CAEE 211
Geology Laboratory 6
Lab Date: 29 July 2016

Rock Mechanics and Seismology Laboratory

Due Date: 5 August 2016
Attendance (based on signing): 30 points

Submitting Student Name: ______________________

Members of laboratory group (no more than three):
____

Rock Mechanics

1) During a site investigation, a boring was advanced to a depth of 30 ft (9.1 m) at which point rock was encountered. The ground water table (GWT) was encountered at 30 ft (9.1m), the depth of rock, during the investigation. The engineering geologist decided to advance the boring into the rock by drilling to a depth of 16.4 ft (5 m). The recovered rock cores were positioned in a rock core box from top down as shown in Figure 1. The beginning of the rock core was located in the upper left hand corner of the box and each following piece of the core was placed from left to right on each row with increasing depth. Each row of the rock core box represents a depth of the 3.2 ft (1 m) of drilling depth, therefore the total drill depth that can be contained in the box is 16.4 ft (5 m)

Figure 1 – Recovered Rock Cores

Using Figure 1 determine the amount of recovered rock in pieces of 10 cm or longer in length. Determine the Rock Quality Designation (RQD) for the recovered rock cores using Equation 1. Using Table 7.7 provide a description of rock quality.

$$RQD = \frac{\sum of\ the\ rock\ core\ lengths\ greater\ the\ 10\ cm}{\sum of\ the\ total\ drill\ depth}\ x\ 100\% \ldots\ \ Eq\ 1$$

Total Amount of Recovered Rock = ___________ (ft) ________ (m)

RQD = ___________

Table 7.7 Rock Quality Designation (RQD)

RQD (%)	Description of Rock Quality
0–25	Very poor
25–50	Poor
50–75	Fair
75–90	Good
90–100	Excellent

Description of Rock Quality = ___________

2) The profile of the soil stratum was developed from the boring during the site investigation is shown in Figure 2. Calculate the existing vertical stress (σ_v) on the rock bed (at a depth of 30 ft) using Equation 2:

$$\sigma_v = \gamma_a h_a + \gamma_b h_b + \gamma_c h_c \ \ldots\ Eq\ 2$$

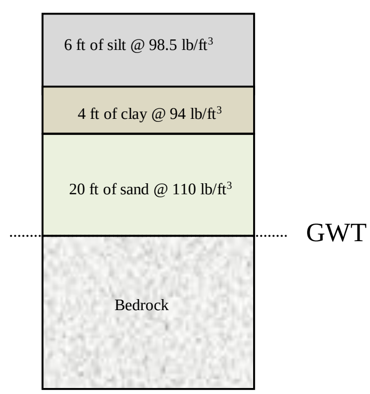

Figure 2 – Soil Profile

Existing Vertical Stress (σ_v) = ___________ (psf) ________ (kg/cm^2)

3) From the recovered rock cores, two unconfined compression tests were conducted on test specimens, which were 2 in. in diameter and 4 in. long. The load verses displacement data for the two tests are presented in Tables 1 (sandstone) and 2 (gneiss).

Table 1 – Unconfined Compression Data for Sandstone

Axial Deformation (in)	Compressive Load (lb)
0	0
0.0012	3140
0.0024	6280
0.0044	12560
0.0064	18840
0.0084	25120
0.0112	31400
0.0144	32970
0.016	31400

Table 2 – Unconfined Compression Data for Gneiss

Axial Deformation (in)	Compressive Load (lb)
0	0
0.001332	7534.964
0.002664	15069.93
0.004884	30139.86
0.007104	45209.78
0.009324	60279.71
0.012432	75349.64
0.015984	79117.12
0.01776	75349.64

Develop the compressive stress (σ_a in psi) verses axial strain (ε in in. /in.) plots for both tests using equations 3, 4 and 5. Present these plots in the same graph for comparison. Determine the ultimate unconfined compressive strength (σ_a) for each rock type. Calculate the Modulus of Elasticity (E_{t50}) at 50% of σ_a using the corresponding strain at 50% of σ_a and Modulus Ratio (M_r) for each rock type using equations 6 and 7. Using Tables 7.3, 7.4, and Figure 7.28 to determine the Strength Classification of the Intact Rock, the Modulus of Elasticity Classification of the Intact Rock and plot the M_r for each rock type.

$$Area = \pi r^2 \ \ldots \ Eq\ 3$$

$$\sigma_a = \frac{Force}{Area} \ \ldots \ Eq\ 4$$

$$\epsilon = \frac{change\ in\ length}{initial\ length} \ldots \ Eq\ 5$$

$$E_{t50} = \frac{\sigma_{a\ 50\%}}{\epsilon} \ \ldots \ Eq\ 6$$

$$M_r = E_{t50}/\sigma_a \ \ldots \ Eq\ 7$$

Unconfined Compressive strength (σ_a) of sandstone = ________ (psi) ________ (kg/cm^2)

Unconfined Compressive strength (σ_a) of gneiss = ________ (psi) ________ (kg/cm^2)

Modulus of Elasticity (E_{t50}) of sandstone = ________ (psi) ________ (kg/cm^2)

Modulus of Elasticity (E_{t50}) of gneiss = ________ (psi) ________ (kg/cm^2)

Modulus Ratio (M_r) of sandstone = ___________

Modulus Ratio (M_r) of gneiss = ___________

Do the Modulus Ratios correlate well with respective figures in your textbook for the rock types?

____

Table 7.3 Strength Classification of Intact Rock

Class	Description	Unconfined Compressive Strength (kg/cm^2)
A	Very high strength	>2250
B	High strength	1125–2250
C	Medium strength	562–1125
D	Low strength	281–562
E	Very low strength	<281

Table 7.4 Modulus of Elasticity Classification of Rocks

Description	$E_{t_{50}}$ (kg/cm^2 × 10^5)
Very stiff	8–16
Stiff	4–8
Medium stiffness	2–4
Low stiffness	1–2
Yielding	0.5–1
Highly yielding	0.25–0.5

Strength Classification of the Intact Rock of sandstone = ______________________

Strength Classification of the Intact Rock of gneiss = ______________________

Modulus of Elasticity Classification of the Intact Rock of sandstone = __________________

Modulus of Elasticity Classification of the Intact Rock of gneiss = __________________

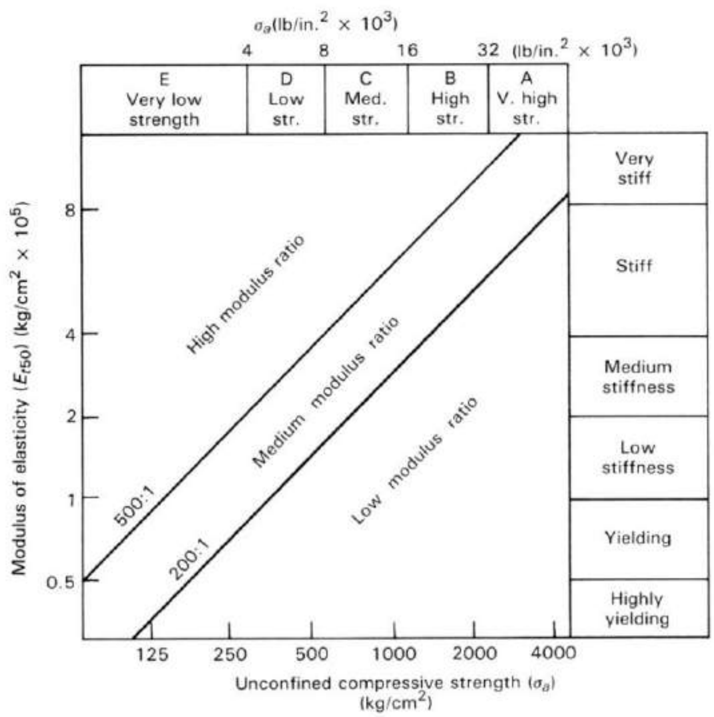

Figure 7.28 – Classification of Intact Rock

4) Additional triaxial testing was conducted on the gneiss. Three triaxial tests were performed on intact specimens of the gneiss at confining pressures of 1000, 2000, and 3000 psi (70.3, 140.4, and 210.9 kg/cm^2). The test data for the three triaxial tests are presented in Figure 3.

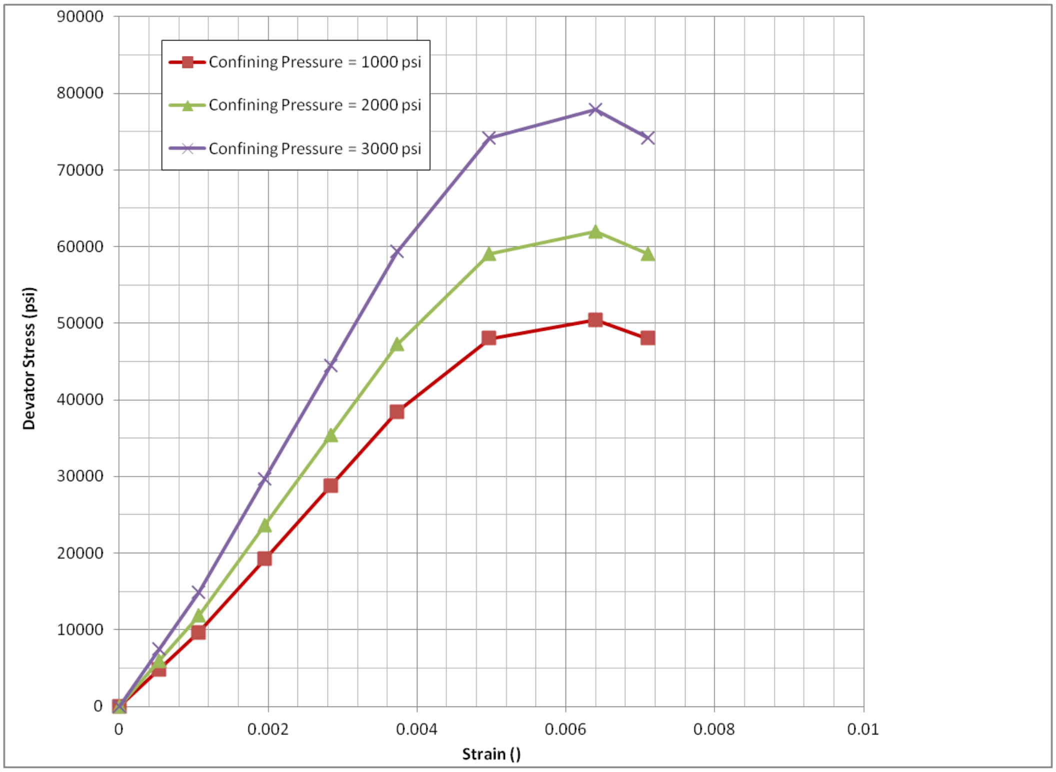

Figure 3 – Triaxial Compression Tests on Intact Specimens of Gneiss

Develop the Mohr Circles for each of the three tests using equations 8, 9 and 10. Determine the cohesion (c) and friction angle (Φ) that best fits the test data for the gneiss as defined by equation 11.

$$\sigma_3 = minor\ principal\ stress\ \ ...\ \ Eq\ 8$$

$$\sigma_1 = major\ principal\ stress = \sigma_3 + \Delta P\ \ ...Eq\ 9$$

$$\Delta P = deviator\ stress\ \ ...\ \ Eq\ 10$$

$$\tau = c + \sigma \tan \Phi\ \ ...Eq\ 11$$

Cohesion (C) of gneiss = _______________ (psi) _________ (kg/cm^2)

Friction Angle (Φ) of gneiss = _______________ (°)

Using equation 12 calculate the unconfined compressive strength (σ_a) for the gneiss.

$$\sigma_a = 2\,C\ \tan\left(45 + \frac{\Phi}{2}\right)\ \ ....\ Eq\ 12$$

Unconfined compressive strength (σ_a) of gneiss = ______________ (psi) ________ (kg/cm^2)

How does this σ_a compare to the actual unconfined compression test on the gneiss?

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Knowing that the tensile strength of rock is typically 5 to 10% of σ_a, estimate the tensile strength (T_0) of the gneiss.

Tensile strength (T_0) of gneiss = ______________ (psi) ________ (kg/cm^2)

5) Using the an RQD value calculated from Part 1 and the Unconfined Compressive Strength determined from Part 3 for the gneiss determine the Rock Mass Rating (RMR) for a tunnel which is to be excavated 50 ft (15.2 m) below the ground surface in the bedrock using the following information. The spacing of the discontinuities were found to be 380 mm apart and consisted of slightly weathered, slightly rough surfaces separated by less 1mm. The rock mass inflow per 10 m of tunnel length was observed to be approximately 70 liter/minute, with considerable outwash of joint fillings. The strike parallel to the tunnel axis had a dip of 35°. Provide the Rock Mass Rating, Class Number, Description, and Meaning of Rock Mass Class using the Tables 7.8 and 7.9 provided in the Appendix.

Rock Mass Rating = ______________________

Class Number = __________________

Description = __________________

Provide the meaning of the Rock Mass Class with regard to stand-up time, cohesion and friction angle of the rock mass.

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Seismology

We will be using a "virtual" seismogram laboratory developed at UCLA for this lab. Go to this website:

http://www.sciencecourseware.com/virtualearthquake/VQuakeExecute.html?x=131&y=80 to get started.

This page has additional explanations and tutorials if you run into a snag:
http://www.sciencecourseware.org/eec/earthquake/

The USGS has an interactive website that discusses the 1906 San Francisco EQ. You can import a few files into Google Earth and look at historic pictures of the earthquakes. It is really neat!
http://earthquake.usgs.gov/earthquakes/

Assignment/Questions

1. What is a seismic wave?

2. What are the two types of seismic waves that seismologists use? Describe each type of wave and the differences between them.

3. What earthquake did you select?

4. Do a screen capture or cut and paste the following results:

   a) Comparison of your location of the Epicenter to the actual location of the Epicenter with the summary table of the results.

   b) The Richter's nomogram with your estimated magnitude.

   c) Virtual Seismologist Certificate of Completion showing your finalized tabulated results. **Please do not e-mail a certificate to the instructor (5 points OFF if you do!!!).**

5. Answer problems 13, 14, 15, 16 and 17 from Chapter 8 from the Kehew textbook.

APPENDIX

Table 7.8 The Geomechanics Classification of Rock Masses (Rock Mass Rating System)
Rating is determined by evaluating factors 1 through 5 and summing. Final value is determined by subtraction of the value of factor 6, if necessary.

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	Parameter		Range of Values						
1	Strength of intact rock mineral	Point-load strength index (MPa)	>10	4–10	2–4	1–2	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength (MPa)	>250	100–250	50–100	25–50	5–25	1–5	<1
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD (%)		90–100	75–90	50–75	25–50	<25		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2 m	0.6–2 m	200–600 mm	60–200 mm	<60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation <1 mm Slightly weathered walls	Slightly rough surfaces Separation <1 mm Highly weathered walls	Slickensided surfaces or Gouge <5 mm thick or Separation 1–5 mm Continuous	Soft gouge >5 mm thick or Separation >5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (L/min)	None	<10	10–25	25–125	>125		
		or	or	or	or	or	or		
		Ratio $\frac{\text{Joint water pressure}}{\text{Major principal stress}}$	0	<0.1	0.1–0.2	0.2–0.5	>0.5		
		or	or	or	or	or	or		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS

Parameter		Range of Values				
Strike and dip orientations of discontinuities		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels and mines	0	−2	−5	−10	−12
	Foundations	0	−2	−7	−15	−25
	Slopes	0	−5	−25	−50	−60

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100–81	80–61	60–41	40–21	<20
Class no.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK MASS CLASSES

Class no.	I	II	III	IV	V
Average stand-up time	20 yr for 15-m span	1 yr for 10-m span	1 wk for 5-m span	10 h for 2.5-m span	30 min for 1-m span
Cohesion of the rock mass (kPa)	>400	300–400	200–300	100–200	<100
Friction angle of the rock mass (deg)	>15	35–45	25–35	15–25	<15

Source: Z. T. Bieniawski, *Engineering Rock Mass Classifications*, New York, Wiley Interscience, © 1989.

Table 7.9 Effect of Discontinuity Strike and Dip Orientations in Tunneling

Strike Perpendicular to Tunnel Axis: Drive with Dip		Drive against Dip	
Dip 45–90	Dip 20–45	Dip 45–90	Dip 20–45
Very favorable	Favorable	Fair	Unfavorable

Strike Parallel to Tunnel Axis		Irrespective of Strike
Dip 20–45	Dip 45–90	Dip 0–20
Fair	Very unfavorable	Fair

Source: Z. T. Bieniawski, *Engineering Rock Mass Classifications*, New York, Wiley Interscience, © 1989.