NATIONAL EXAMINATION – MAY 2011
04-GEOL-A6 SOIL MECHANICS

3 HOURS DURATION

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED-BOOK exam. Only Casio or Sharp approved model calculators are permitted. **A formula sheet and some charts are attached to this exam.**

3. Questions have the values shown. The total value is 100.

4. In the absence of specific parameters required in the formulation and solution of problems, the candidates are expected to exercise sound engineering judgment and to clearly state their assumptions.

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1. Readings obtained with a nuclear densometer on a compacted soil give an average dry density of 2.067 Mg/m^3. For the purpose of verification, an actual sample is collected. The volume of the hole occupied by the sample was 3375 cm^3. The total mass of the sample collected was 7530g. The moisture content of the sample was 13%. The Specific Gravity of the solids is 2.65.

   a. Were the readings from the densometer confirmed by the sample?
   (Value 5)

   b. Using the densometer readings, calculate the void ratio and the degree of saturation of the compacted soil.
   (value 10)

2. Classify the soils of figure Q.2 according to the Unified Soil Classification System. The fines of soil A have a liquid limit of 60% and a plastic limit of 20%, while those of soil B have a liquid limit of 30% and a plastic limit of 20%. In addition to providing the "letter" classification, provide a descriptive name for each soil.
   (value 10)

3. A 5m by 3m rectangular slab applies a load of 10000 kN at the surface of the sand fill illustrated on Figure Q.3.

   a. Calculate the consolidation settlement of the slab 1 year after emplacement.
   (value 15)

   b. Determine the degree of consolidation reached by the clay in the middle of the clay layer after 1 year.

   (value 5)

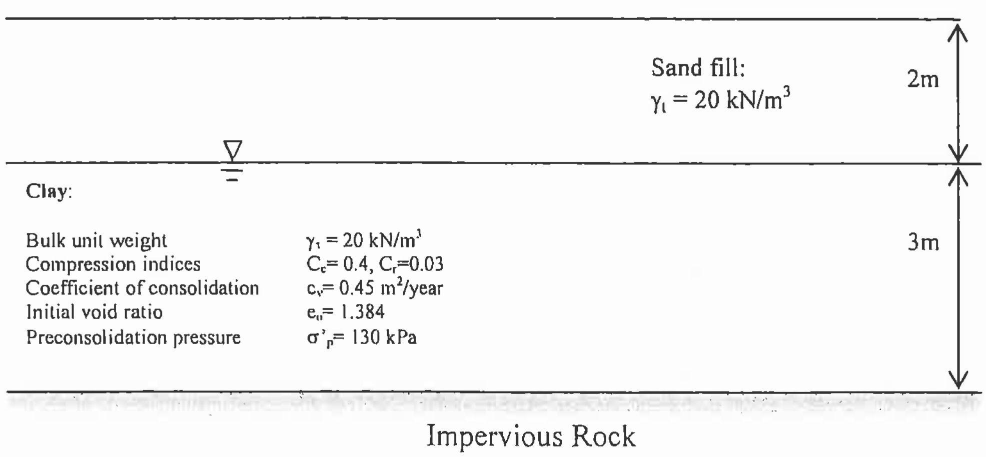


Figure Q.3

4. On figure Q.4, three stress conditions in a small volume of soil are considered. Under scenario A the conditions are "at rest". Under scenario B, a rigid retaining wall is present and will move outward (to the left). Under scenario C, the rigid retaining wall will be forced to move into the soil (to the right). The graph below shows the Mohr circle of stresses existing at rest (A) in the small volume of soil illustrated. The failure envelope of the soil is also shown on the graph.

   a. Assuming that the vertical effective stress remains unchanged, sketch the Mohr circles of the effective stresses when the soil reaches shear failure, under scenarios B and C.

   (value 5)

   b. Write and explain the equations (eg, $\sigma_h' = f(\sigma_v')$) that you would use to calculate the horizontal stress exerted by the soil at any location along the retaining wall, under scenarios B and C.

   (value 5)

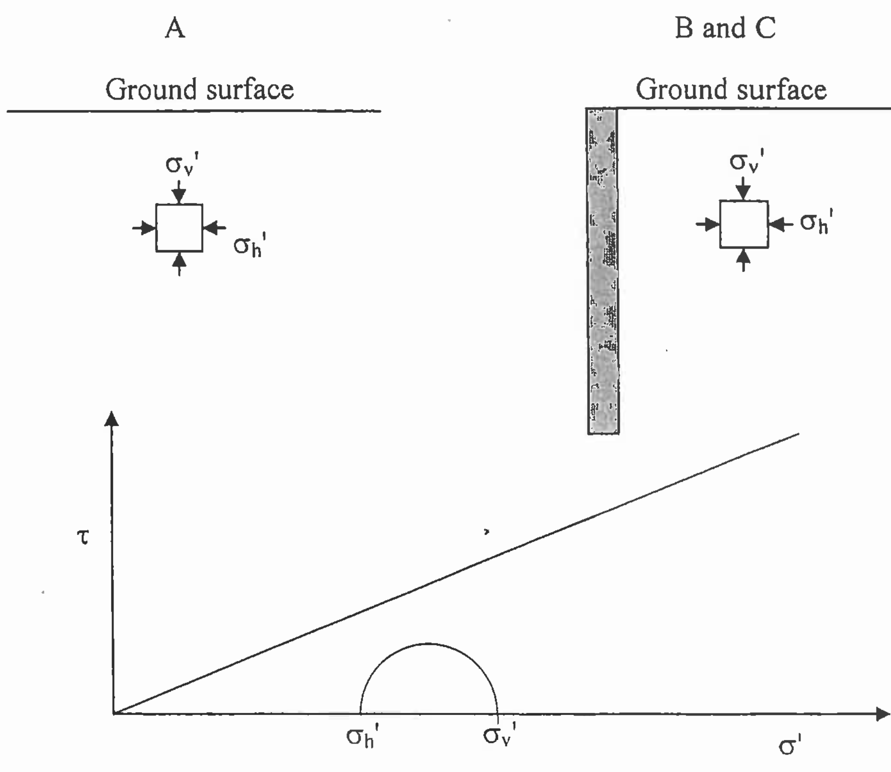


Figure Q.4

5. Fig. Q.5. illustrates a weir under which seepage flow occurs. A partial flownet showing only flow lines is drawn on the figure.

   a. Draw equipotential lines that would reasonably complete the flownet. (Value 5)

   b. Calculate the water pressure at points A, B and C along the base of the weir. (Value 10)

6. Discuss the reasons why excavation walls in clay soils generally lose strength with time and why embankments over clay soils tend to gain strength with time. (Value 10)

7. Describe and explain the behaviour of "sensitive clays" (such as those found in the Ottawa river valley or in Rissa, Norway). (Value 10)

8. Explain the swelling and shrinking of clays and discuss their respective engineering significance. (value 10)

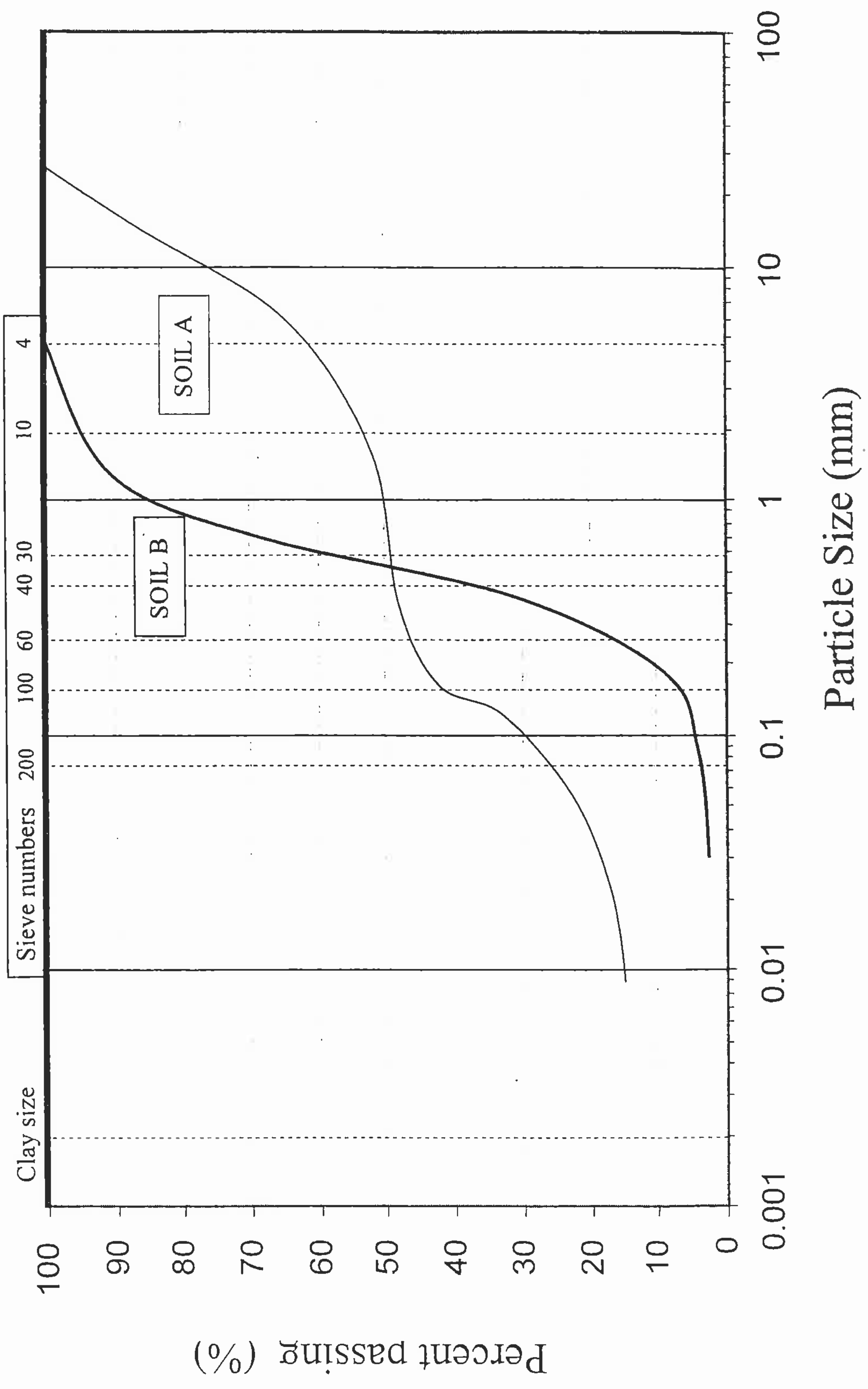

Sieve numbers
4
10
30
40
60
100
200
Clay size
SOIL A
SOIL B
100
10
1
0.1
0.01
0.001
Particle Size (mm)
100
90
80
70
60
50
40
30
20
10
0
Percent passing (%)

Figure Q.2

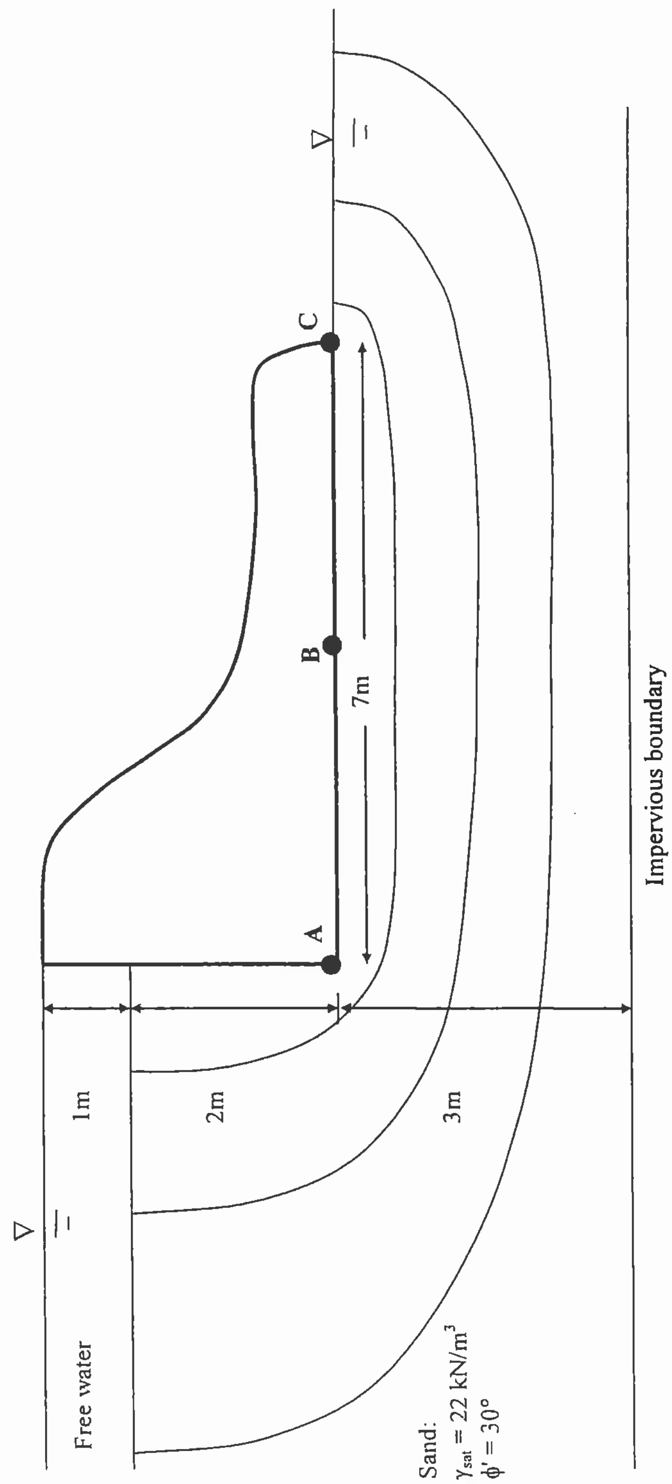
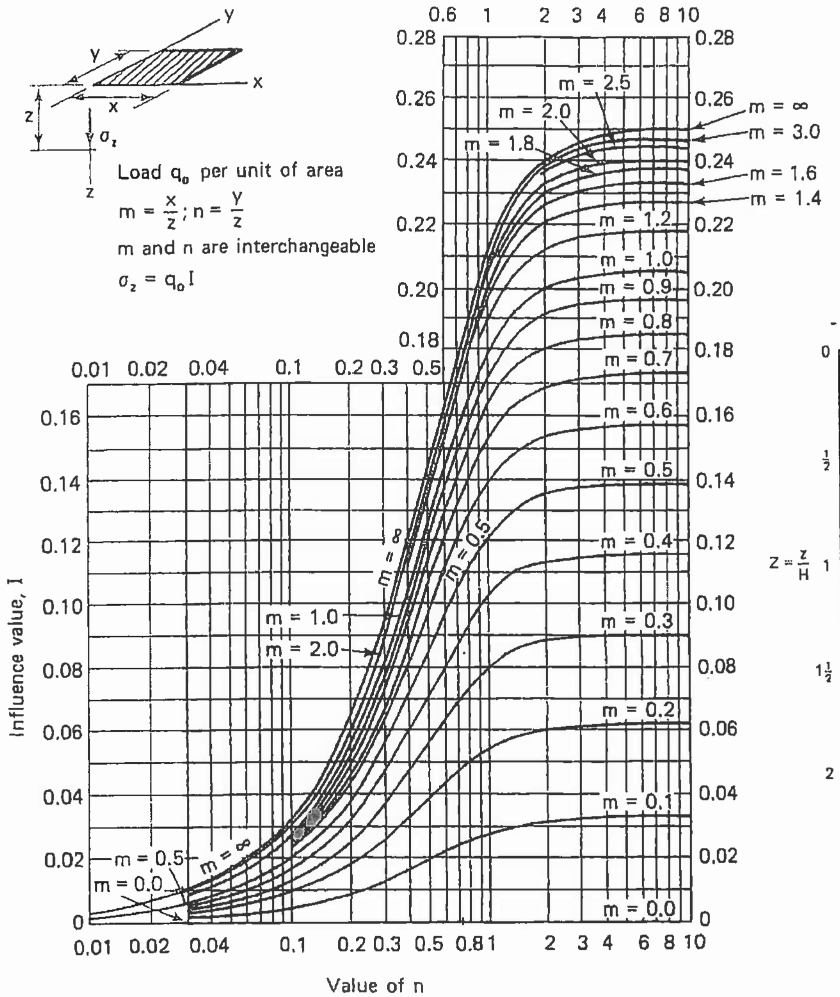
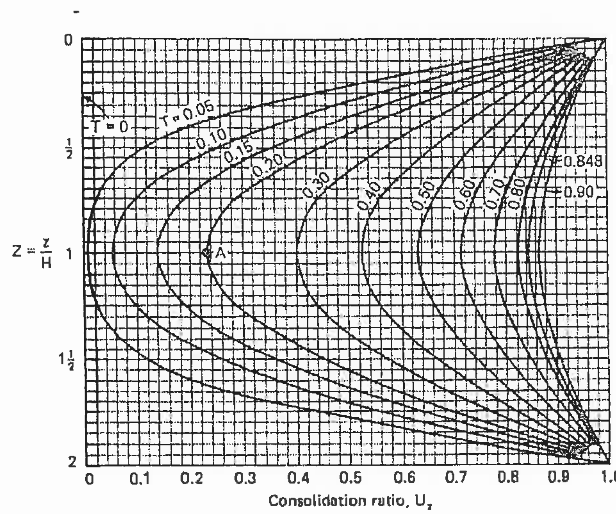
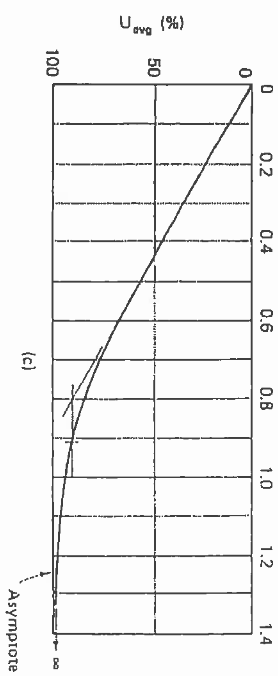

Free water
1m
2m
3m
7m
A
B
C
Impervious boundary
Sand:
γ_{sat} = 22 kN/m^3
ϕ' = 30°

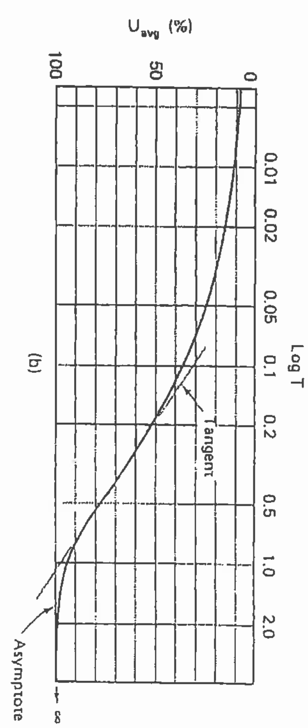
Figure Q.5

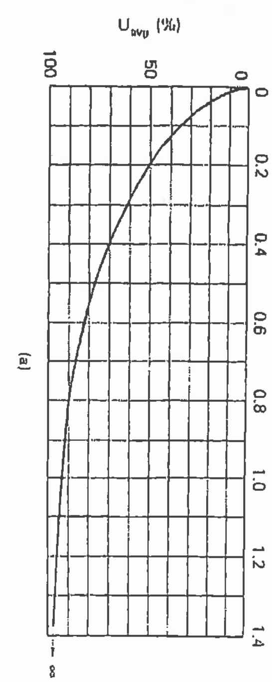
NATIONAL EXAMS – MAY 2011
04-GEOL-A6 SOIL MECHANICS
Formulas and Charts











$$\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$$

$$\sigma' = \sigma - u$$

$$\tau_f = c' + \sigma' \tan\phi'$$

$$S_c = C_r\left(\frac{H_o}{1+e_o}\right)\log\frac{\sigma'_p}{\sigma'_{vo}} + C_c\left(\frac{H_o}{1+e_o}\right)\log\frac{\sigma'_{vf}}{\sigma'_p}$$

$$T = \frac{c_v t}{H_{dr}^{\ 2}}$$

$$q = k\Delta h\frac{N_f}{N_d}$$

$$h_t = h_p + z = \frac{u}{\gamma_w} + z$$

$$C_u = \frac{D_{60}}{D_{10}}$$

$$C_c = \frac{(D_{30})^2}{D_{10}D_{60}}$$

$$i = \frac{\Delta h}{l}$$

$$\rho_d = \frac{\rho_t}{(1+w)}$$

$$\psi' = \arctan(\sin\phi') \qquad a = c'\cos\phi'$$

$e = V_v / V_s$ (void ratio)
$n = V_v / V_t$ (porosity)
$w = M_w / M_s$ (moisture content)
$S = V_w / V_v$ (saturation)

$$p = \frac{\sigma_1 + \sigma_3}{2} \qquad q = \frac{\sigma_1 - \sigma_3}{2}$$

$$k_N = \frac{H}{\left(\frac{H_1}{k_1} + \frac{H_2}{k_2} + \frac{H_3}{k_3}\right)}$$

$$k_p = \frac{k_1H_1 + k_2H_2 + k_3H_3}{H}$$

$k = CD_{10}^2$ (C=100, k = cm/s & D_{10} = cm)

$\rho' = \rho_{sat} - \rho_w$ $\qquad \rho_w = 1000\ kg/m^3$
$\gamma_w = 9.81\ kN/m^3$

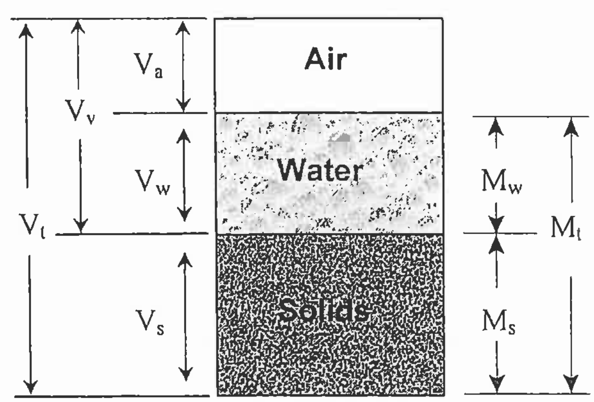
Force → Newton (N) → 1 N = 1 kg m/s^2
Pressure → Pascal (Pa) → 1 Pa = 1N/m^2
→ 1 kPa = 1 kN/m^2

$N_{corr} = 100 \times (N - N_{fines}) / (100 - N_{fines})$

$$\Delta\sigma_{v(avg)} = \frac{(\Delta\sigma_{v(top)} + 4\Delta\sigma_{v(mid)} + \Delta\sigma_{v(bot)})}{6}$$

$$K_a = \frac{1 - \sin\phi'}{1 + \sin\phi'} \qquad K_p = 1/K_a \qquad K_o \approx 1 - \sin\phi'$$

$$\sigma'_h = \sigma'_v K_a - 2C'\sqrt{K_a} \qquad \sigma'_h = \sigma'_v K_p + 2C'\sqrt{K_p}$$



Major Divisions 1	Major Divisions 2		Group Symbols (†) 3	Typical Names 4	Laboratory Classification Criteria 6
Coarse-grained Soils: More than half of material is larger than No. 200 (‡) (75 µm) sieve size.	Gravels: More than half of coarse fraction is larger than No. 4 sieve size. (4.75 mm)	Clean Gravels (little or no fines)	GW	Well-graded gravels, gravel sand mixtures, little or no fines.	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3 (See Sec. 2-5)
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.	Not meeting all gradation requirements for GW
		Gravels with Fines (appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	Atterberg limits below A-line, or PI less than 4. Above A-line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			GC	Clayey gravels, gravel-sand-clay mixtures.	Atterberg limits above A-line with PI greater than 7
	Sands: More than half of coarse fraction is smaller than No. 4 sieve size. (4.75 mm)	Clean Sands (little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3 (See Sec. 2-5)
			SP	Poorly graded sands, gravelly sands, little or no fines.	Not meeting all gradation requirements for SW
		Sands with Fines (appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Atterberg limits below A-line, or PI less than 4. Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			SC	Clayey sands, sand-clay mixtures.	Atterberg limits above A-line with PI greater than 7
Fine-grained Soils: More than half of material is smaller than No. 200 (75 µm) sieve size.	Silts and Clays	Liquid limit less than 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	
			OL	Organic silts and organic silty clays of low plasticity.	
	Silts and Clays	Liquid limit greater than 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	
			CH	Inorganic clays of high plasticity, fat clays.	
			OH	Organic clays of medium to high plasticity, organic silts.	
Highly Organic Soils			Pt	Peat and other highly organic soils.	

The No. 200 sieve size is about the smallest particle visible to the naked eye.

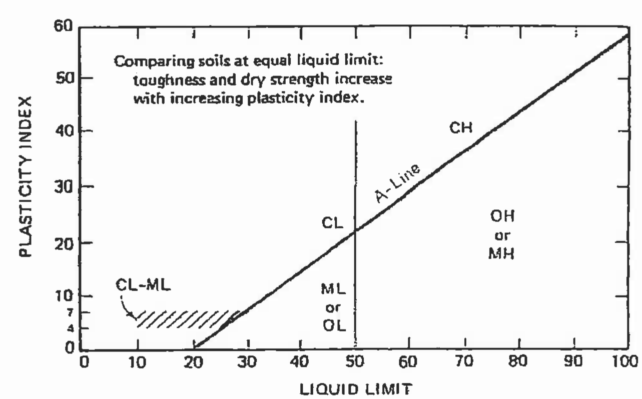
(for visual classification, 5 mm may be used as equivalent to the No. 4 sieve size)

Use grain size curve in identifying the fractions as given under field identification.

Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows:

Less than 5%: GW, GP, SW, SP
More than 12%: GM, GC, SM, SC.
5% to 12%: Borderline cases requiring use of dual symbols.

Plasticity Chart
For laboratory classification of fine-grained soils



† Boundary classifications: soils possessing characteristics of two groups are designated by combinations of group symbols. For example: GW-GC well-graded gravel sand mixture with clay binder.

‡ All sieve sizes on this chart are U.S. Standard