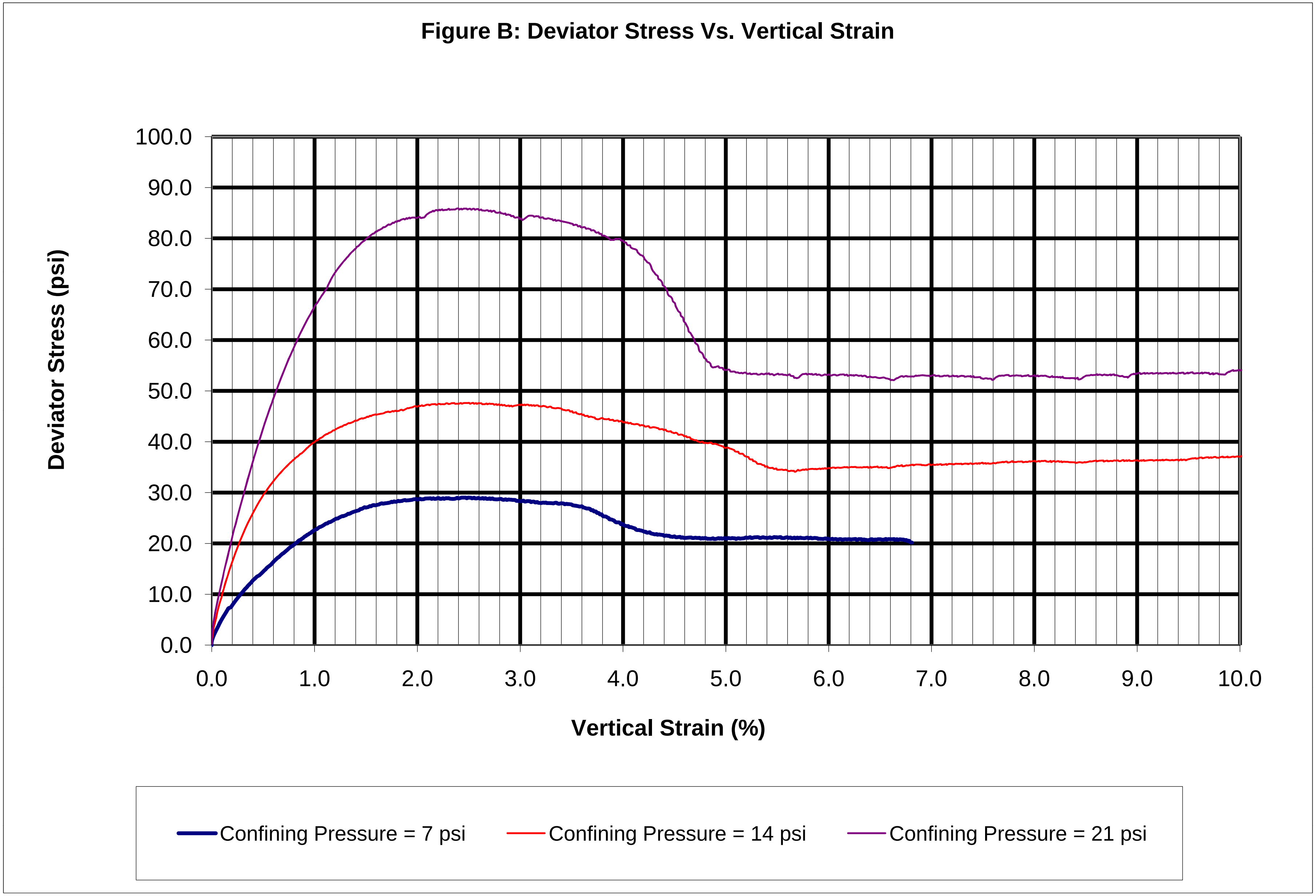


Figure B: Deviator Stress Vs. Vertical Strain
Deviator Stress (psi)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Vertical Strain (%)
Confining Pressure = 7 psi
Confining Pressure = 14 psi
Confining Pressure = 21 psi

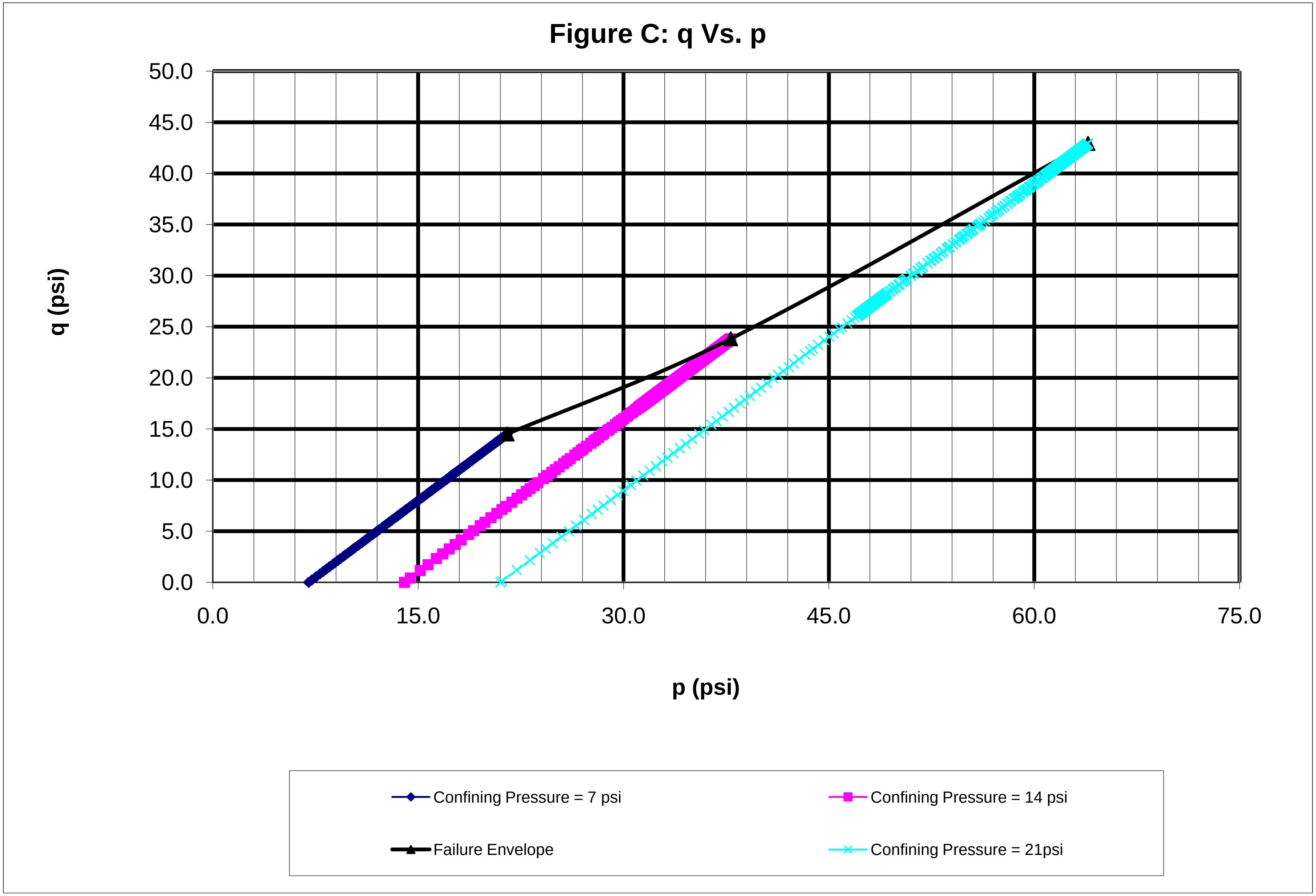


Figure C: q Vs. p
q (psi)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
15.0
30.0
45.0
60.0
75.0
p (psi)
Confining Pressure = 7 psi
Confining Pressure = 14 psi
Failure Envelope
Confining Pressure = 21psi

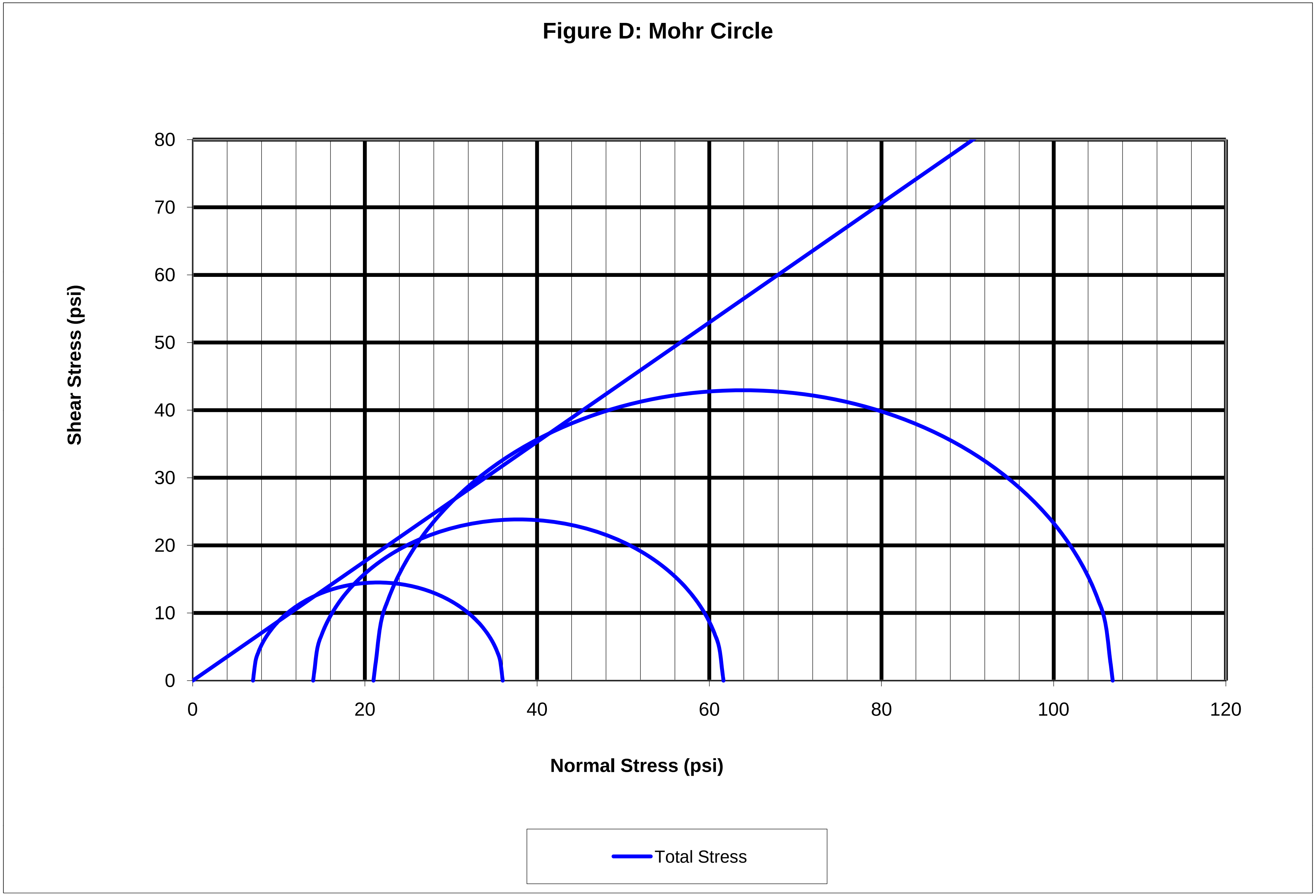


Figure D: Mohr Circle
Shear Stress (psi)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Normal Stress (psi)
Total Stress

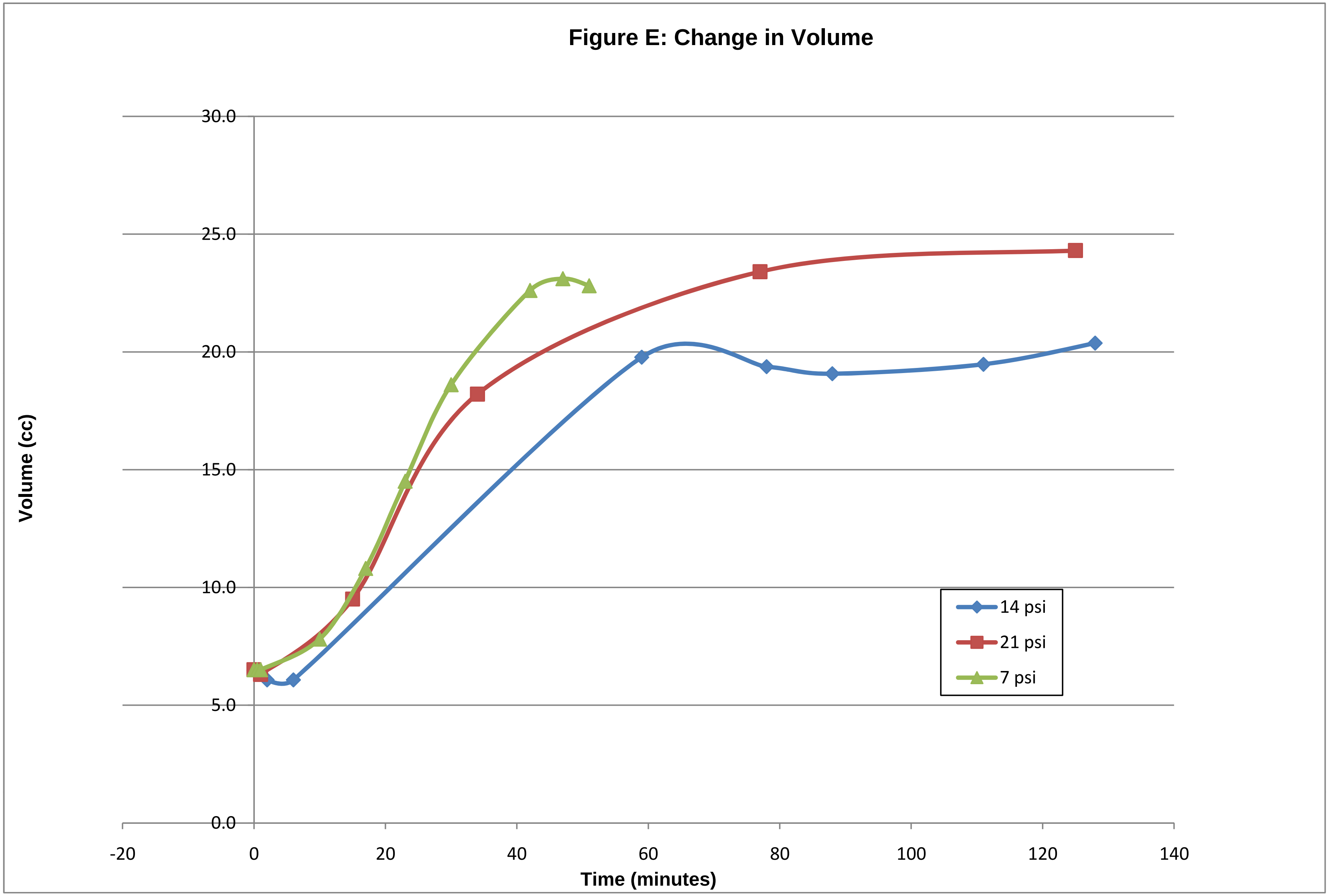


Figure E: Change in Volume
Volume (cc)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-20
0
20
40
60
80
100
120
140
Time (minutes)
14 psi
21 psi
7 psi

Appendix D

Triaxial Test Results for

Sample 23422

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	Consolidated Drained Triaxial Compression Test	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23422 - 7 psi
Date:	10/14/2008
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**142.72**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1357.86**
Mass of sample (g)	1248.72
Mass of sample (lbs)	2.75

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2595**	**0.5255**
2	**6.2465**	**0.5175**
3	**6.2530**	**0.5195**
Average	6.253	0.521
Average Height minus pore stones and filter paper	5.7322	

Diameter (in)	
Top	**2.910**
Middle	**2.910**
Bottom	**2.911**
Average (minus membrane)	2.886
Area (in^2)	6.5431

	Initial	Final
Tare	**77.50**	
Wet	**295.09**	
Dry	**271.00**	
moisture (%)	12.4	#DIV/0!

Optimum Dry Density, pcf	**110.1**
Optimum Moisture, %	**12.3**
Target Density, pcf	109.4
Actual Dry Density, pcf	112.8
Percentage of Optimum	**102.4**

Actual Volume, ft^3	0.0217
Volume Start of Test, cm3	614.6145
Volume After Consol, cm3	596.7879

Shear Failure Sketch	B value	
	u1 =	65.5
	u2 =	74.7
	Δs =	0
	B =	92

Height before saturation (in)	**0.3252**
Height after saturation (in)	**0.3772**
Δ Hs (in)	0.052
Height after consolidation (in)	**0.3819**
Δ Height after sat. and consol. (in)	0.0567
Average height ΔHc+ΔHs (in)	5.6755
Vo (in^3)	37.5061
ΔVs (in^3)	1.0207
ΔVc (cm^3)	**1.1000**
(in^3)	0.0671
ΔV_T (in^3)	1.0878
Ac (in^2)	6.4168
Volume after consolidation, Vc, (cm^3)	596.7879
Confining Pressure (psi)	**7**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23422 - 14 psi
Date:	10/14/2008
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.025**
Mass of 2 pore stones, 2 papers & mem. (g)	**147.93**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1354.15**
Mass of sample (g)	1209.51
Mass of sample (lbs)	2.67

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2250**	**0.5255**
2	**6.2320**	**0.5250**
3	**6.1915**	**0.5265**
Average	6.216	0.526
Average Height minus pore stones and filter paper	5.6905	

Diameter (in)	
Top	**2.911**
Middle	**2.913**
Bottom	**2.910**
Average (minus membrane)	2.861
Area (in^2)	6.4302

	Initial	Final
Tare		
Wet		
Dry		
moisture (%)	12.3	#DIV/0!

Optimum Dry Density, pcf	**110.1**
Optimum Moisture, %	**12.3**
Target Density, pcf	109.4
Actual Dry Density, pcf	112.1
Percentage of Optimum	**101.8**

Actual Volume, ft^3	0.0212
Volume Start of Test, cm3	599.6231
Volume After Consol, cm3	593.3716

Shear Failure Sketch	B value	
	u1 =	65.8
	u2 =	74.8
	Δs =	0
	B =	94

Height before saturation (in)	**0.1329**
Height after saturation (in)	**0.1454**
Δ Hs (in)	0.013
Height after consolidation (in)	**0.1549**
Δ Height after sat. and consol. (in)	0.0220
Average height ΔHc+ΔHs (in)	5.6685
Vo (in^3)	36.5912
ΔVs (in^3)	0.2411
ΔVc (cm^3)	**2.3000**
(in^3)	0.1404
ΔV_T (in^3)	0.3815
Ac (in^2)	6.3879
Volume after consolidation, Vc, (cm^3)	593.3716
Confining Pressure (psi)	**14**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	Consolidated Drained Triaxial Compression Test	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23422 - 21 psi
Date:	11/6/2008
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.020**
Mass of 2 pore stones, 2 papers & mem. (g)	**150.32**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1316.65**
Mass of sample (g)	1166.33
Mass of sample (lbs)	2.57

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2260**	**0.5230**
2	**6.1985**	**0.5275**
3	**6.2350**	**0.5270**
Average	6.220	0.526
Average Height minus pore stones and filter paper	5.6940	

Diameter (in)	
Top	**2.910**
Middle	**2.911**
Bottom	**2.910**
Average (minus membrane)	2.870
Area (in^2)	6.4707

	Initial	Final
Tare	**77.50**	
Wet	**295.09**	
Dry	**271.09**	
moisture (%)	12.4	#DIV/0!

Optimum Dry Density, pcf	**110.1**
Optimum Moisture, %	**12.3**
Target Density, pcf	110.1
Actual Dry Density, pcf	107.3
Percentage of Optimum	**97.4**

Actual Volume, ft^3	0.0213
Volume Start of Test, cm3	603.7723
Volume After Consol, cm3	600.4406

Shear Failure Sketch	B value	
	u1 =	65.8
	u2 =	75.1
	Δs =	10
	B =	0.93

Height before saturation (in)	**0.3619**
Height after saturation (in)	**0.3642**
Δ Hs (in)	0.002
Height after consolidation (in)	**0.3680**
Δ Height after sat. and consol. (in)	0.006
Average height ΔHc+ΔHs (in)	5.6879
Vo (in^3)	36.8444
ΔVs (in^3)	0.0446
ΔVc (cm^3)	**2.6000**
(in^3)	0.1587
ΔV_T (in^3)	0.2033
Ac (in^2)	6.4419
Volume after consolidation, Vc, (cm^3)	600.4406
Confining Pressure (psi)	**21**

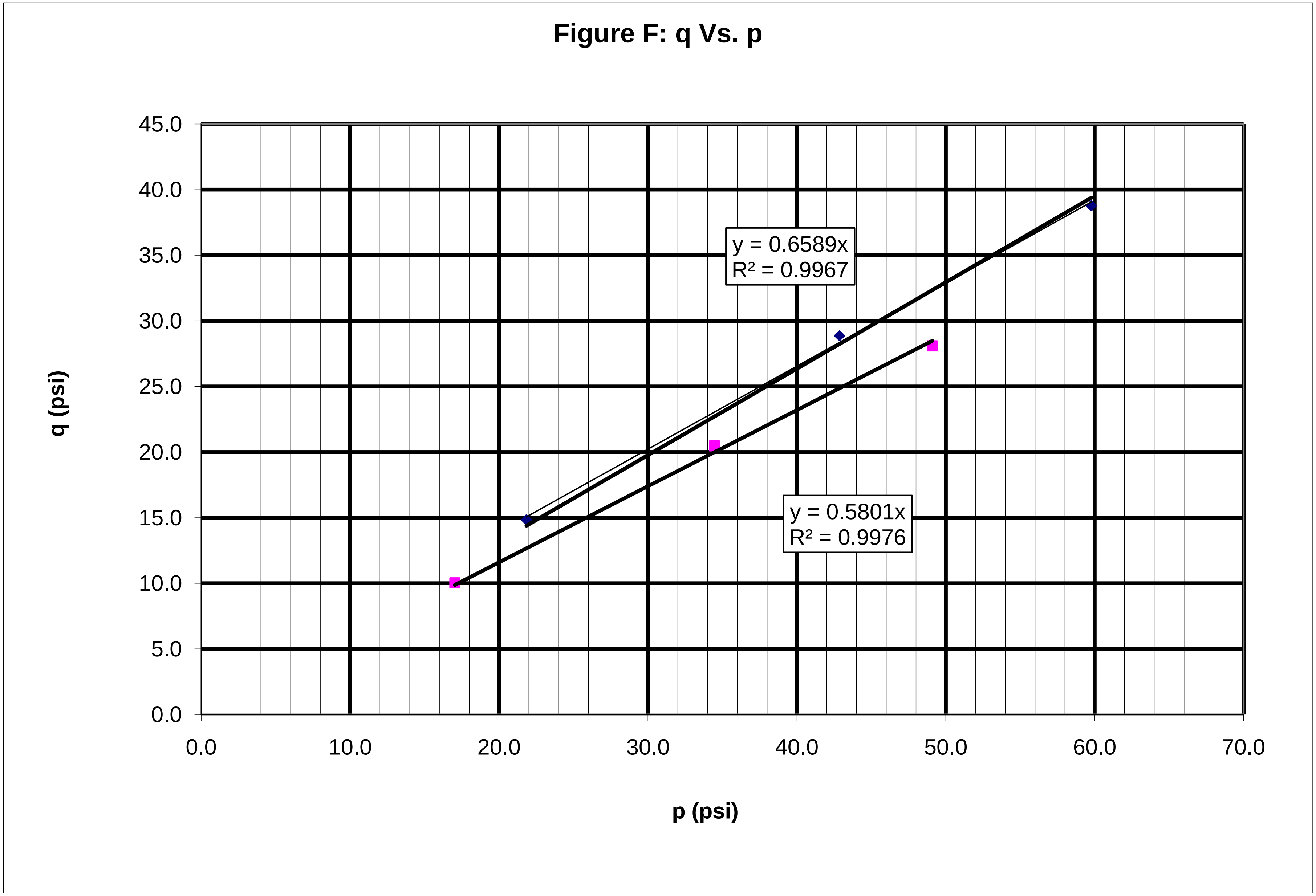


Figure F: q Vs. p
y = 0.6589x
R² = 0.9967
y = 0.5801x
R² = 0.9976
q (psi)
p (psi)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0

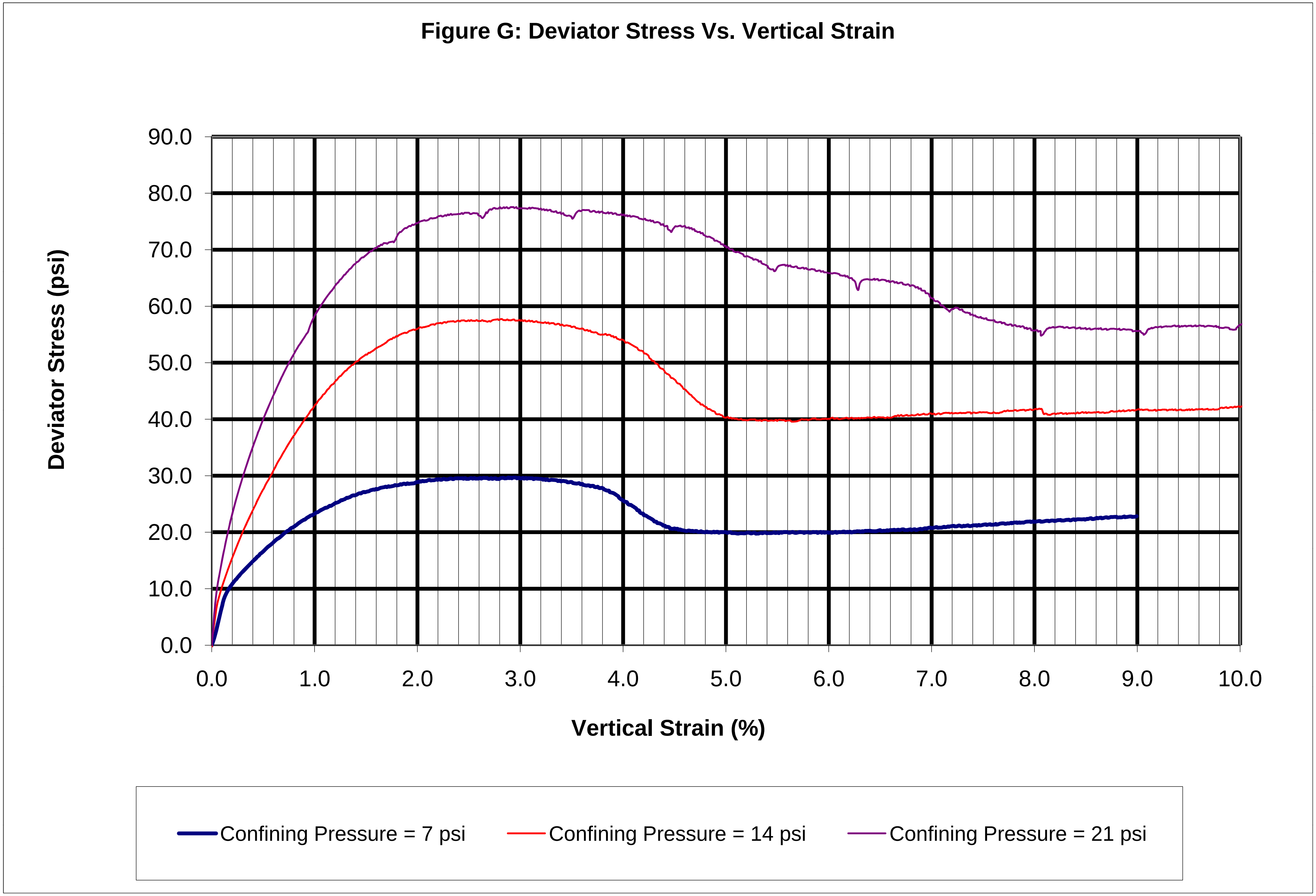


Figure G: Deviator Stress Vs. Vertical Strain
Deviator Stress (psi)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Vertical Strain (%)
Confining Pressure = 7 psi
Confining Pressure = 14 psi
Confining Pressure = 21 psi

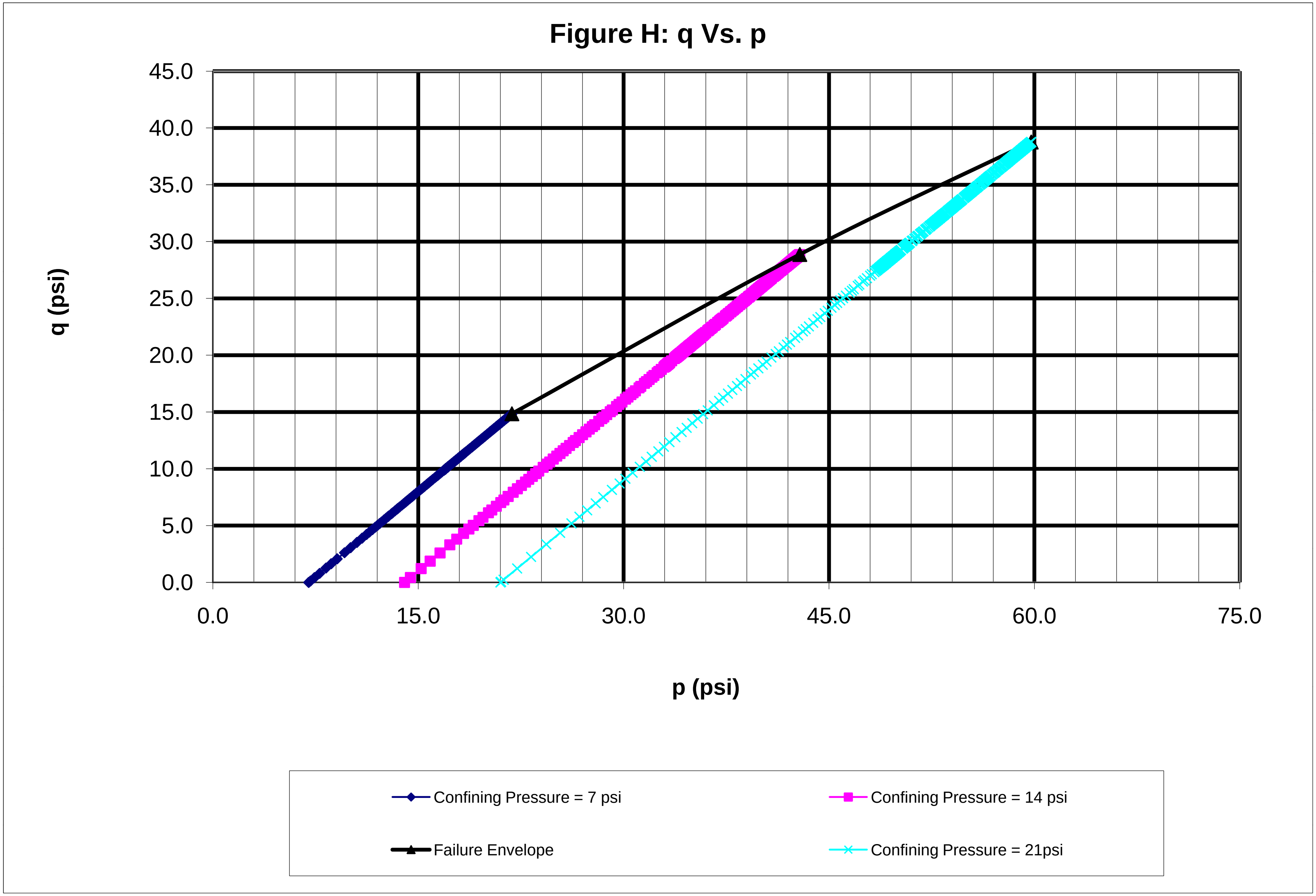


Figure H: q Vs. p
q (psi)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
15.0
30.0
45.0
60.0
75.0
p (psi)
Confining Pressure = 7 psi
Confining Pressure = 14 psi
Failure Envelope
Confining Pressure = 21psi

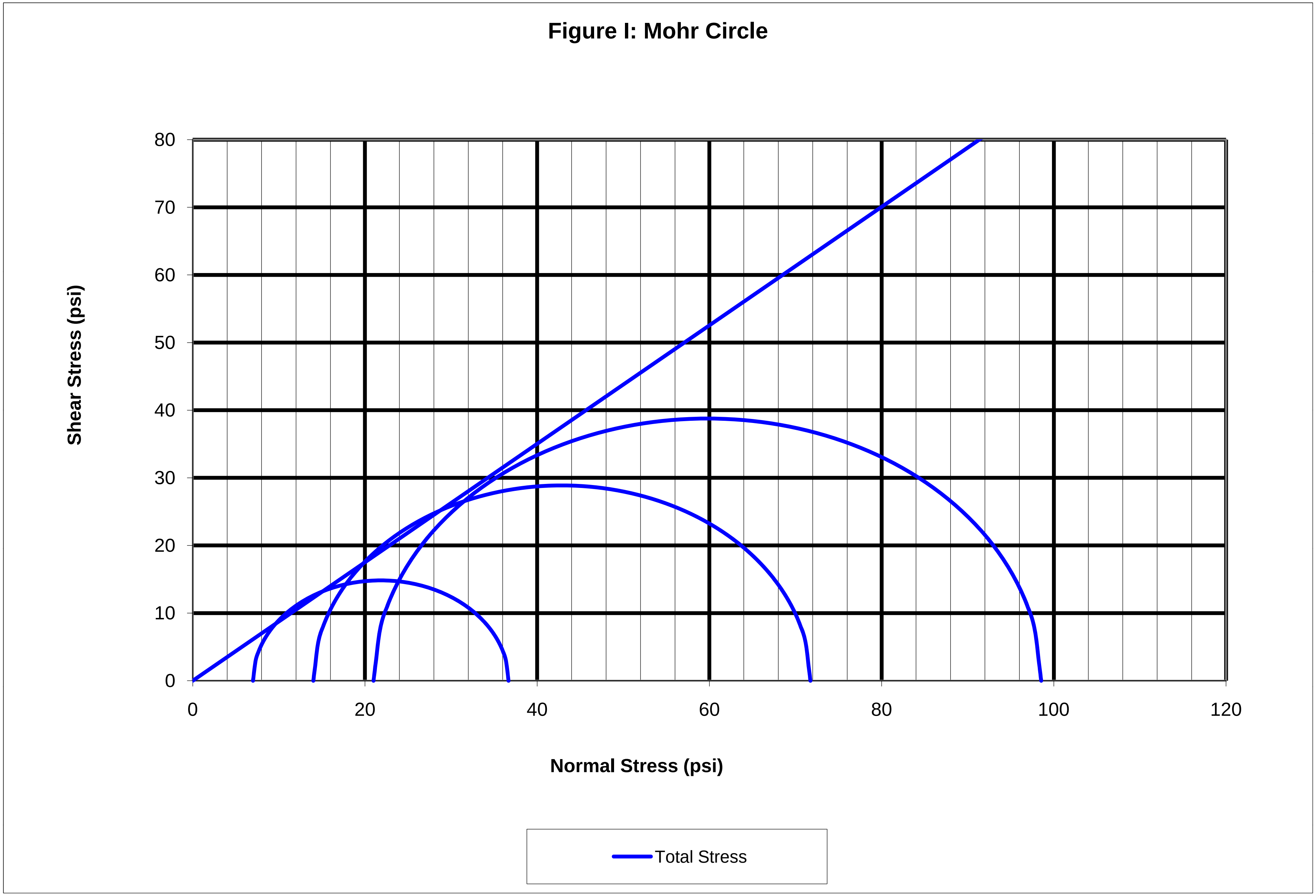


Figure I: Mohr Circle
80
70
60
50
40
30
20
10
0
Shear Stress (psi)
0
20
40
60
80
100
120
Normal Stress (psi)
Total Stress

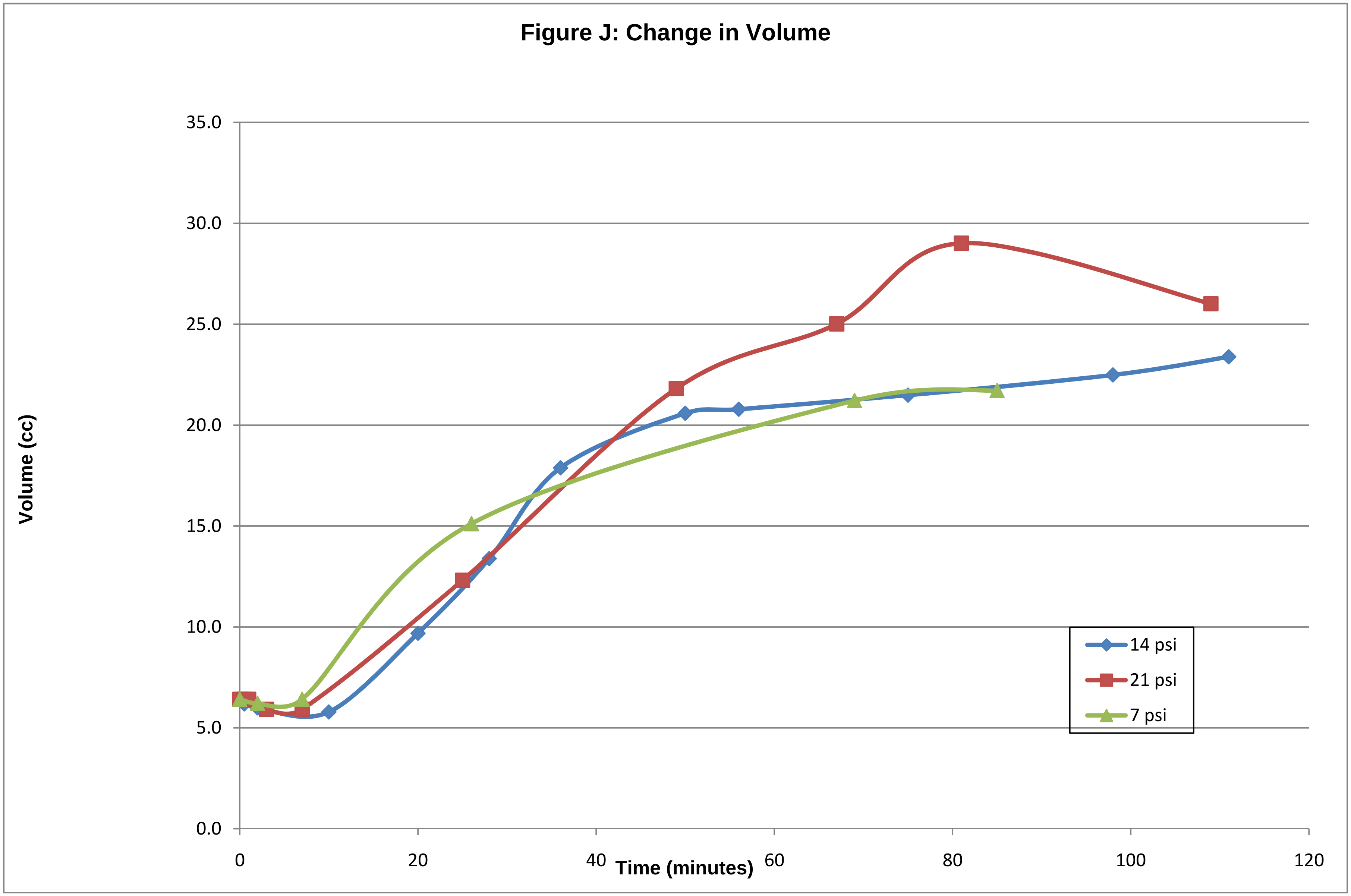


Figure J: Change in Volume
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Volume (cc)
0
20
40
60
80
100
120
Time (minutes)
14 psi
21 psi
7 psi

Appendix E

Triaxial Test Results for

Sample 23423

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	Consolidated Drained Triaxial Compression Test	Revised Date: 2/8/06
		By: SH — Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23423 - 7 psi
Date:	
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	0.018
Mass of 2 pore stones, 2 papers & mem. (g)	137.94
Mass of 2 ps, 2fp, 1 mem + sample (g)	1354.10
Mass of sample (g)	1216.16
Mass of sample (lbs)	2.68

Height	Sample + pore stones + papers	Pore Stones & Papers
1	6.2839	0.5250
2	6.2874	0.5270
3	6.2671	0.5285
Average	6.279	0.527
Average Height minus pore stones and filter paper	5.7526	

Diameter (in)	
Top	2.900
Middle	2.905
Bottom	2.906
Average (minus membrane)	2.868
Area (in^2)	6.4587

	Initial	Final
Tare		76.50
Wet		1334.10
Dry		1142.20
moisture (%)	12.6	18.0

Optimum Dry Density, pcf	111.0
Optimum Moisture, %	12.6
Target Density, pcf	109.4
Actual Dry Density, pcf	110.7
Percentage of Optimum	**99.8**

Actual Volume, ft^3	0.0215
Volume Start of Test, cm3	608.8567
Volume After Consol, cm3	607.8576

Shear Failure Sketch	B value	
	u1 =	65.5
	u2 =	74.7
	Δs =	0
	B =	94%

Height before saturation (in)	0.6076
Height after saturation (in)	0.6104
Δ Hs (in)	0.003
Height after consolidation (in)	0.6106
Δ Height after sat. and consol. (in)	0.0030
Average height ΔHc+ΔHs (in)	5.7496
Vo (in^3)	37.1547
ΔVs (in^3)	0.0543
ΔVc (cm^3)	0.1100
(in^3)	0.0067
ΔV_T (in^3)	0.0610
Ac (in^2)	6.4515
Volume after consolidation, Vc, (cm^3)	607.8576
Confining Pressure (psi)	7

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23423- 14 psi
Date:	
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.018**
Mass of 2 pore stones, 2 papers & mem. (g)	**145.82**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1362.90**
Mass of sample (g)	1209.51
Mass of sample (lbs)	2.67

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2930**	**0.5210**
2	**6.2230**	**0.5250**
3	**6.2360**	**0.5250**
Average	6.251	0.524
Average Height minus pore stones and filter paper	5.7270	

Diameter (in)	
Top	**2.910**
Middle	**2.903**
Bottom	**2.907**
Average (minus membrane)	2.871
Area (in^2)	6.4723

	Initial	Final
Tare		
Wet		
Dry		
moisture (%)	12.6	#DIV/0!

Optimum Dry Density, pcf	**111.0**
Optimum Moisture, %	**12.6**
Target Density, pcf	109.4
Actual Dry Density, pcf	110.4
Percentage of Optimum	**99.5**

Actual Volume, ft^3	0.0215
Volume Start of Test, cm3	607.4125
Volume After Consol, cm3	586.9443

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	0
	B =	94

Height before saturation (in)	**0.5688**
Height after saturation (in)	**0.6215**
Δ Hs (in)	0.053
Height after consolidation (in)	**0.6317**
Δ Height after sat. and consol. (in)	0.0629
Average height ΔHc+ΔHs (in)	5.6641
Vo (in^3)	37.0666
ΔVs (in^3)	1.0233
ΔVc (cm^3)	**3.7000**
(in^3)	0.2258
ΔV_T (in^3)	1.2491
Ac (in^2)	6.3236
Volume after consolidation, Vc, (cm^3)	586.9443
Confining Pressure (psi)	**14**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	D2 I-75 Coastal research
Sample No.:	23423- 21 psi
Date:	12/24/2008
Test By:	dp
Description:	A-3 sand
	.006 in/m

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**133.58**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1376.46**
Mass of sample (g)	1242.88
Mass of sample (lbs)	2.74

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.2835**	**0.5270**
2	**6.2730**	**0.5315**
3	**6.2630**	**0.5310**
Average	6.273	0.530
Average Height minus pore stones and filter paper	5.7433	

Diameter (in)	
Top	**2.910**
Middle	**2.911**
Bottom	**2.911**
Average (minus membrane)	2.887
Area (in^2)	6.5446

	Initial	Final
Tare	**77.12**	
Wet	**383.70**	
Dry	**349.55**	
moisture (%)	12.5	#DIV/0!

Optimum Dry Density, pcf	**111.0**
Optimum Moisture, %	**12.6**
Target Density, pcf	110.1
Actual Dry Density, pcf	111.9
Percentage of Optimum	**100.8**

Actual Volume, ft^3	0.0218
Volume Start of Test, cm3	615.9541
Volume After Consol, cm3	602.5688

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	
	B =	0.95

Height before saturation (in)	**0.4138**
Height after saturation (in)	**0.4467**
Δ Hs (in)	0.033
Height after consolidation (in)	**0.4549**
Δ Height after sat. and consol. (in)	0.041
Average height ΔHc+ΔHs (in)	5.7022
Vo (in^3)	37.5878
ΔVs (in^3)	0.6460
ΔVc (cm^3)	**2.8000**
(in^3)	0.1709
ΔV_T (in^3)	0.8168
Ac (in^2)	6.4485
Volume after consolidation, Vc, (cm^3)	602.5688
Confining Pressure (psi)	**21**

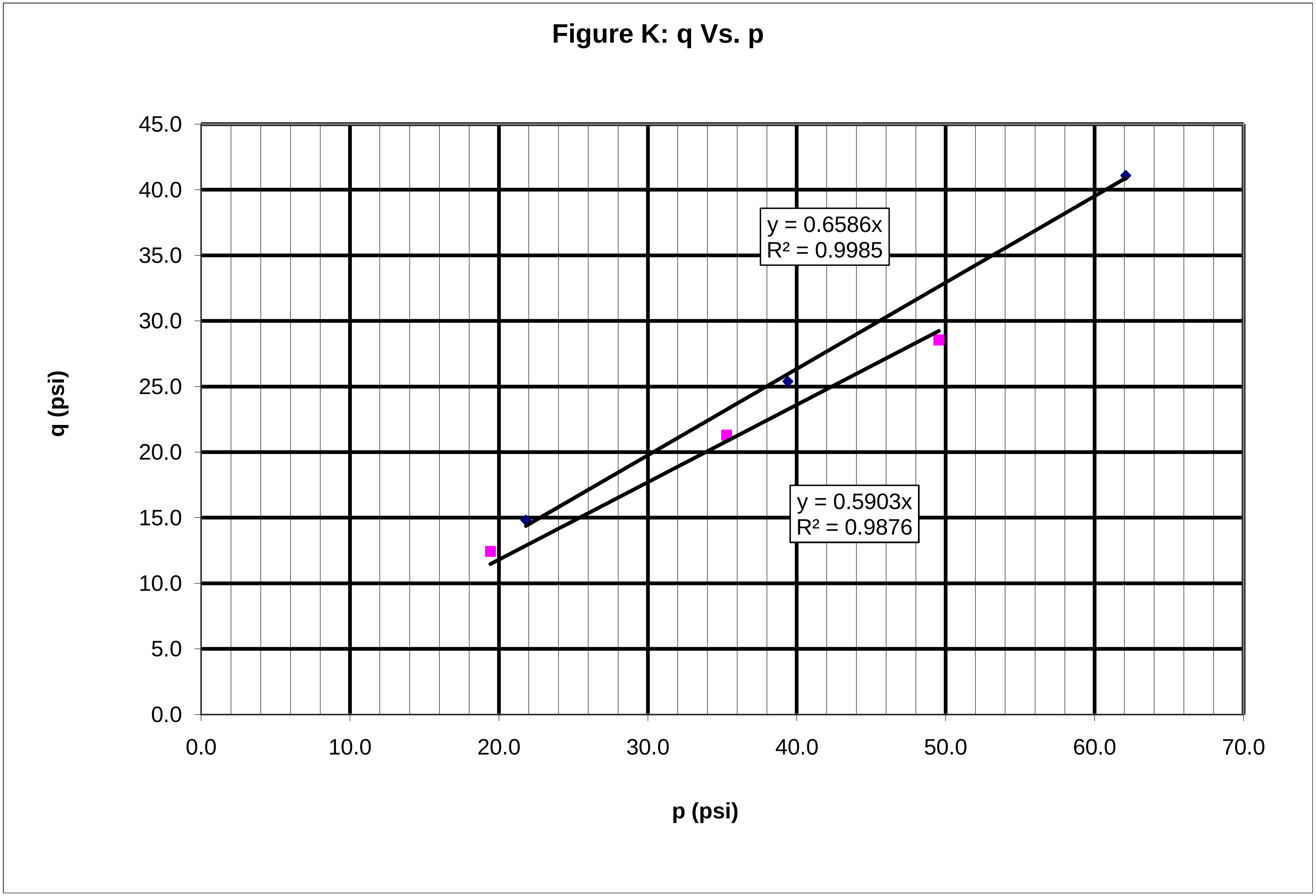
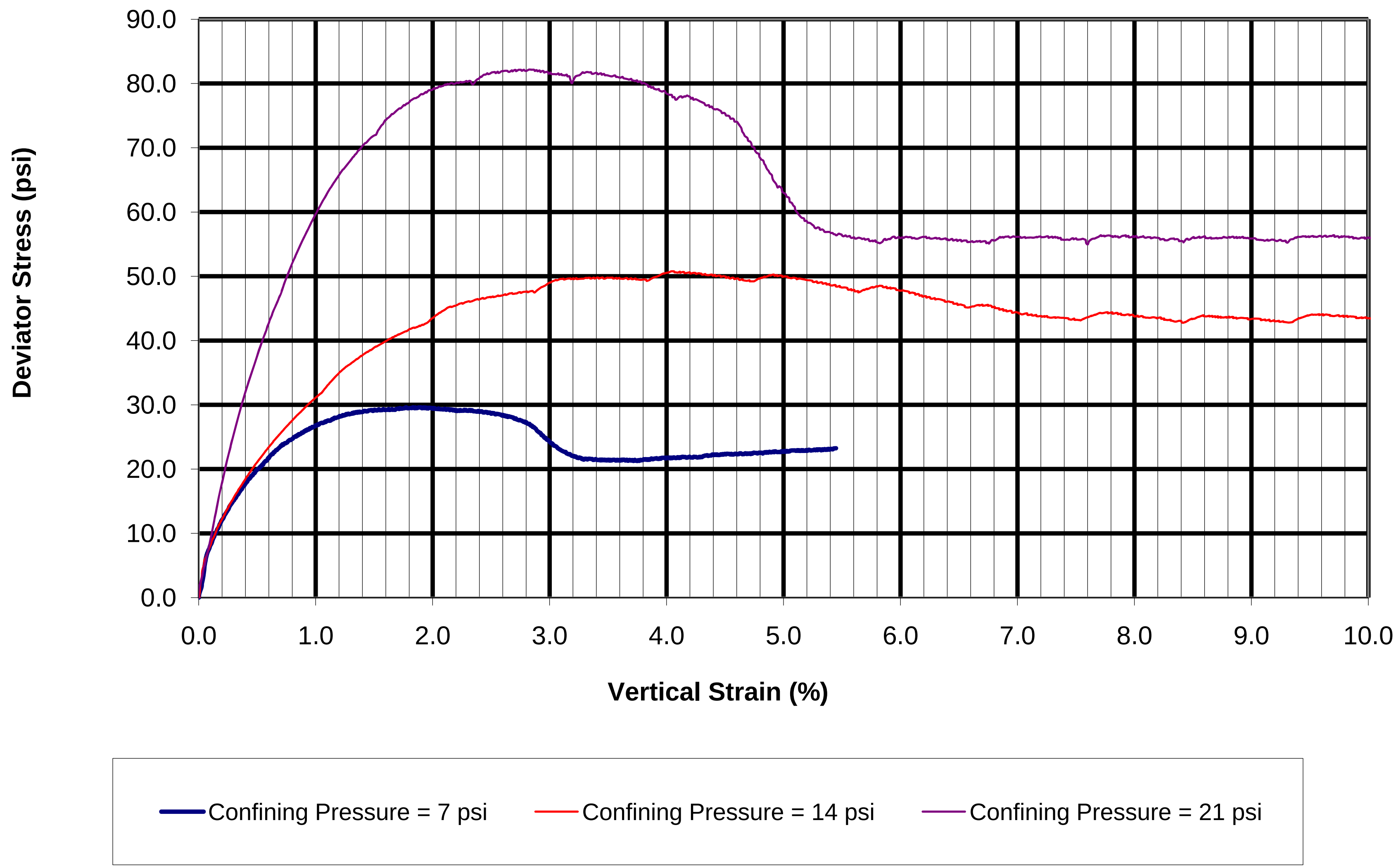


Figure K: q Vs. p
y = 0.6586x
R² = 0.9985
y = 0.5903x
R² = 0.9876
q (psi)
p (psi)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0

Figure L: Deviator Stress Vs. Vertical Strain



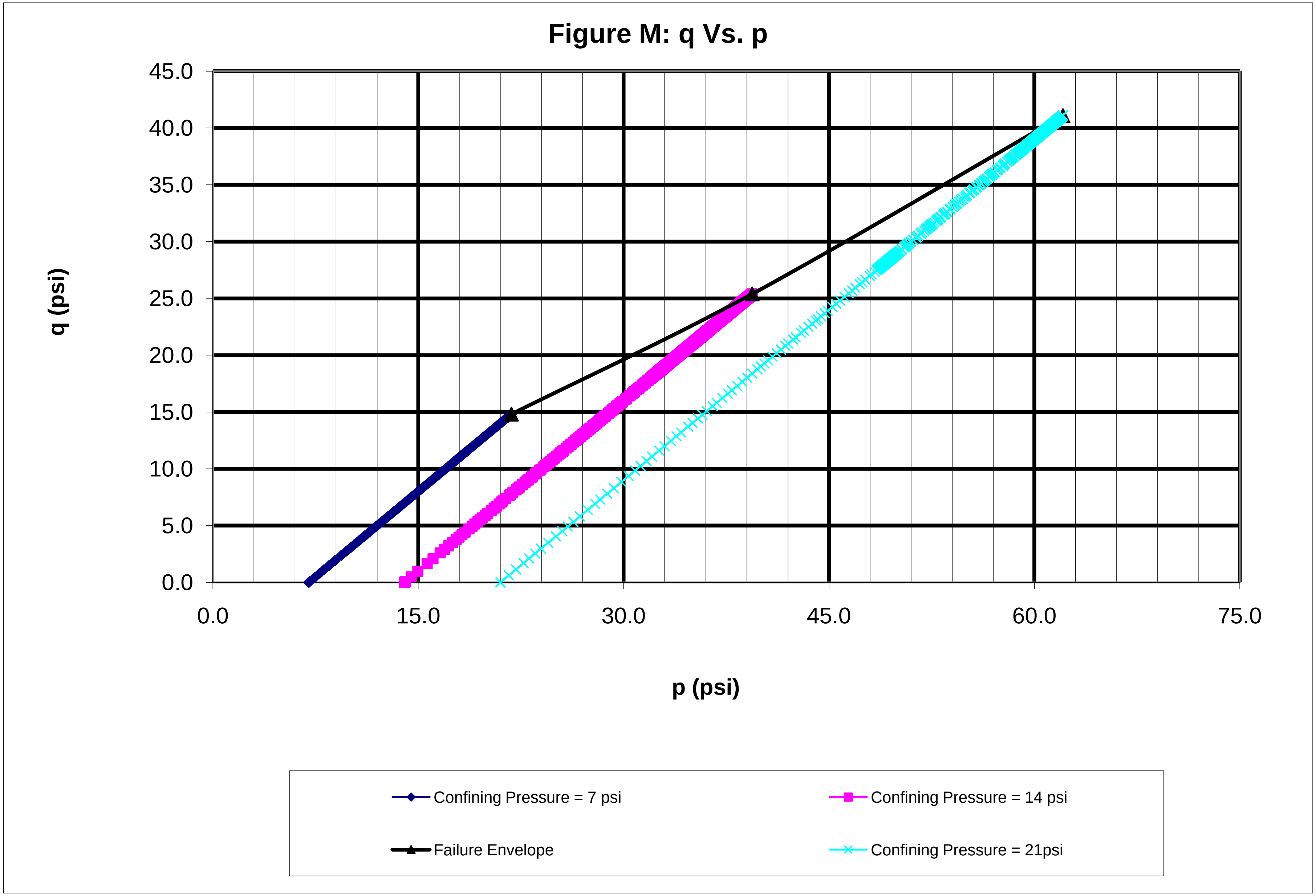


Figure M: q Vs. p
q (psi)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
15.0
30.0
45.0
60.0
75.0
p (psi)
Confining Pressure = 7 psi
Confining Pressure = 14 psi
Failure Envelope
Confining Pressure = 21psi

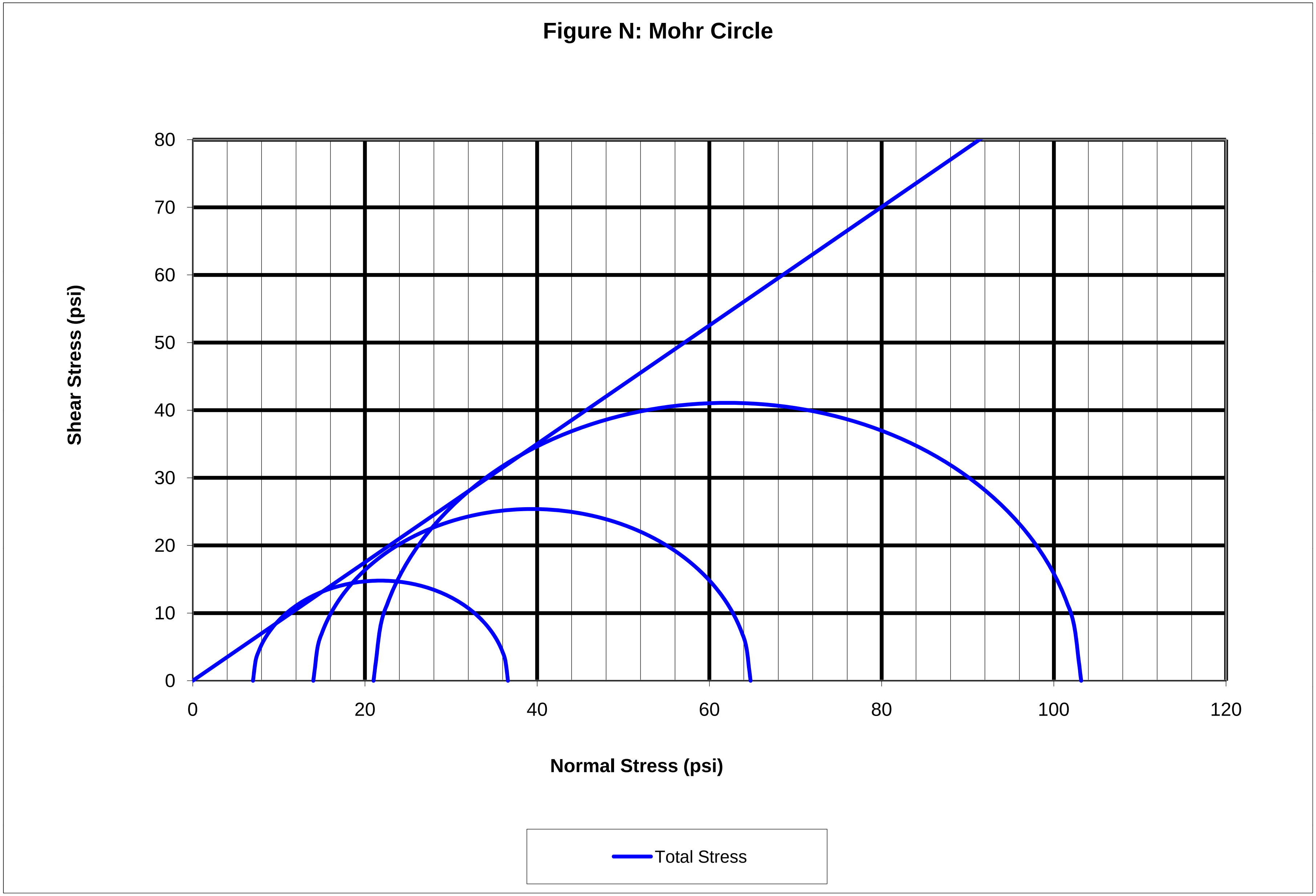


Figure N: Mohr Circle
Shear Stress (psi)
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
Normal Stress (psi)
Total Stress

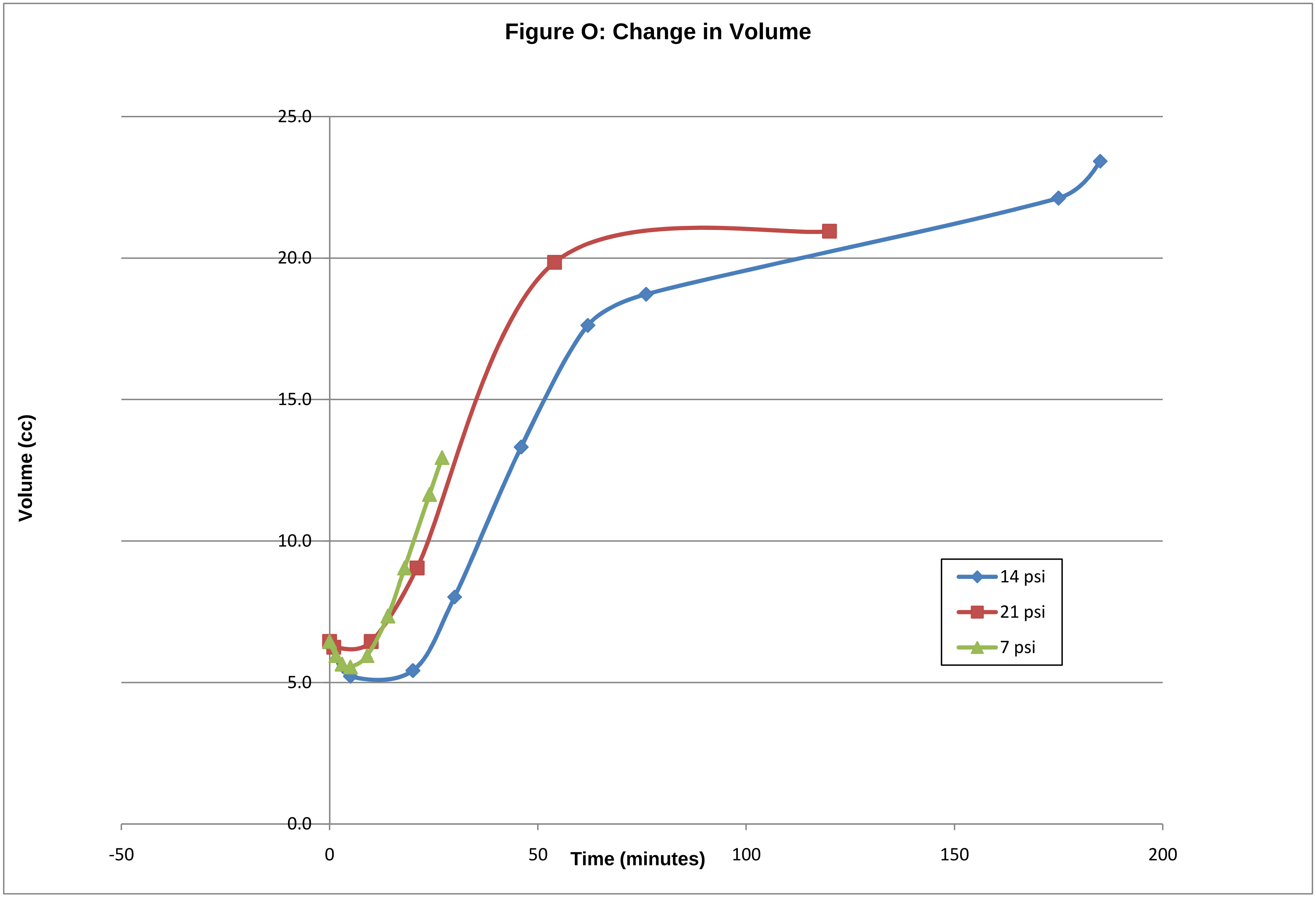


Figure O: Change in Volume
Volume (cc)
25.0
20.0
15.0
10.0
5.0
0.0
-50
0
50
100
150
200
Time (minutes)
14 psi
21 psi
7 psi

Appendix F

Triaxial Test Results for

Sample with 90% Standard Density

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	Consolidated Drained Triaxial Compression Test	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	UF Soil Box
Sample No.:	S-1
Date:	5/20/2010
Test By:	Dan Pitocchi
Description:	90% std proctor @ 3 psi confining
Strain Rate:	0.006 in/min

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**145.79**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1236.52**
Mass of sample (g)	1090.73
Mass of sample (lbs)	2.40

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.1510**	**0.5175**
2	**6.1620**	**0.5240**
3	**6.1535**	**0.5240**
Average	6.156	0.522
Average Height minus pore stones and filter paper	5.6337	

Diameter (in)	
Top	**2.907**
Middle	**2.908**
Bottom	**2.908**
Average (minus membrane)	2.884
Area (in^2)	6.5310

	Initial	Final
Tare	**68.29**	
Wet	**205.45**	
Dry	**190.22**	
moisture (%)	12.5	#DIV/0!

Optimum Dry Density, pcf	**109.5**
Optimum Moisture, %	**12.5**
Target Density, pcf	98.6
Actual Dry Density, pcf	100.4
Percentage of Optimum	**91.7**

Actual Volume, ft^3	0.0213
Volume Start of Test, cm3	602.9375
Volume After Consol, cm3	597.2361

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	10
	B =	0

Height before saturation (in)	**0.0489**
Height after saturation (in)	**0.0651**
Δ Hs (in)	0.016
Height after consolidation (in)	**0.0833**
Δ Height after sat. and consol. (in)	0.0344
Average height ΔHc+ΔHs (in)	5.5993
Vo (in^3)	36.7935
ΔVs (in^3)	0.3174
ΔVc (cm^3)	**0.5000**
(in^3)	0.0305
ΔV_T (in^3)	0.3479
Ac (in^2)	6.5090
Volume after consolidation, Vc, (cm^3)	597.2361
Confining Pressure (psi)	**3**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	UF Soil Box
Sample No.:	S-2
Date:	5/20/2010
Test By:	dp
Description:	90% std proctor @ 5 psi confining
	0.006 in/min

Membrane Thickness (in)	0.012
Mass of 2 pore stones, 2 papers & mem. (g)	147.79
Mass of 2 ps, 2fp, 1 mem + sample (g)	1238.95
Mass of sample (g)	1091.16
Mass of sample (lbs)	2.41

Height	Sample + pore stones + papers	Pore Stones & Papers
1	6.1515	0.5405
2	6.1400	0.5300
3	6.2010	0.5305
Average	6.164	0.534
Average Height minus pore stones and filter paper	5.6305	

Diameter (in)	
Top	2.908
Middle	2.909
Bottom	2.909
Average (minus membrane)	2.885
Area (in^2)	6.5355

	Initial	Final
Tare	59.49	
Wet	219.17	
Dry	201.45	
moisture (%)	12.5	#DIV/0!

Optimum Dry Density, pcf	109.5
Optimum Moisture, %	12.5
Target Density, pcf	98.6
Actual Dry Density, pcf	100.4
Percentage of Optimum	**91.7**

Actual Volume, ft^3	0.0213
Volume Start of Test, cm3	603.0166
Volume After Consol, cm3	600.7238

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	10
	B =	0

Height before saturation (in)	0.0481
Height after saturation (in)	0.0487
Δ Hs (in)	0.001
Height after consolidation (in)	0.0537
Δ Height after sat. and consol. (in)	0.0056
Average height ΔHc+ΔHs (in)	5.6249
Vo (in^3)	36.7983
ΔVs (in^3)	0.0118
ΔVc (cm^3)	2.1
(in^3)	0.1281
ΔV_T (in^3)	0.1399
Ac (in^2)	6.5172
Volume after consolidation, Vc, (cm^3)	600.7238
Confining Pressure (psi)	5

Test Notes:

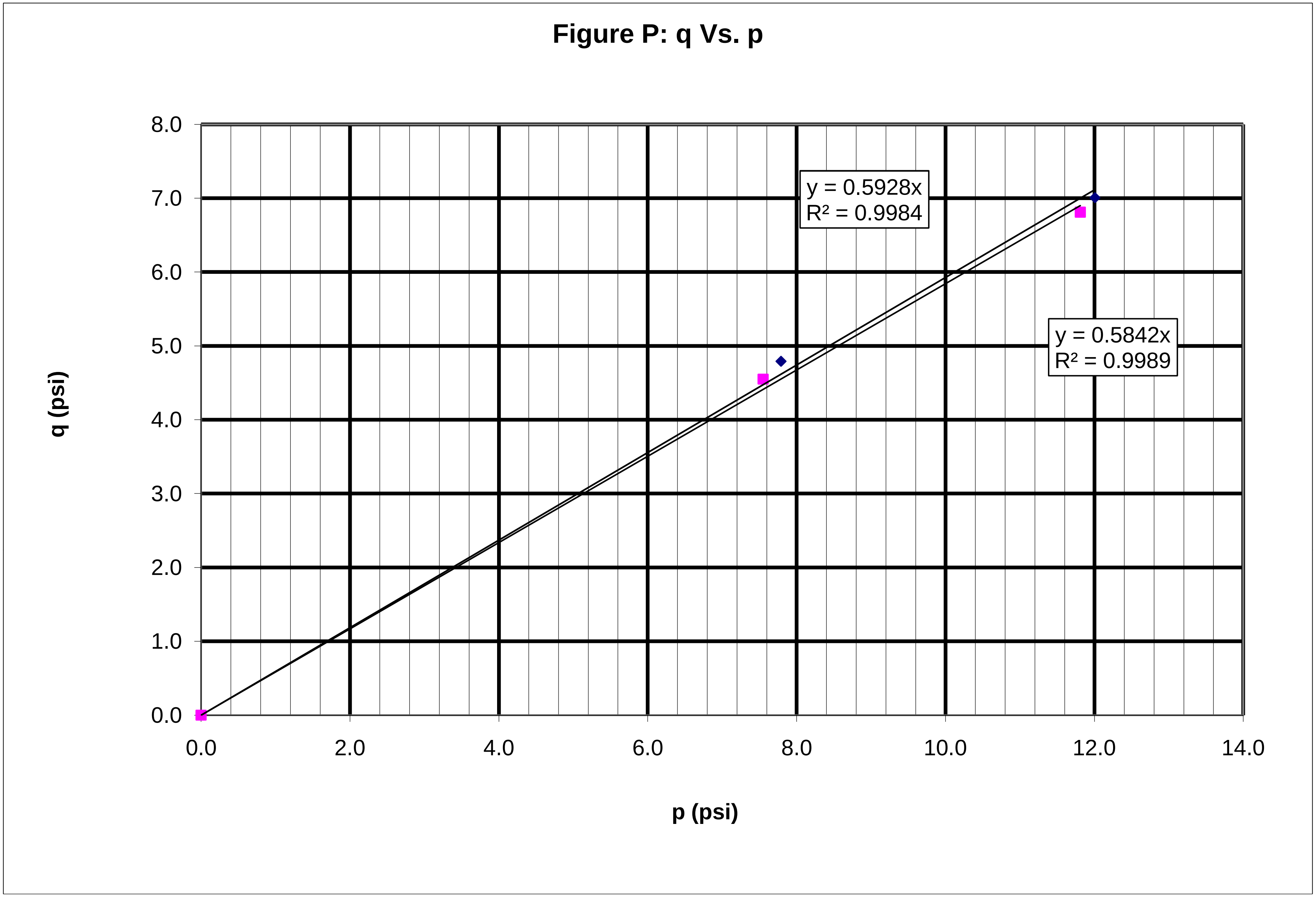


Figure P: q Vs. p
y = 0.5928x
R² = 0.9984
y = 0.5842x
R² = 0.9989
q (psi)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
p (psi)

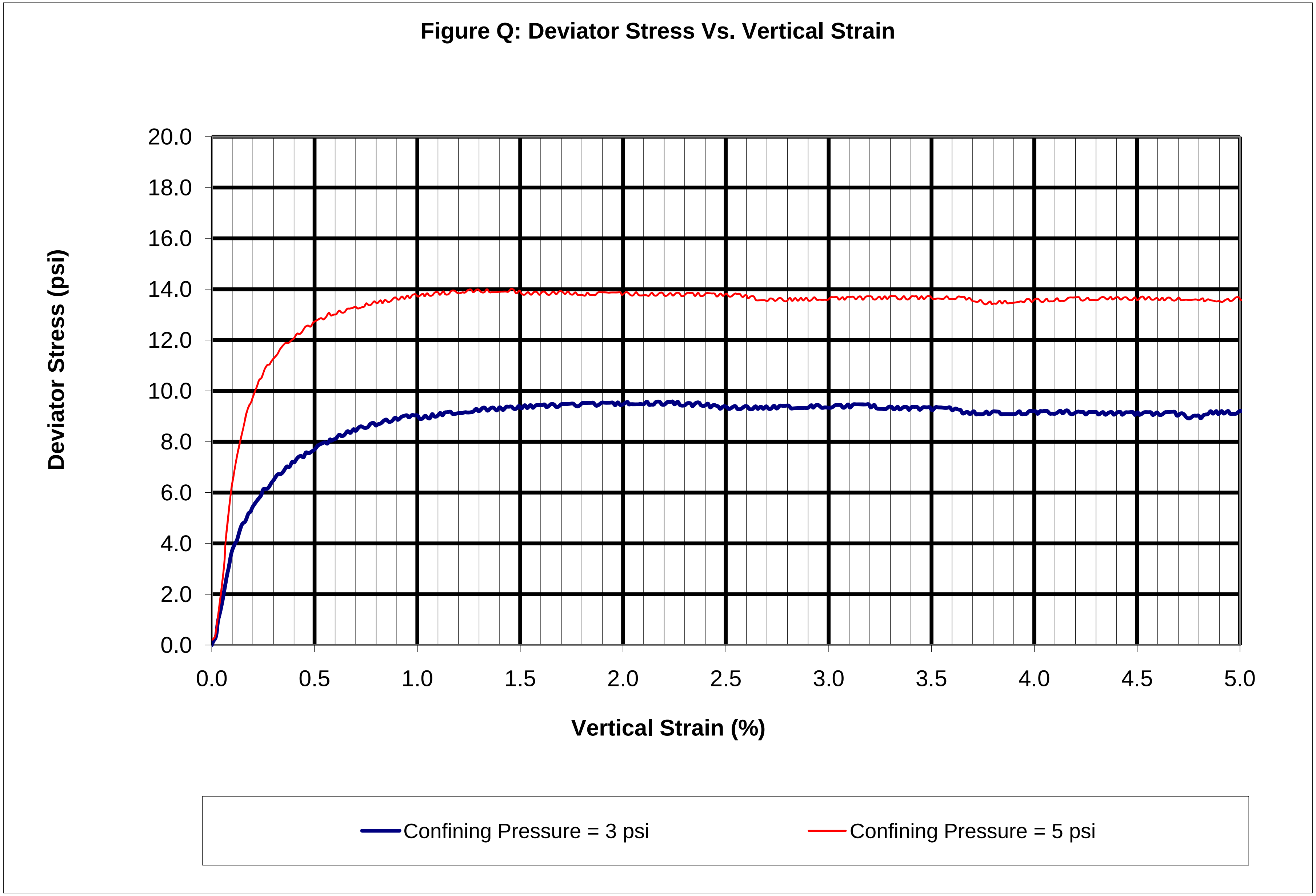


Figure Q: Deviator Stress Vs. Vertical Strain
Deviator Stress (psi)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Vertical Strain (%)
Confining Pressure = 3 psi
Confining Pressure = 5 psi

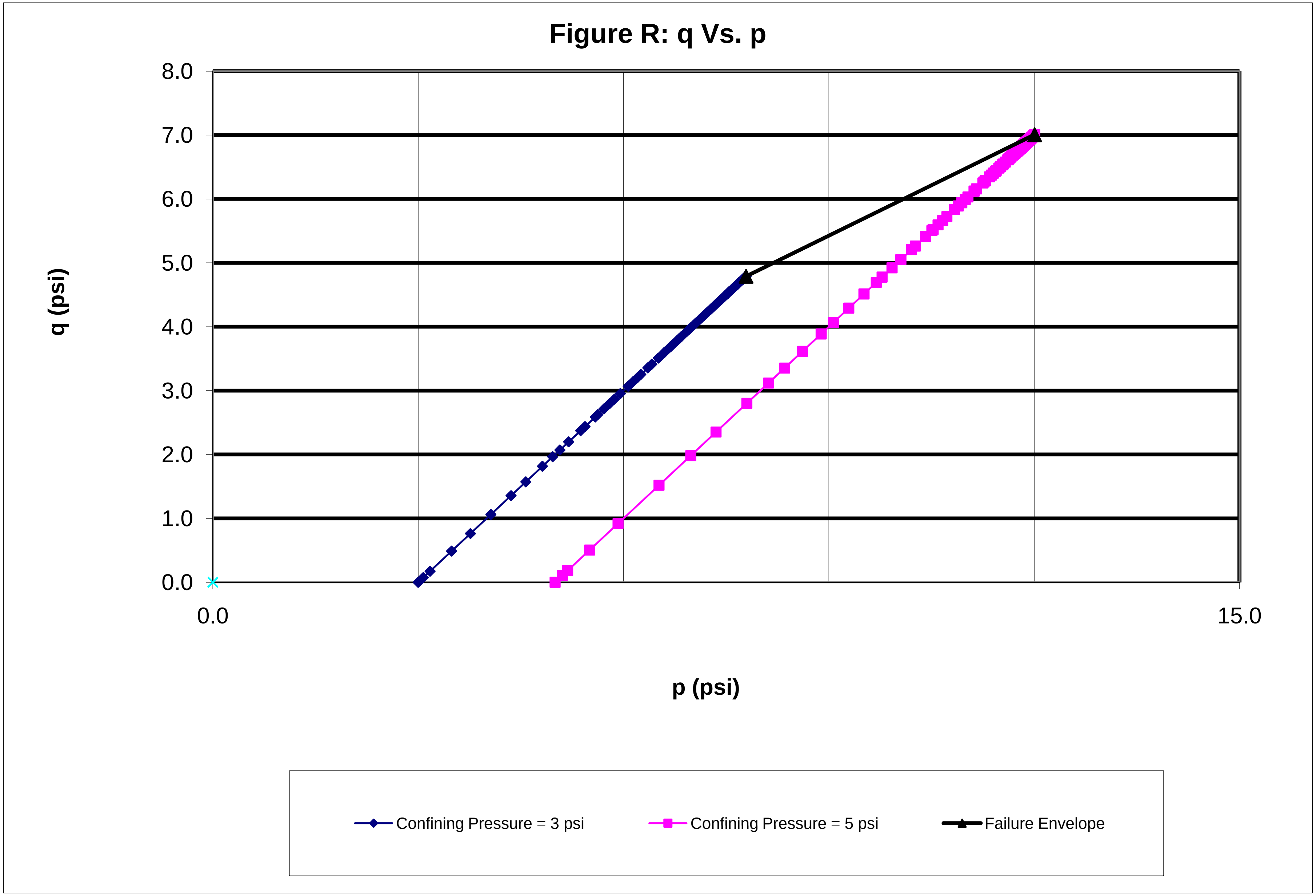


Figure R: q Vs. p
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
q (psi)
0.0
15.0
p (psi)
Confining Pressure = 3 psi
Confining Pressure = 5 psi
Failure Envelope

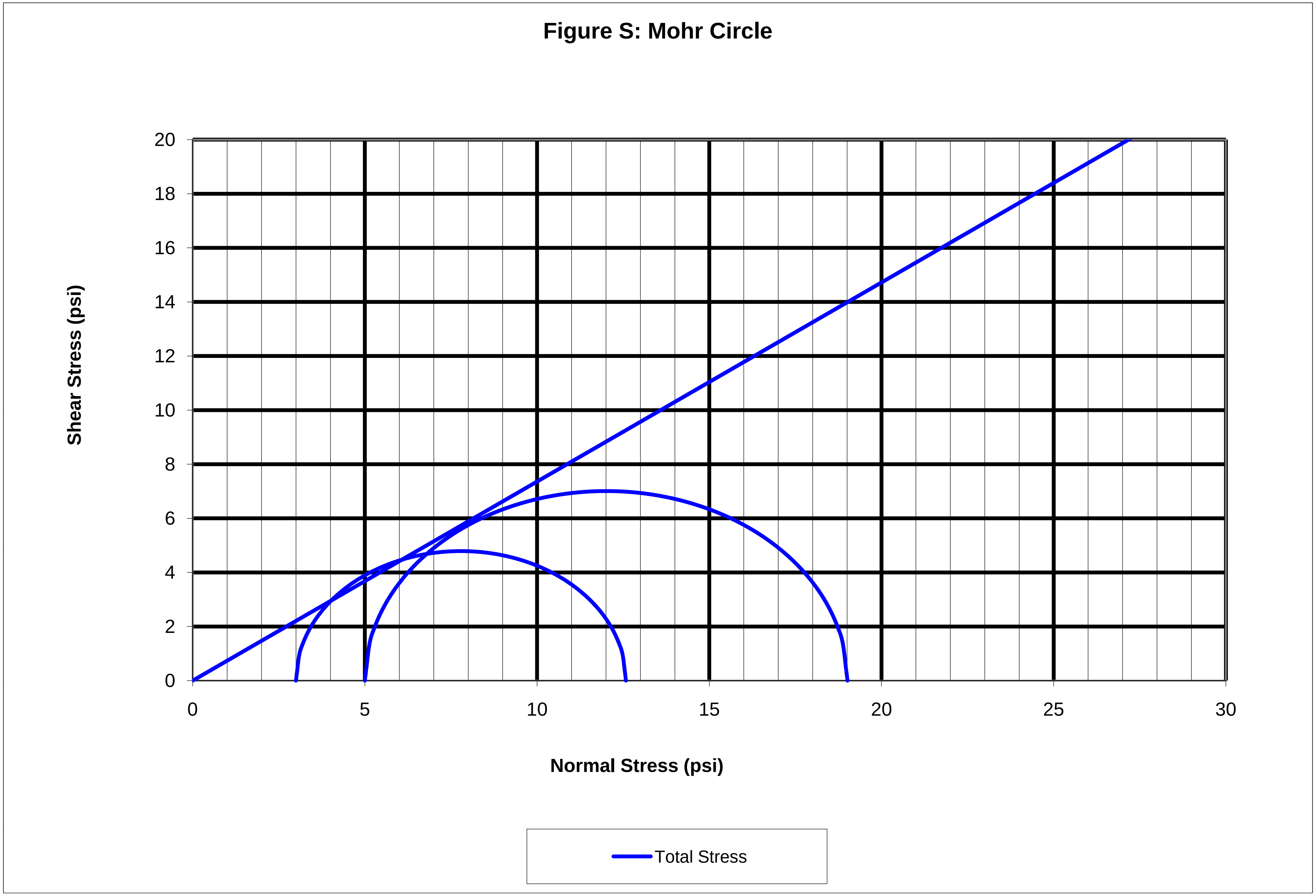


Figure S: Mohr Circle
Shear Stress (psi)
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
Normal Stress (psi)
Total Stress

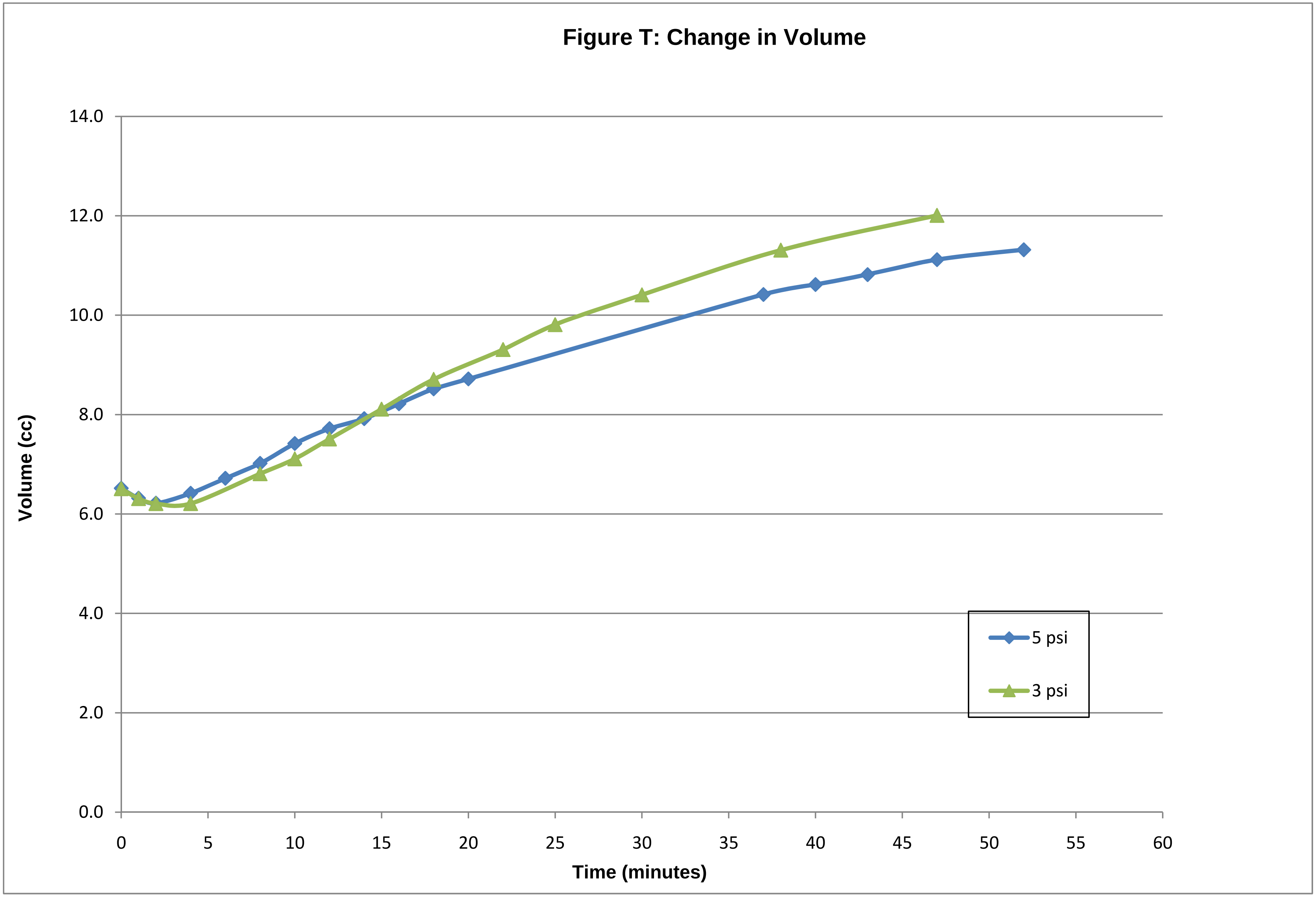


Figure T: Change in Volume
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Volume (cc)
0
5
10
15
20
25
30
35
40
45
50
55
60
Time (minutes)
5 psi
3 psi

Appendix G

Soil Saturation Calculations

Calculation of Soil Dry Unit Weight and Soil Moisture Content...

Triaxial Test 23421

Actual Dry Unit Weights:

$\gamma_{d1} := 113.1$ (pcf)

$\gamma_{d2} := 109.4$ (pcf)

$\gamma_{d3} := 109.2$ (pcf)

Triaxial Test 23422

Actual Dry Unit Weights:

$\gamma_{d4} := 112.8$ (pcf)

$\gamma_{d5} := 112.1$ (pcf)

$\gamma_{d6} := 107.3$ (pcf)

Triaxial Test 23423

Actual Dry Unit Weights:

$\gamma_{d7} := 110.7$ (pcf)

$\gamma_{d8} := 110.4$ (pcf)

$\gamma_{d9} := 111.9$ (pcf)

$$\gamma_{davg1} := \frac{\gamma_{d1} + \gamma_{d2} + \gamma_{d3}}{3} \qquad \gamma_{davg1} = 110.6 \quad \text{(pcf)}$$

$$\gamma_{davg2} := \frac{\gamma_{d4} + \gamma_{d5} + \gamma_{d6}}{3} \qquad \gamma_{davg2} = 110.7 \quad \text{(pcf)}$$

$$\gamma_{davg3} := \frac{\gamma_{d7} + \gamma_{d8} + \gamma_{d9}}{3} \qquad \gamma_{davg3} = 111.0 \quad \text{(pcf)}$$

$$\gamma_{davg} := \frac{\gamma_{davg1} + \gamma_{davg2} + \gamma_{davg3}}{3} \qquad \gamma_{davg} = 110.8 \quad \text{(pcf)}$$

$$\gamma_d := \gamma_{davg} = 110.8 \quad \text{(pcf)}$$

Moisture Content, *w*, obtained from nuclear density test results...

$w := 3.0$ (%)

Soil Box Dimensions...

$L_{SB} := 20$ (ft)

$W := 10$ (ft)

$H := 8$ (ft)

Pipe Dimensions...

$D := 3$ (ft)

$L_P := 10$ (ft)

Soil Box Volume...

$$V_{SB} := L_{SB} \cdot W \cdot H = 1600.0 \quad (\text{ft}^3)$$

Pipe Volume...

$$V_P := 2\frac{\pi \cdot D^2}{4} \cdot L_P = 141.4 \quad (\text{ft}^3)$$

Calculation of Soil Parameters...

Total Volume of Soil... $V := V_{SB} - V_P = 1458.6$ (ft^3)

Weight of Solids... $\gamma_d := \frac{W_S}{V}$ $W_S := \gamma_d \cdot V$ $W_S = 161567.4$ (lbs)

Weight of Water... $w := \frac{W_W}{W_S} \cdot 100$ $W_W := \frac{w \cdot W_S}{100}$ $W_W = 4847.0$ (lbs)

Volume of Water... $\gamma_W := 62.4$ (pcf)

$\gamma_W := \frac{W_W}{V_W}$ $V_W := \frac{W_W}{\gamma_W}$ $V_W = 77.7$ (ft^3)

Total Unit Weight... $\gamma := \frac{W}{V}$ $\gamma := \frac{W_S + W_W}{V}$ $\gamma = 114.1$ (pcf)

Specific Gravity of Solids... Assume G_S = 2.72... $G_S := 2.72$

Volume of Solids... $G_S := \frac{W_S}{V_S \cdot \gamma_W}$ $V_S := \frac{W_S}{G_S \cdot \gamma_W}$ $V_S = 951.9$ (ft^3)

Void Ratio... $e := \frac{V_V}{V_S}$ $e := \frac{V - V_S}{V_S}$ $e = 0.532$

Volume of Voids... $e := \frac{V_V}{V_S}$ $V_V := e \cdot V_S$ $V_V = 506.7$ (ft^3)

Volume of Air... $V_A := V_V - V_W$ $V_A = 429.0$ (ft^3)

Amount of water needed to saturate the soil is equal to the volume of air.

Convert volume of air (water needed) to gallons...

$V_{WN} := V_A \cdot 7.48051948 = 3209.4$ (gallons)

As per field experiment with lawn sprinkler, it took 1 minute and 55 seconds to fill a 3 gallon bucket with water.

$t := 1 + \frac{55}{60} = 1.92$ (min)

Time needed to saturate soil...

$T := V_{WN} \cdot \frac{t}{3}$ $T = 2050.4$ (min)

$T := \frac{T}{60}$ $T = 34.2$ (hours)