5.0

Direct Shear Lab

Joseph Bell

April 6, 2007

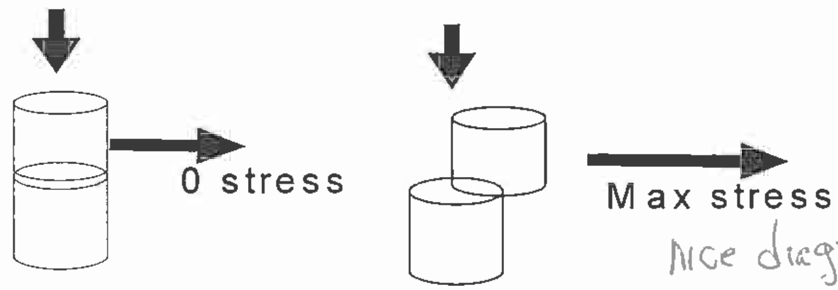
Lab assistance provided by Tanner Simens

Introduction

Every solid material fails internally under some amount of stress. It is imperative to know this point of failure when dealing with a soil that will serve as a foundational unit for construction. Equally important is to be able to compare soils and their limitations. Typically a triaxial test is employed to perform such analysis. However, there are alternate methods that achieve similar results at a fraction of the cost. Such alternative methods were used to analyze a Millrock and Endcav soil series at the James Madison Geology and Environmental Science Soil Laboratory. Our tests were conducted by observing the relationship between stresses normal to a soil and perpendicular shear stresses adjusted to inducing failure. Quantitative analysis of test results allowed us to identify which of the two soils were stronger; what aspect of each soil provided its strength; and which soil was better fit for engineering applications.

Procedure

As mentioned above we employed the relationship between stresses normal to a cylinder of soil to that of perpendicular shear stresses adjusted to induce failure. This simplified illustration shows how results were achieved.



Nice diagram

Lower cylinder was mounted down and secured as a hydraulic crank provided shear stress to act against normal stresses. Our apparatus has a mounted gage to identify max shear stress as well as setscrews, set at 1mm depth, which prevented contact between the two brass cylinders.

From observing gage readings and knowing normal stress weights we were able to construct a Mohr's failure envelope. A step-by-step instruction on how to reproduce tests performed is included at the back of this report, also included are technician notes annotated throughout the process. Table 1-1 in the results section contains an organized layout of these notes and calculations.

Limitations and Possible Error

There are many opportunities for error to enter the test trials, but after scrutinizing the graphs and Mohr envelopes I feel there was little error introduced during our analyses. If accuracy is desired to a fraction of a whole number then possible errors could be the result of:

1. Soils weight
2. Soil moisture: Possible evaporation could influence later trails
3. Rate of induced shear stress: Technician could have cranked too rapid or too slow
4. Soil may have been torqued at an off angle
5. A general lack of formularization with testing procedure and equipment: Technicians may have used initial results without practice and proficiency.
6. Data could have been calculated and graphed improperly

Results

Table 1-1 includes raw gage readings, converted gage reading, calculated PSI values as well as weights for normal stress. In addition, amounts of deionized water added to each soil are annotated. Table is labeled and attached toward end of report.

Calculations

Table 1-2 contains values of quantitative analysis preformed on each soil. Following this table we provide an assessment and comparison of the Millrock and Endcav soils.

Millrock	$\sigma_n = 2$	**Endcav**
8.9 PSI	σ_1	8.4 PSI
3.25 PSI	Γ	4.3 PSI
.6 PSI	σ_3	-.9 PSI
66 degrees	θ	57 °
1.1 PSI	Cohesion	3.25 PSI
39 degrees	φ	26 °

Table 1-2

Values obtained from constructed Mohr Envelopes based on observed and calculated data
For Millrock Series information view graph 1-1 located toward end of lab.
For Endcav Series information view graph 1-2 located toward end of lab.

Soil Comparisons

- **Strength:**
  For Normal stresses below 5-PSI we found the Endcav to have a greater amount of strength. After 5-PSI Endcav strength remains nearly constant.
  Though not as strong as the Endcav under stresses less than 5-PSI, the Millrock soil tested has the ability to handle far greater stresses above 5-PSI. Reasons for these disparities are provided in the following bullets.

Soil Comparisons continued

- **Source of Strength:**
  The Endcav has a higher clay composition, which provides it with an increased level of cohesion as shown in the above table and plotted Mohr Envelope.
  The Millrock is sandier and gets its strength from grain-to-grain contact. We can see this by a lower cohesion value, lower initial failure values (below 5-PSI) and a large increase in bearing ability as normal stress increases in excess of 5-PSI.

- **Engineering Applications:**
  As mentioned above the Endcav has a higher clay composition allowing for greater load bearing ability under lower stresses. The Endcav can handle building construction but not without limitations. Clay concentrations at site locations need to be accounted for because an Endcav soil could experience shrink swell behavior as a result of water level fluctuations. Such fluctuations are capable of inducing differential stresses on constructed structures. Poor drainage is another problem associated with areas of higher clay concentrations. Endcav is best suited for housing and farm use.
  Millrock soils have do not have any limitations with regards to engineering applications. Its low initial strength can easily be negated by compaction. Millrock soil will be well drained and consistent, with regards to settling, as a result of having a higher sand concentration.

Conclusion

Triaxial testing is considered the industry standard for defining the engineering properties of a soil. This lab has displayed a viable alternative for testing a soil for such properties at a fraction of the cost. (As a caution, it must be noted that our testing procedure may not be as efficient or accurate with regards to multiple test reproductions as the triaxial testing procedure.) Through inducing failure of a soil by increasing shear stress, under multiple known normal stress conditions, we were able to construct a Mohr Envelope of failure for Millrock and Endcav soil series. From these constructions we then calculated such values as σ_1, γ, σ_3, θ, Cohesion and φ for each respective soil. Such analyses allows for soil comparison and evaluation which in turn lets us chose which soil is best suited for the engineering task at hand.

Table 1-1

diameter 2.5 inches

Preweighed plastic beaker .175 lbs. Added .114 lbs of deiononized **water,** which is 12% of Millrock **1.2 lbs.** soil.

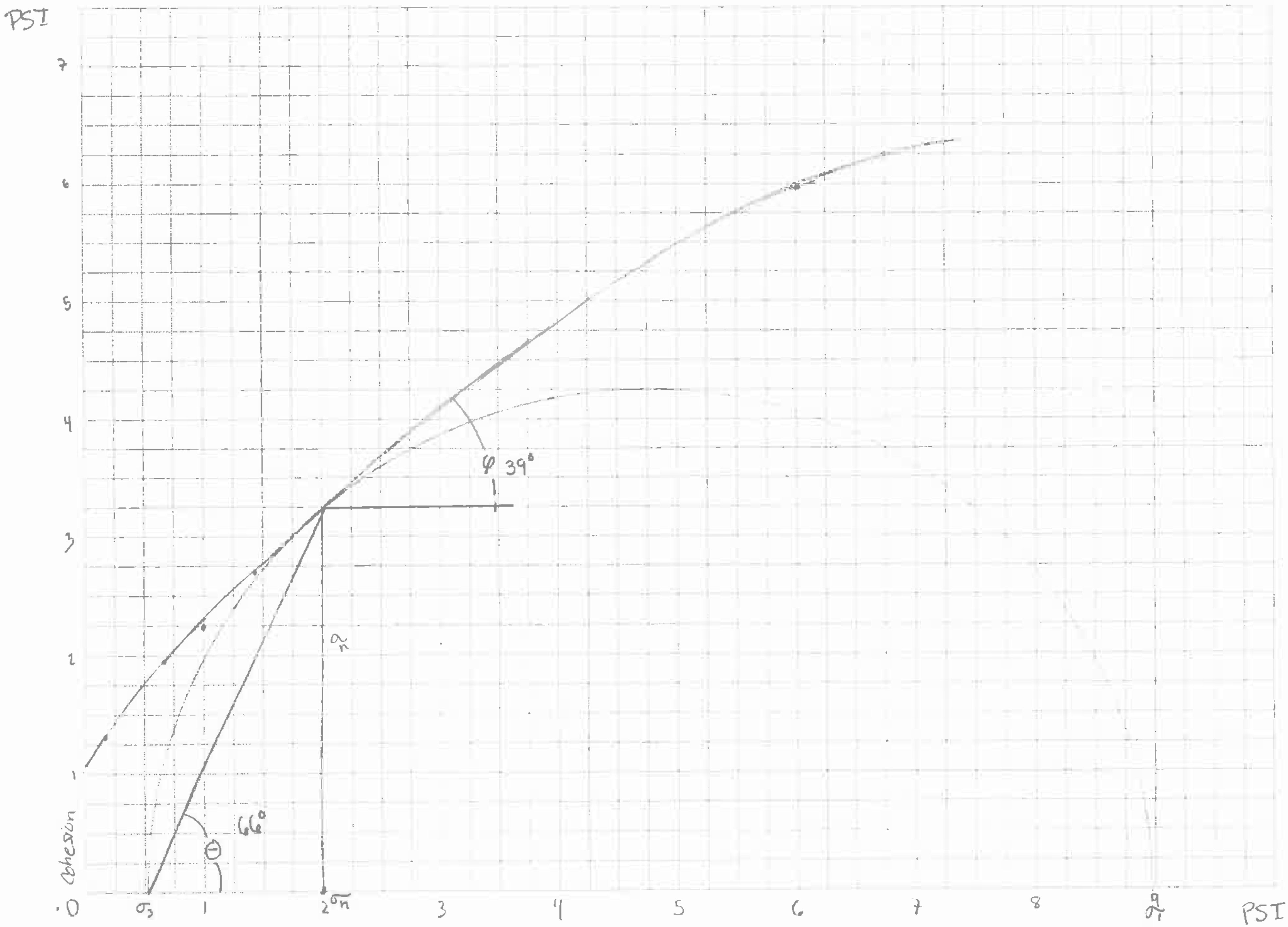
Millrock	normal stress	normal stress per in^2	gage reading at zero	gage reading at failure	absolute gage movement	conversion to gage to lb force	area inches^2	lbs/in^2
run 1	0.995	0.20	87	69	18	6.624	4.91	1.35
run 2	3.445	0.70	87.5	62	25.5	9.384	4.91	1.91
run 3	7	1.43	87	50.5	36.5	13.432	4.91	2.74
run 4	5	1.02	92	62	30	11.04	4.91	2.25
run 5	29.59	6.03	90	11	79	29.072	4.91	5.93

Preweighed plastic beaker .175 **lbs. Added .228** lbs of deiononized water, **which is 24% of Endcav** 1.2 **lbs. soil.**

Endcav		0.00			0	0	4.91	0.00
run 1	4.59	0.94	88	40	48	17.664	4.91	3.60
run 2	14.59	2.97	87	24	63	23.184	4.91	4.73
run 3	29.59	6.03	78	11	67	24.656	4.91	5.03
run 1a	0.995	0.20	92	48	44	16.192	4.91	3.30

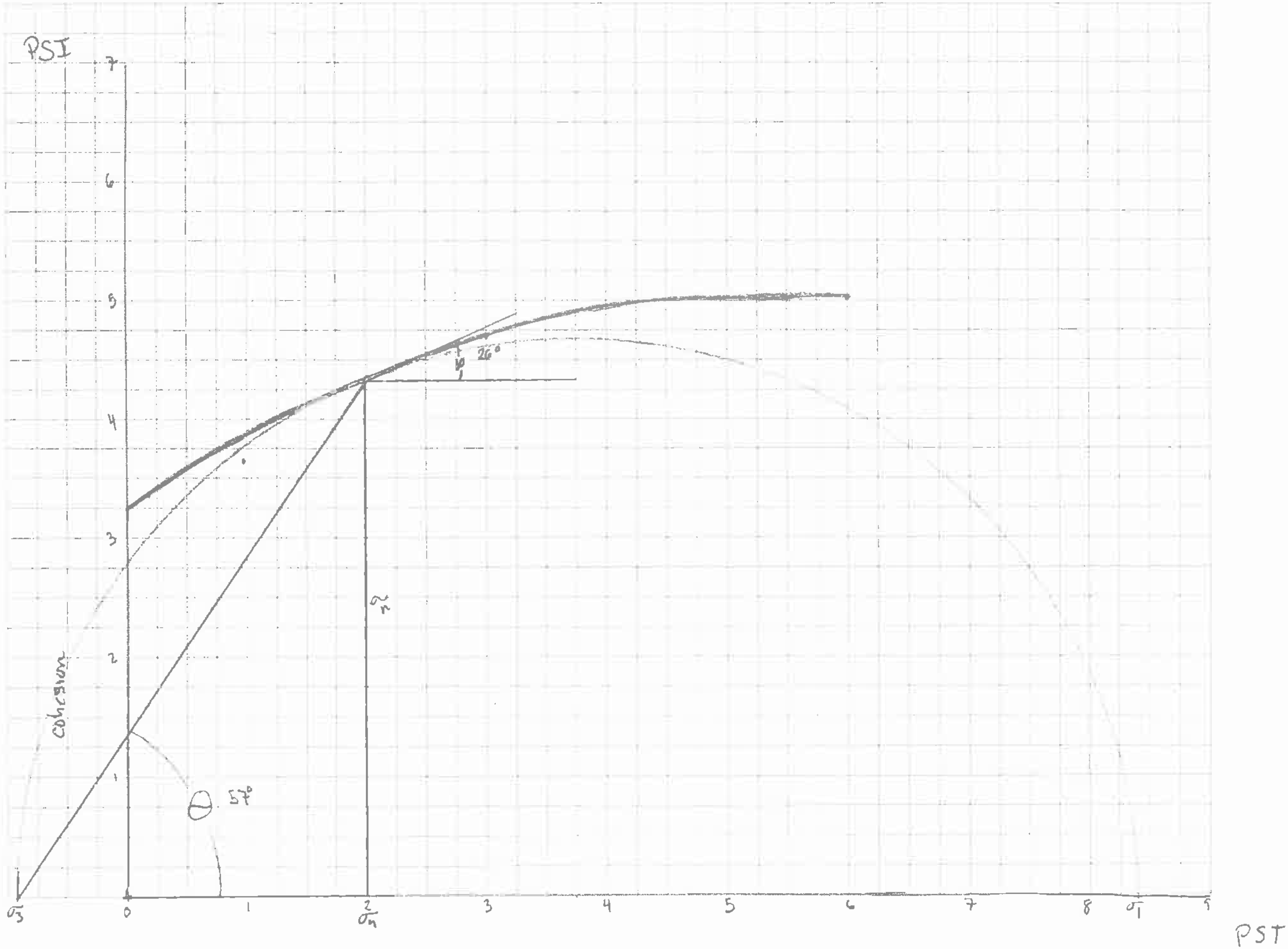
Bell, Joseph

Millrock Graph 1-1



Bell, Joseph

EndCav Graph 1-2



DIRECT SHEAR EXERCISE

I. In Lab

A. Phase I

Plastic Beaker .75 lbs

1. Weight out ≈ 1.2 lb of dry Endcav and Millrock soils provided and measure area of shear chamber in in^2.

2. Disaggregate soil in mortar and pestle (do not crush grains). Work under chemical hood.

3. Add H_2O: 24% to Endcav 24% of 1.2 lbs = .288 lbs
   12% to Millrock 12% of 1.2 lbs = .144 lbs more req.

   .175 .144 .319 .175 .144 .219

4. Add H_2O to soil and mix thoroughly. Keep soil covered to prevent evaporation.

5. Place one brass weight in bottom of shear chamber with fins at ⊥ to stress direction. Adjust the three spacing thumb screws in top ring to extend 1 mm. Add top ring and secure with brass rods.

6. Fill chamber to top with moist soil compacting gently with fingers. Cap soil container to prevent evaporation.

run I (3.445 lbs − 2.45 lbs)

7. Compact to 50 inch pounds using torque wrench. Add weight to soil to approximate 1 lb/in^2. (Weights of top brass plate and weight of assembly must be included).

1 lbs @ 87 start 69 finish

8. Back off the three spacing thumb screws and **remove brass rods** before shearing.

9. Record meter reading.

10. Apply stress at rate of one handle turn/1 second.

run II 3.445 @ 873 62.

11. Record maximum meter reading during shear (one unit on meter = 0.368 lb of force).

B. Phase II

1. Remove soil from chamber. **Note:** Use allen wrench to remove bottom half of shear chamber.

2. Clean and replace shear chamber.

run III 2 lbs 87 50

run IV for Millrock @ 4.59 + 25 lbs @ 29.59 lbs on Gage @ 90 Stop @ 11

3. Follow steps 5, 6 and 7 of Phase I again.

4. Add weights to reach approximately 3 lb/in^2.

5. Back off the set screws and **remove brass rods** before shearing.

6. Follow steps 9, 10, 11 of Phase I.

After 1.765

C. Phase III

run V millrock 14.59 lbs Gage 89 End 39

1. Follow previous steps but add weight to approximately 6 lb/in^2.

II. Data Interpretation

A. Construct a Mohrs Envelope

1. Lay out X-Y axes with a scale of 1 unit of length = 1 pound per in^2.
2. Plot the 3 points resulting from σ_n and Υ determined in lab.
3. Construct a Mohr's envelope.

B. **Using the envelope – plot a circle** assuming a σ_n of 2 lb/in^2. Based on this circle report the following in lb/in^2.

1. σ_1
2. Υ
3. σ_n
4. θ angle
5. cohesion
6. φ

C. **Compare the two soils:**

1. Strength
2. Source of strength
3. Engineering applications