# NATIONAL EXAMS – DECEMBER 2011
## 04-GEOL-A6 SOIL MECHANICS

### 3 HOURS DURATION

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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. Classify soils A, B and C according to the Unified Soil Classification System. Soil B has a liquid limit of 20% and a plastic limit of 7%. Soil C is a mix of 70% (by dry mass) soil A and 30% soil B.

(value 15)

| | | Percent Finer | |
|---|---|---|---|
| **Metric Sieve Size** | **US Sieve Size** | **Soil A** | **Soil B** |
| 25 mm | 1 in | 100 | 100 |
| 19 mm | 0.75 in | 96 | 100 |
| 9.5 mm | 0.375 in | 88 | 100 |
| 4.76 mm | No. 4 | 74 | 100 |
| 2.38 mm | No. 8 | 56 | 100 |
| 0.84 mm | No. 20 | 35 | 100 |
| 420 μm | No. 40 | 16 | 94 |
| 250 μm | No. 60 | 7 | 83 |
| 150 μm | No. 100 | 0 | 70 |
| 75 μm | No. 200 | 0 | 60 |

2. Fig. Q.2. on page 4 illustrates a slope cut into a silty sand for a road. The expected water table is identified by the dotted line and groundwater flow equipotentials are shown. All units are in meters. The circular arc shows a failure surface.

   a) What is the datum elevation used to compute the heads in the flow system?
   (Value 2)
   b) Calculate the pore pressure at points A, B, C and D along the failure surface.
   (Value 8)
   c) The analysis shows the slope to be unstable. What measures are available to improve the stability of this slope?
   (Value 5)

3. Answer the following questions.

   a) Name two glacial drift deposits that can be expected to provide good materials for highway construction and explain why.
   (Value 4)
   b) Discuss the origins and useful properties of Bentonite.
   (Value 4)
   c) What weathering processes produce clay?
   (Value 4)
   d) Why are some soils susceptible to swelling? Where are they encountered?
   (Value 4)
   e) Explain the concept of effective stress.
   (Value 4)

4. For typical geotechnical design calculations, the shear strength of clays is either modeled by the Mohr-Coulomb failure criterion or by the Undrained Shear Strength.

   a) Which model is more appropriate for the design of a foundation on clay and for the design of a permanent excavation in clay.

   (Value 5)

   b) Describe the laboratory tests performed to obtain the parameters of both shear strength models.

   (Value 5)

5. A sample of glacial till was taken from below the groundwater table. The moisture content was found to be 35%. Estimate the bulk unit weight, the dry unit weight, the buoyant unit weight, the porosity and the void ratio. Clearly state any necessary assumptions.

   (Value 15)

6. Describe one method each, used for the rough estimation and for the rigorous analysis of the short-term stability of a slope in clay.

   (Value 10)

7. A 5 m thick clay layer rests on impervious bedrock and is overlain by 5m of sandy soil. The water table is at a depth of 2m. The soils properties are:

   Sandy soil: $\gamma_t = 20$ kN/m$^3$, $\gamma_{sat} = 22$ kN/m$^3$,
   Friction angle, $\phi' = 33°$

   Clay: $\gamma_{sat} = 19$ kN/m$^3$, $\phi' = 28°$, $c' = 5$ kPa,
   Undrained shear strength, $C_u = 100$ kPa
   Initial void ratio, $e_o = 2.055$
   Compression Index, $C_c = 0.8$
   Recompression or Swelling Index $C_{(r\ or\ s)} = 0.03$
   Preconsolidation pressure, $\sigma'_c = 110$ kPa
   Coefficient of Consolidation, $c_v = 7.5 \times 10^{-8}$ m$^2$/sec

   A very wide, 2m high embankment ($\gamma_t = 21$ kN/m$^3$) will be placed on top of the sandy soil. What will be the resulting consolidation settlement after 3 years?

   (Value 15)

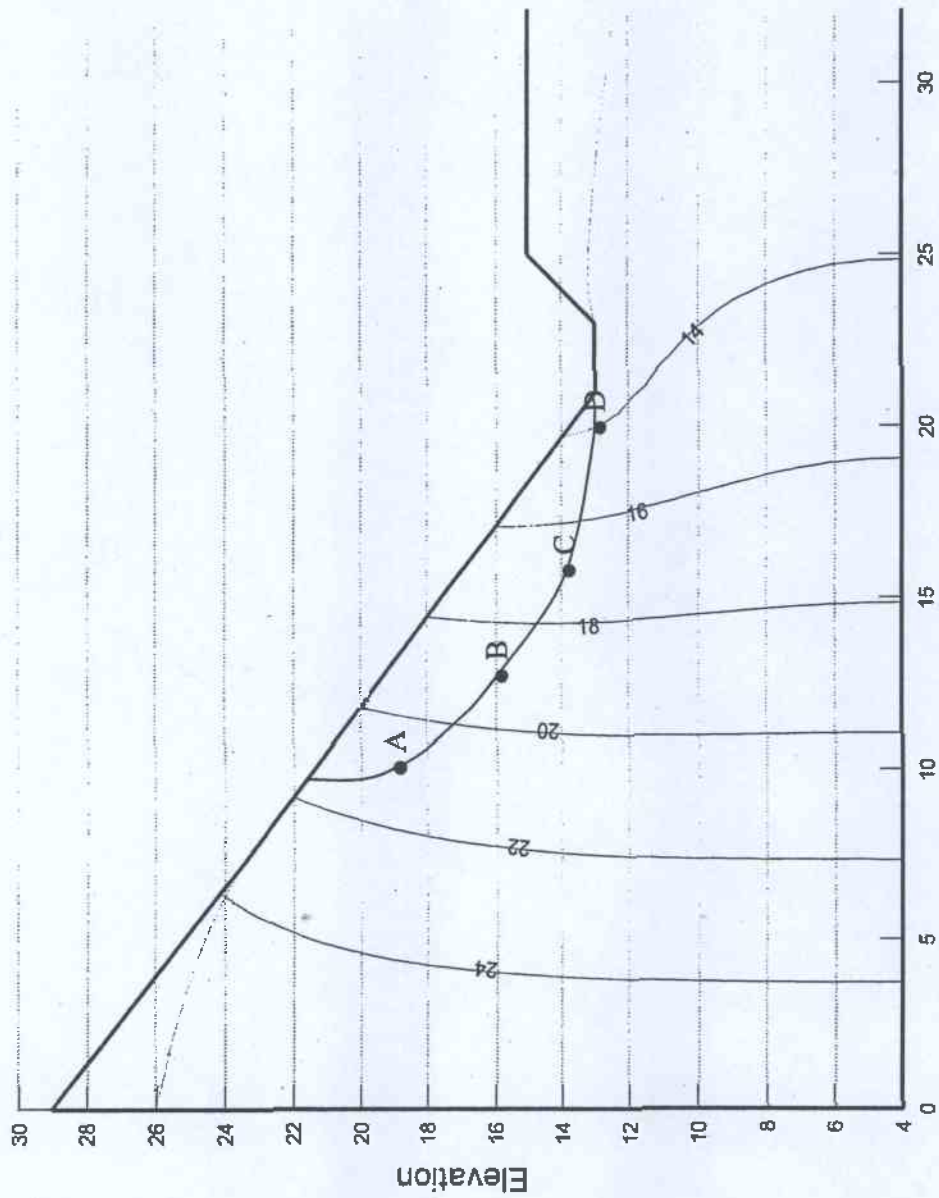
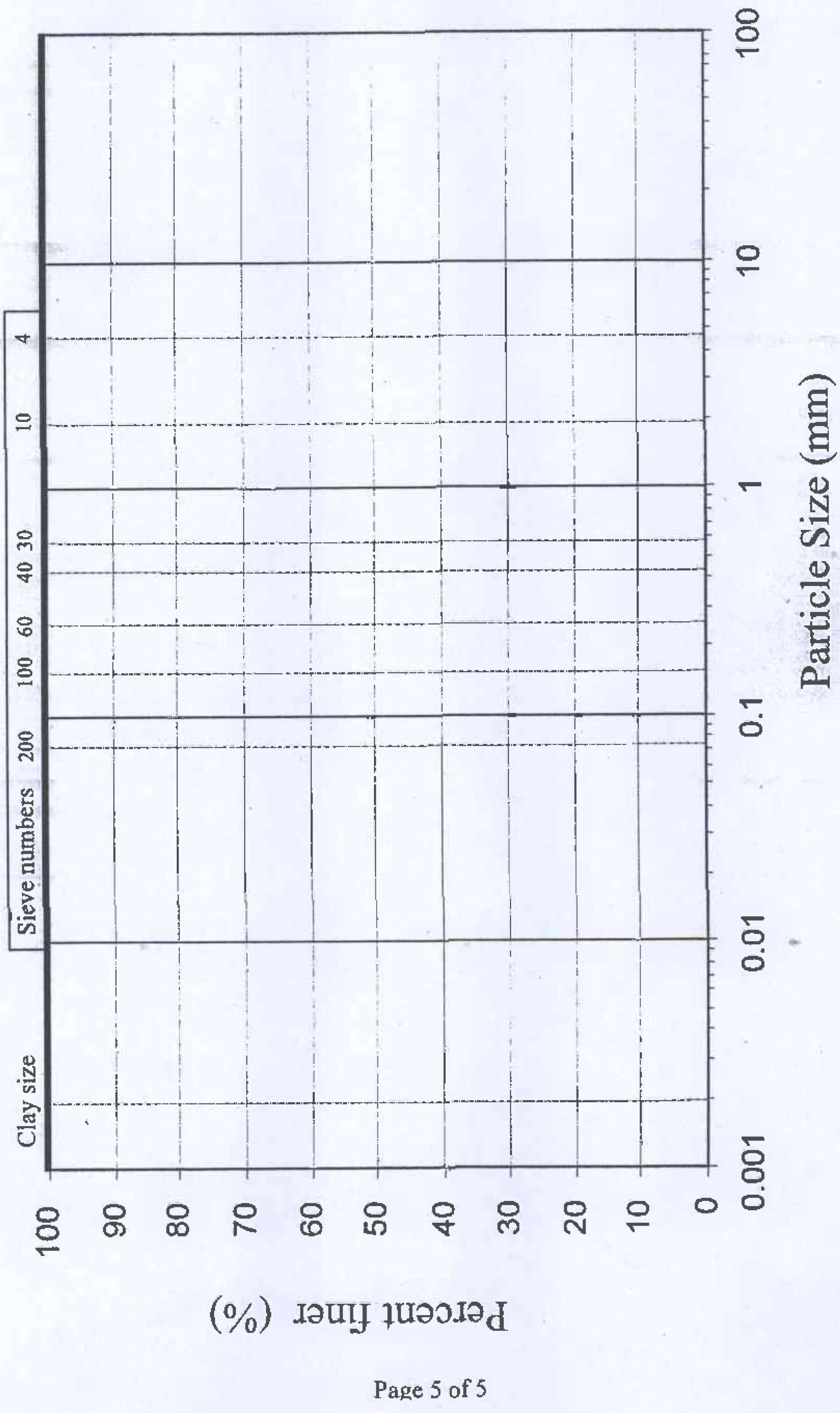
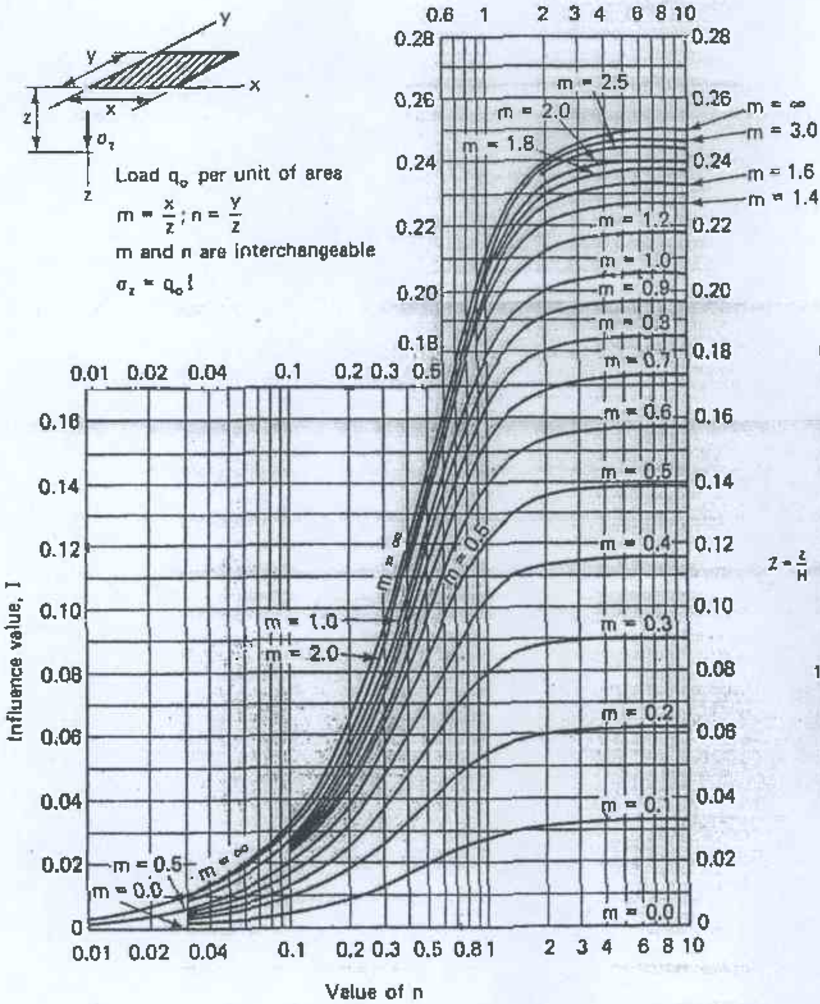

Elevation
30
28
26
24
22
20
18
16
14
12
10
8
6
4
0
5
10
15
20
25
30
24
22
20
18
16
14
A
B
C
D

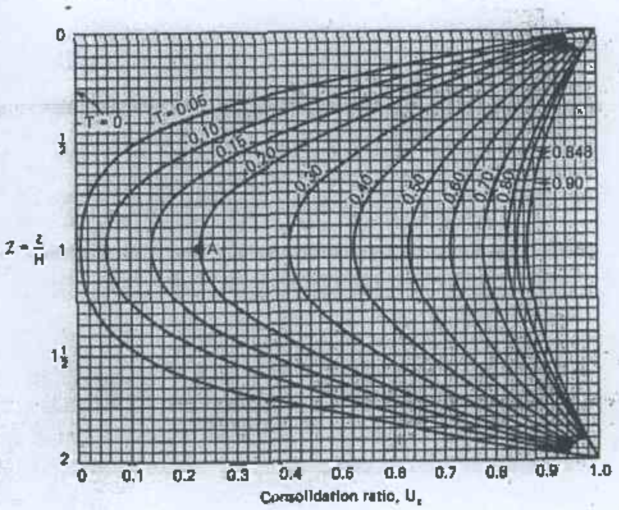
Figure Q.2

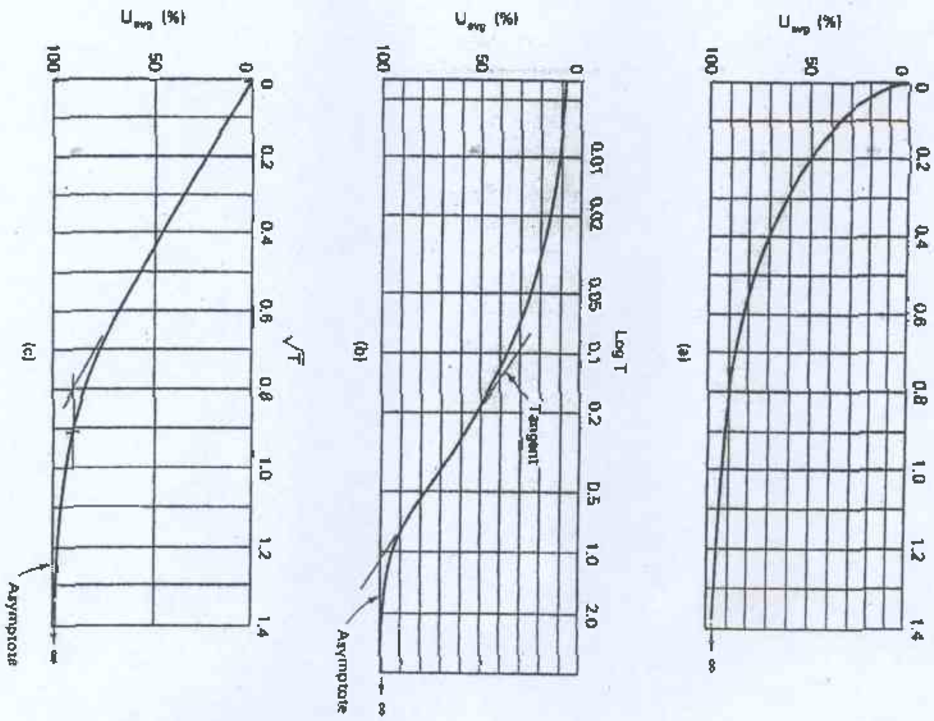

Sieve numbers
4
10
40 30
100 60
200
Clay size
100
10
1
0.1
0.01
0.001
Particle Size (mm)
100
90
80
70
60
50
40
30
20
10
0
Percent finer (%)

# NATIONAL EXAMS – DECEMBER 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)

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

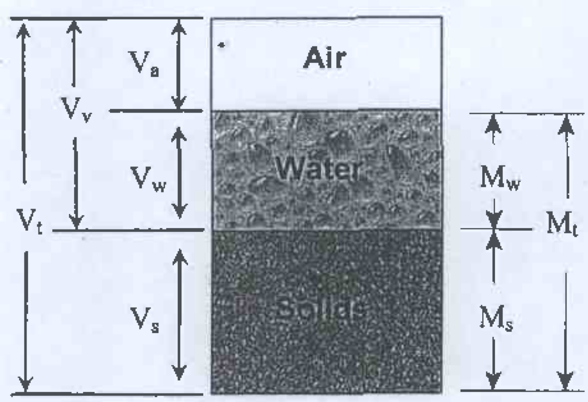
**Force** → Newton (N) → 1 N = 1 kg m/s$^2$
**Pressure** → Pascal (Pa) → 1 Pa = 1N/m$^2$
→ 1 kPa = 1 kN/m$^2$

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

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

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

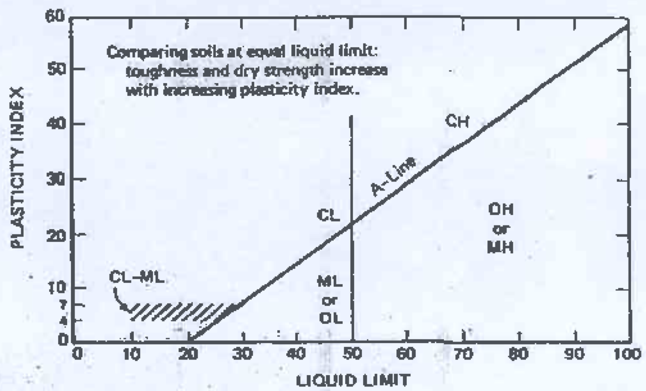
$$\sigma'_h = \sigma'_v K_a - 2C'\sqrt{K_a} \qquad \sigma'_h = \sigma'_v K_p + 2C'\sqrt{K_p}$$



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



| Major Divisions | | | Group Symbols (†) | Typical Names | Laboratory Classification Criteria | | |
|---|---|---|---|---|---|---|---|
| 1 | 2 | | 3 | 4 | | 6 | |
| Coarse-grained Soils<br>More than half of material is larger than No. 200 (‡) (75 μm) sieve size. | Gravels<br>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. | 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:<br>Less than 5%: GW, GP, SW, SP<br>More than 12%: GM, GC, SM, SC<br>5% to 12%: Borderline cases requiring use of dual symbols. | $C_u = \frac{D_{60}}{D_{10}}$ greater than 4<br>$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ 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<br>More than half of coarse fraction is smaller than No. 4 sieve size. (4.75 mm)<br>(for visual classification, 6 mm may be used as equivalent to the No. 4 sieve size) | 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<br>$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ 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 |
| The No. 200 sieve size is about the smallest particle visible to the naked eye. | | | | | | Plasticity Chart<br>For laboratory classification of fine-grained soils | |
| Fine-grained Soils<br>More than half of material is smaller than No. 200 (75 μm) sieve size. | Silts and Clays<br>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<br>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. | | | |




† 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.