CƠ HỌC ĐẤT

Presented By

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BỘ MÔN ĐỊA CƠ NỀN MÓNG

KHOA KỸ THUẬT XÂY DỰNG

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Reference books

Vietnamese

- Cơ Học Đất (Châu Ngọc Ẩn)
- Bài Tập Cơ Học Đất (Đỗ Bằng etc.)
- Cơ Học Đất (Whilow)
- Cơ Học Đất (Lê Quí An etc.)
- Cơ Học Đất (Xưtôvich)

English

- Principles of geotechnical engineering (5th Edition, Das)
- Advanced Soil Mechanics (2nd edition, Das)
- Essentials of Soil Mechanics and Foundation (6th Edition, McCarthy)
- Soil Mechanics, SI version (Lambe and Whitman)
- Soil Mechanics in Engineering Practice (Terzaghi, Peck, Mesri)
- Soil Mechanics and Foundations (Budhu)
- Fundamentals of soil mechanics (Taylor)
- Element of soil mechanics (7th edition, Smith and Smith)

Quantity	English to SI Units		SI to English Units	
	English	SI	SI	English
Length	1 in.	25.4 mm	1 mm	3.937×10^{-2} in.
	1 ft	0.3048 m		3.281×10^{-3} ft
		304.8 mm	1 m	39.37 in.
				3.281 ft
Area	1 $in.^2$	6.4516 × 10^{-4} m^2	1 cm^2	0.155 $in.^2$
		6.4516 cm^2		1.076 × 10^{-3} ft^2
		645.16 mm^2	1 m^2	1550 $in.^2$
	1 ft^2	929 × 10^{-4} m^2		10.76 ft^2
		929.03 cm^2		
		92903 mm^2		
Volume	1 $in.^3$	16.387 cm^3	1 cm^3	0.061 $in.^3$
	1 ft^3	0.028317 m^3		3.531×10^{-5} ft^3
	1 ft^3	28.3168 l	1 m^3	61023.74 $in.^3$
				35.315 ft^3
Velocity	1 ft/s	304.8 mm/s	1 cm/s	1.969 ft/min
		0.3048 m/s		1034643.6 ft/year
	1 ft/min	5.08 mm/s		
		0.00508 m/s		
Force	1 lb	4.448 N	1 N	0.22482 lb
			1 kN	0.22482 kip
Stress	1 $lb/in.^2$	6.9 kN/m^2	1 kN/m^2	0.145 $lb/in.^2$
	1 lb/ft^2	47.88 N/m^2		2.089×10^{-2} lb/ft^2
Unit Weight	1 lb/ft^3	157.06 N/m^3	1 kN/m^3	6.367 lb/ft^3
Coefficient of Consolidation	1 $in.^2/s$	6.452 cm^2/s	1 cm^2/s	0.155 $in.^2/s$
	1 ft^2/s	929.03 cm^2/s		2.883×10^3 ft^2/month
Mass			1 kg	2.2046 lb
				2.2046×10^{-3} kip

LENGTH

To Convert From	To	Multiply By
1. Inches	feet	0.083333
	angstrom units	2.54×10^{8}
	microns	25400
	millimeters	25.4
	centimeters	2.54
	meters	0.0254
2. Feet	inches	12.0
	angstrom units	3.048×10^{9}
	microns	304800
	millimeters	304.80
	centimeters	30.48
	meters	0.3048
3. Angstrom units	inches	3.9370079×10^{-9}
	feet	3.28084×10^{-10}
	microns	0.0001
	millimeters	1×10^{-7}
	centimeters	1×10^{-8}
	meters	1×10^{-10}
4. Microns	inches	3.9370079×10^{-5}
	feet	3.2808399×10^{-6}
	angstrom units	1×10^{4}
	millimeters	1×10^{-3}
	centimeters	1×10^{-4}
	meters	1×10^{-6}
5. Millimeters	inches	3.9370079×10^{-2}
	feet	3.2808399×10^{-3}
	angstrom units	1×10^{7}
	microns	1×10^{3}
	centimeters	1×10^{-1}
	meters	1×10^{-3}
6. Centimeters	inches	0.39370079
	feet	0.032808399
	angstrom units	1×10^{8}
	microns	1×10^{4}
	millimeters	10
	meters	1×10^{-2}
7. Meters	inches	39.370079
	feet	3.2808399
	angstrom units	1×10^{10}
	microns	1×10^{6}
	millimeters	1×10^{3}
	centimeters	1×10^{2}

AREA

To Convert From	To	Multiply By
1. Square meters	square feet	10.76387
	square centimeters	1×10^{4}
	square inches	1550.0031
2. Square feet	square meters	9.290304×10^{-2}
	square centimeters	929.0304
	square inches	144
3. Square centimeters	square meters	1×10^{-4}
	square feet	1.076387×10^{-3}
	square inches	0.1550031
4. Square inches	square meters	6.4516×10^{-4}
	square feet	6.9444×10^{-3}
	square centimeters	6.4516

VOLUME

To Convert From	To	Multiply By
1. Cubic centimeters	cubic meters	1×10^{-6}
	cubic feet	3.5314667×10^{-5}
	cubic inches	0.061023744
2. Cubic meters	cubic feet	35.314667
	cubic centimeters	1×10^{6}
	cubic inches	61023.74
3. Cubic inches	cubic meters	1.6387064×10^{-5}
	cubic feet	5.7870370×10^{-4}
	cubic centimeters	16.387064

To Convert From	To	Multiply By
4. Cubic feet	cubic meters	0.028316847
	cubic centimeters	28316.847
	cubic inches	1728
FORCE		
1. Pounds (avdp)	dynes	4.44822×10^5
	grams	453.59243
	kilograms	0.45359243
	tons (long)	4.464286×10^{-4}
	tons (short)	5×10^{-4}
	kips	1×10^{-3}
	tons (metric)	4.5359243×10^{-4}
	newtons	4.44822
2. Kips	pounds	1000
	tons (short)	0.500
	kilograms	453.59243
	tons (metric)	0.45359243
3. Tons (short)	kilograms	907.18474
	pounds	2000
	kips	2
	tons (metric)	0.907185
4. Kilograms	dynes	980665
	grams	1000
	pounds	2.2046223
	tons (long)	9.8420653×10^{-4}
	tons (short)	11.023113×10^{-4}
	kips	2.2046223×10^{-3}
	tons (metric)	0.001
	newtons	9.806650
5. Tons (metric)	grams	1×10^6
	kilograms	1000
	pounds	2204.6223
	kips	2.2046223
	tons (short)	1.1023112
	kilonewtons	9.806650
6. Kilonewtons	pounds	224.81
	tons (short)	0.1124
	kips	0.22481
	tons (metric)	0.102
	kilograms	101.97
STRESS		
1. Pounds/square foot	pounds/square inch	0.0069445
	feet of water	0.016018
	kips/square foot	1×10^{-3}
	kilograms/square centimeter	0.000488243
	tons/square meter	0.004882
	atmospheres	4.72541×10^{-4}
	kilonewtons/square meter	0.04788
2. Pounds/square inch	pound/square foot	144
	feet of water	2.3066
	kips/square foot	0.144
	kilograms/square centimeter	0.070307
	tons/square meter	0.70307
	atmospheres	0.068046
	kilonewtons/square meter	6.895
3. Tons (short)/ square foot	atmospheres	0.945082
	kilograms/sqiare meter	9764.86
	tons (metric)/ square meter	9.76487
	pounds/square inch	13.8888
	pounds/square foot	2000
	kips/square foot	2.0
	kilonewtons/square meter	95.76
4. Feet of water (at 4°C)	pounds/square inch	0.43352
	pounds/square foot	62.427
	kilograms/square centimeter	0.0304791
	tons/square meter	0.304791
	atmospheres	0.029499
	inches of Hg	0.88265
	kilonewtons/square meter	2.989
5. Kips/square foot	pounds/square inch	6.94445
	pounds/square foot	1000
	tons (short)/ square foot	0.5000
	kilograms/square centimeter	0.488244
	tons (metric)/square meter	4.88244
	kilonewtons/square meter	47.88
6. Kilograms/ square centi-meter	pounds/square inch	14.223
	pounds/square foot	2048.1614
	feet of water (4°C)	32.8093
	kips/square foot	2.0481614
	tons/square meter	10
	atmospheres	0.96784
	kilonewtons/square meter	98.067
7. Tons (metric)/ square meter	kilograms/square centimeter	0.10
	pounds/square foot	204.81614
	kips/square foot	0.20481614

To Convert From	To	Multiply By
7. Tons (metric)/ square meter *(contd.)*	tons (short)/ square foot	0.102408
	kilonewtons/square meter	9.806650
8. Atmospheres	bars	1.0133
	centimeters of mercury at 0°C	76
	millimeters of mercury at 0°C	760
	feet of water at 4°C	33.899
	kilograms/square centimeter	1.03323
	grams/square centimeter	1033.23
	kilograms/square meter	10332.3
	tons (metric)/ suqare meter	10.3323
	pounds/square foot	2116.22
	pounds/square inch	14.696
	tons (short)/square foot	1.0581
	kilonewtons/square meter	101.325
9. Kilonewtons/ square meter	pounds/square foot	20.886
	pounds/square inch	0.145
	tons (short)/square foot	0.01044
	feet of water (at 4°C)	0.3346
	meters of water	0.1020
	kips/square foot	0.02089
	kilograms/square centimeter	0.01020
	tons (metric)/square meter	0.1020
	atmospheres	0.00987

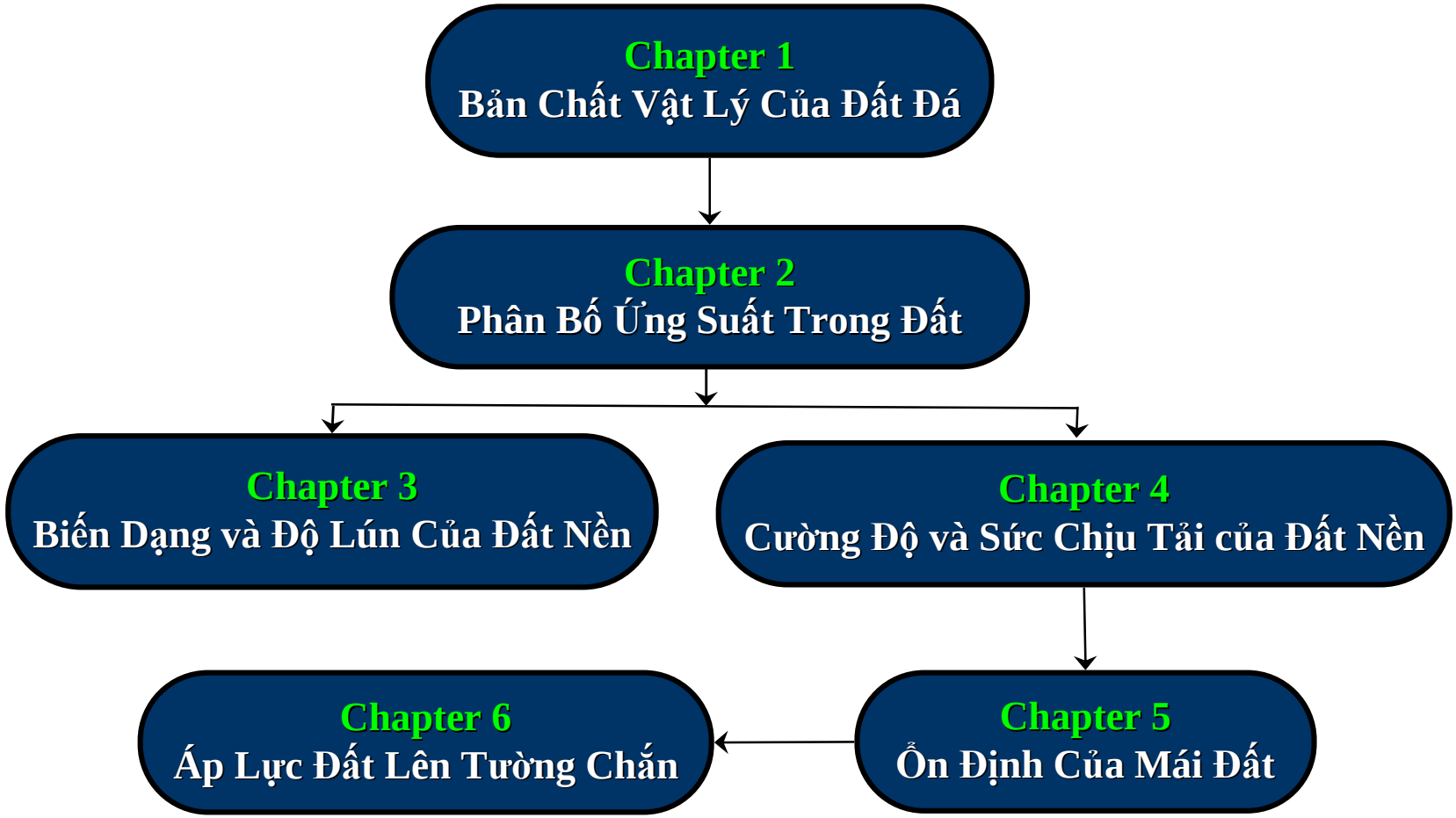
UNIT WEIGHT

To Convert From	To	Multiply By
1. Grams/cubic centimeter	tons (metric)/cubic meter	1.00
	kilograms/cubic meter	1000.00
	pounds/cubic inch	0.036127292
	pounds/cubic foot	62.427961
	kilonewtons/cubic meter	
2. Tons (metric)/ cubic meter	grams/cubic centimeter	1.00
	kilograms/cubic meter	1000.00
	pounds/cubic inch	0.036127292
	pounds/cubic foot	62.427961
	kilonewtons/cubic meter	
3. Kilograms/ cubic meter	grams/cubic centimeter	0.001
	tons (metric)/cubic meter	0.001
	pounds/cubic inch	3.6127292×10^{-5}
	pounds/cubic foot	0.062427961
	kilonewtons/cubic meter	
4. Pounds/cubic inch	grams/cubic centimeter	27.679905
	tons (metric)/cubic meter	27.679905
	kilograms/cubic meter	27679.905
	pounds/cubic foot	1728
	kilonewtons/cubic meter	
5. Pounds/cubic foot	grams/cubic centimeter	0.016018463
	tons (metric)/cubic meter	0.016018463
	kilograms/cubic meter	16.018463
	pounds/cubic inch	$5.78703704 \times 10^{-4}$
	kilonewtons/cubic meter	
6. Kilonewtons/ cubic meter	grams/cubic centimeter	0.1020
	tons (metric)/cubic meter	0.1020
	kilograms/cubic meter	101.98
	pounds/cubic inch	0.003685
	pounds/cubic foot	6.3654

TIME

To Convert From	To	Multiply By
1. Milliseconds	seconds	10^{-3}
	minutes	1.66666×10^{-5}
	hours	2.777777×10^{-7}
	days	1.1574074×10^{-8}
	months	3.8057×10^{-10}
	years	3.171416×10^{-11}
2. Seconds	milliseconds	1000
	minutes	1.66666×10^{-2}
	hours	2.777777×10^{-4}
	days	1.1574074×10^{-5}
	months	3.8057×10^{-7}
	years	3.171416×10^{-8}
3. Minutes	milliseconds	60000
	seconds	60
	hours	0.0166666
	days	6.944444×10^{-4}

CONTENT



Chapter 1

1

1 Bản Chất Vật Lý của Đất

1.1 Nguồn góc và quá trình hình thành của đất

- Đất được hình thành bởi sự phong hóa của đá
- Đá có thể được phân loại
  - **Đá magma (igneous)**
  - **Đá trầm tích (sedimentary)**
  - **Đá biến chất (Metamorphic)**

- Phong hóa
  - **Do cơ học: do nhiệt độ, nước, gió, sống, etc. → không có sự thay đổi thành phần hóa học**
  - **Do hóa học: khóang của đá góc bị thay đổi do các phản ứng hóa học giữa nước, CO_2 và khóang**

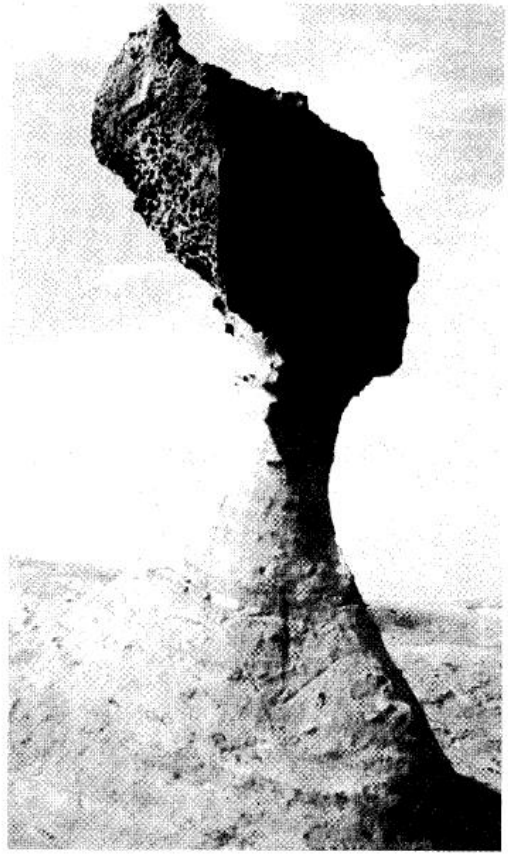
$$H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + (HCO_3)$$

Carbonic acid

$$2K(AlSi_3O_8) + 2H^+ + H_2O \rightarrow 2K^+ + 4SiO_2 + Al_2Si_2O_5(OH)_4$$

Orthoclase — Silica — Kaolinite (clay mineral)

1 Bản Chất Vật Lý của Đất

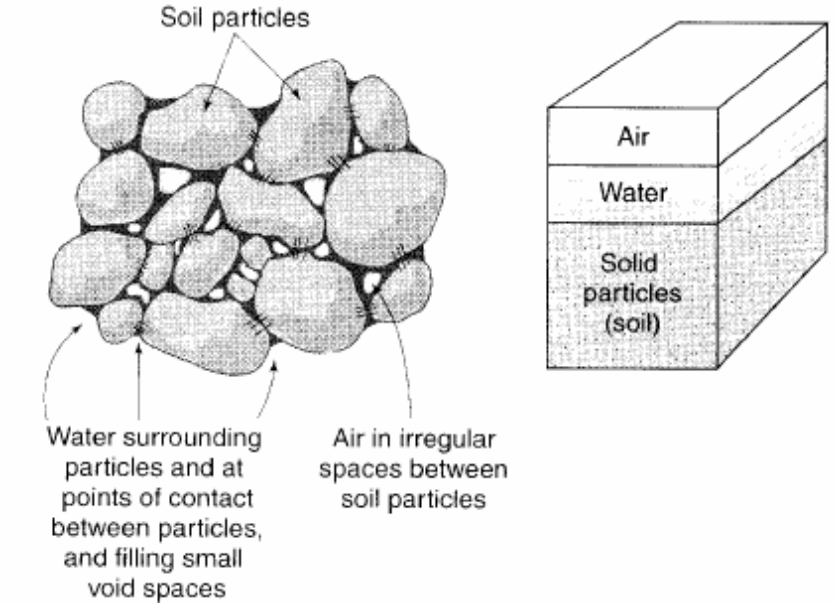


- *Glacial Soil*: do sự dịch chuyển và lắng động của băng
- *Alluvial soil*: lắng động dọc theo sông suối
- *Lacustrine Soil*: lắng động ở hồ
- *Marine Soil*: lắng động ở biển
- *Aeolian*: dịch chuyển và lắng động bởi gió
- *Colluvial soil*: do trọng lực như landslides

1 Bản Chất Vật Lý của Đất

1.2 Thành phần của đất

- Đất: hạt đất, nước và không khí trong lỗ rỗng



1.2.1 Cấp phối hạt đất

- Kích cở hạt

Name of organization	Grain size (mm)			
	Gravel	Sand	Silt	Clay
Massachusetts Institute of Technology (MIT)	>2	2 to 0.06	0.06 to 0.002	<0.002
U.S. Department of Agriculture (USDA)	>2	2 to 0.05	0.05 to 0.002	<0.002
American Association of State Highway and Transportation Officials (AASHTO)	76.2 to 2	2 to 0.075	0.075 to 0.002	<0.002
Unified Soil Classification System (U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and American Society for Testing and Materials)	76.2 to 4.75	4.75 to 0.075	Fines (i.e., silts and clays) <0.075	

1 Bản Chất Vật Lý của Đất

- Phương pháp phân tích thành phần hạt
  - Ø **Sieve analysis: $D_{hạt} \geqslant 0.075$ mm**
  - Ø **Hydrometer analysis: $D_{hạt} < 0.075$ mm**

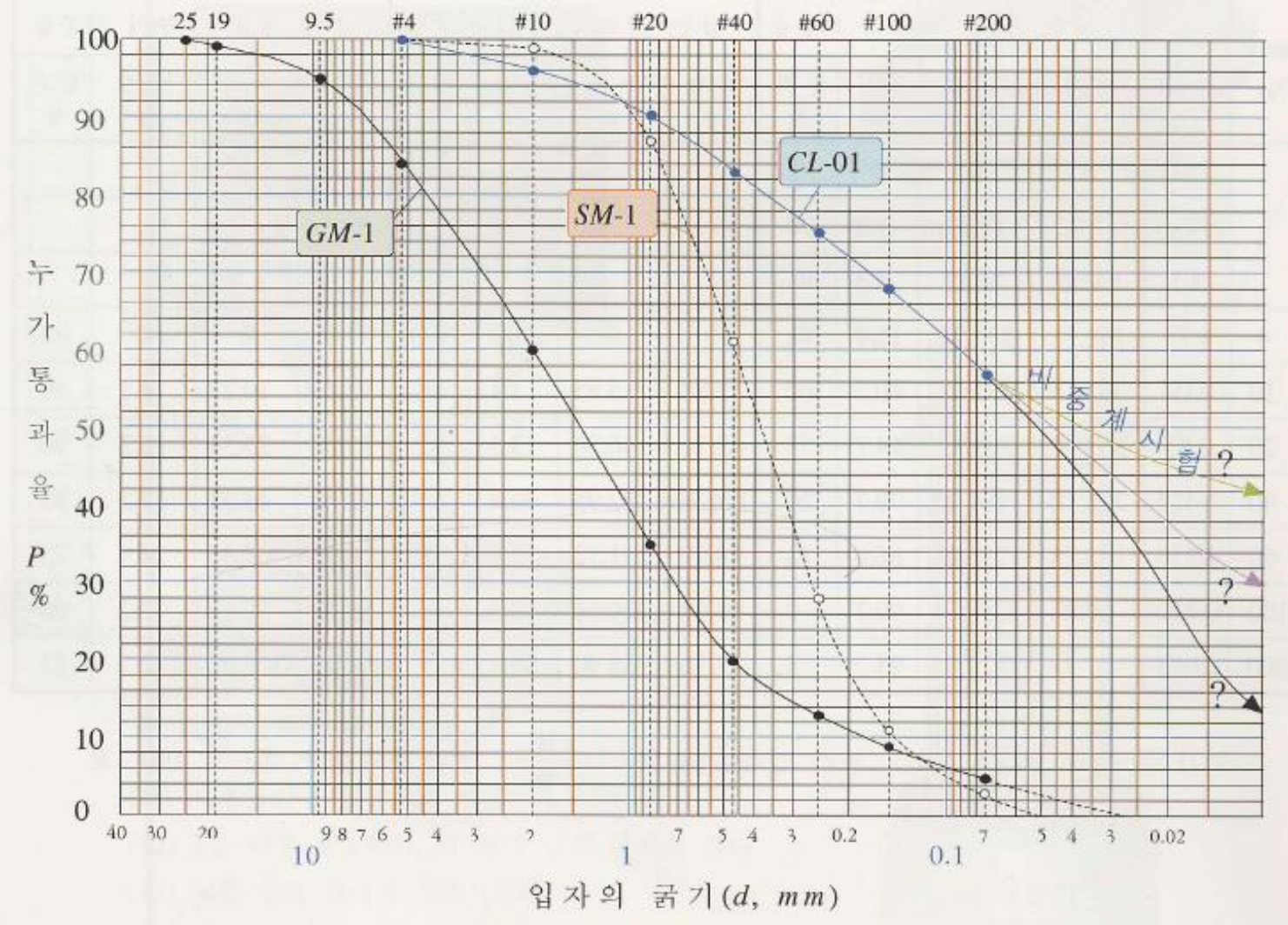
- **Sieve Analysis :**

$W_{s(GM-1)}$ = 1493.33 g, $W_{s(SM-1)}$ = 350 g, $W_{s(CL-01)}$ = 250.49 g

Sieve No.	입경 d, mm	Sample No. GM-1 씻기 전 무게 1495.3 g				Sample No. SM-1 씻기 전 무게 350.1 g				Sample No. CL-01 씻기 전 무게 250.4 g			
		남은 무게		누가 백분율		남는 시료		누가 백분율		남는 시료		누가 백분율	
		각체 g	누가 g	잔류 %	통과 %	각체 g	누가 g	잔류 %	통과 %	각체 g	누가 g	잔류 %	통과 %
	25.0	0	0	0	100								
	19.0	17.92	17.92	1.2	99								
	9.5	61.30	79.22	5.3	95								
4	4.75	158.71	237.93	15.9	84	0	0	0	100	0	0	0	100
10	2.00	363.15	601.08	40.2	60	3.85	3.85	1.1	99	10.27	10.27	4.1	96
20	0.85	367.07	968.15	64.7	35	42.71	46.56	13.3	87	15.27	25.54	10.2	90
40	0.425	223.10	1191.25	79.7	20	126.39	172.95	49.4	51	17.78	43.32	17.3	83
60	0.250	103.78	1295.03	86.6	13	78.77	251.72	71.9	28	19.03	62.35	24.9	75
100	0.150	60.81	1355.84	90.7	9	58.82	310.54	88.7	11	18.28	80.63	32.2	68
200	0.075	67.11	1422.95	95.2	5	28.36	338.90	96.8	3	26.29	106.92	42.7	57

누가 무게(W_i, g) = ΣW_i, 누가 잔류율(R_i, %) = $\frac{W_i}{W_s}$, 누가 통과율(P_i, %) = 100 - R_i

1 Bản Chất Vật Lý của Đất



1 Bản Chất Vật Lý của Đất

Hydrometer Analysis

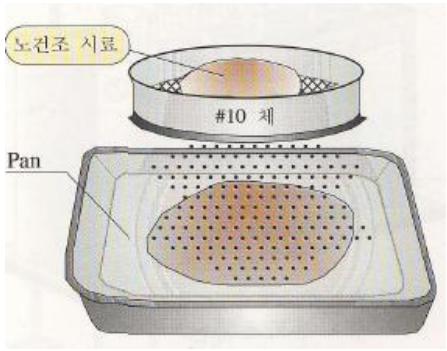
Giả thuyết:

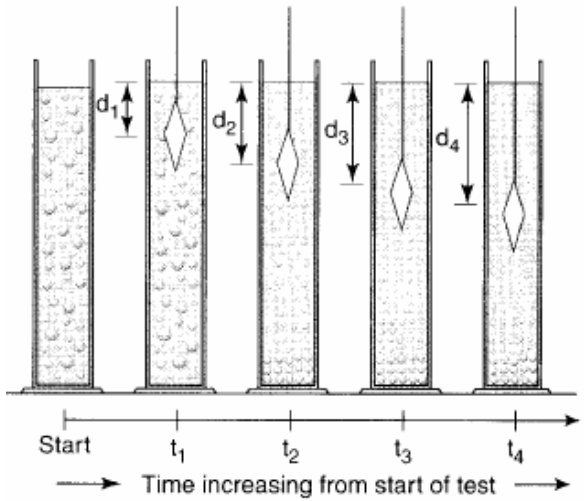
- Hạt là hình cầu
- Vận tốc lắng động của hạt đất được tính tóan theo ***Stoke's law***

$$v = \frac{g_s - g_w}{18h} gD^2$$

$$v(cm/s) = \frac{L(cm)}{60t(\min)} = \frac{(G_s - 1)g_w g}{18h}\left[\frac{D(mm)}{10}\right]^2$$

$$D(mm) = \sqrt{\frac{30h}{(G_s - 1)g_w 980}}\sqrt{\frac{L(cm)}{t(\min)}}$$

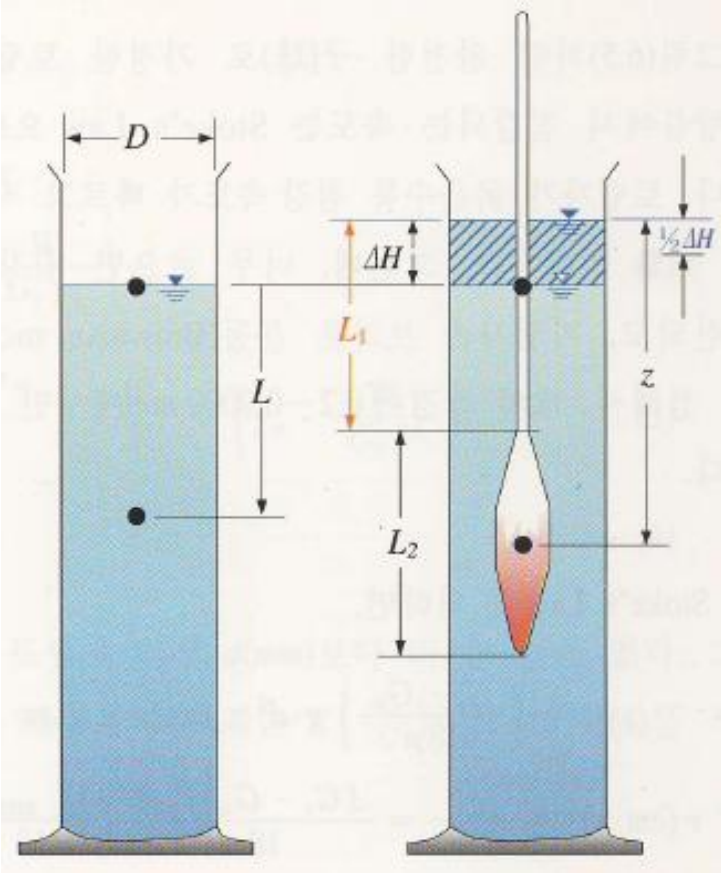




Nhiệt độ	Hệ số nhớt	Nhiệt độ	Hệ số nhớt	Nhiệt độ	Hệ số nhớt
18	0,01056	25	0,00894	32	0,00768
19	0,0105	26	0,00874	33	0,00752
20	0,01005	27	0,00854	34	0,00737
21	0,00981	28	0,00836	35	0,00722
22	0,00958	29	0,00818	36	0,00718
23	0,00936	30	0,00801	37	0,00695
24	0,00914	31	0,00784	38	0,00681
				39	0,00668

1 Bản Chất Vật Lý của Đất

Ø Tỷ trọng kế



$$L + \Delta H = z + \tfrac{1}{2}\Delta H$$

$$L = z - \tfrac{1}{2}\Delta H = (L_1 + \tfrac{1}{2}L_2) - \tfrac{1}{2}\left(\frac{V_b}{A}\right)$$

$$= L_1 + \tfrac{1}{2}\left(L_2 - \frac{V_b}{A}\right)$$

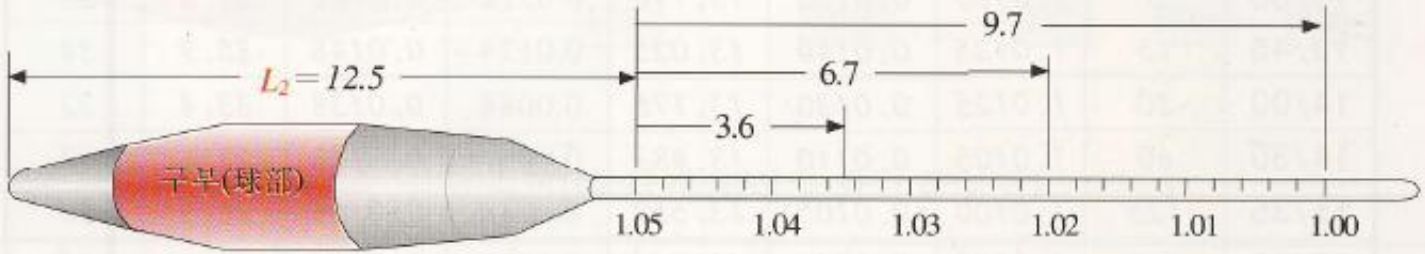
$$\therefore \quad L = L_1 + \tfrac{1}{2}\left(L_2 - \frac{V_b}{A}\right)$$

1 Bản Chất Vật Lý của Đất

Ø Tỷ trọng kế

메스 실린더(meas. cylinder) : No. 5 - 1 내경(D) 5.385 cm 면적(A) 22.775 cm^3

비중계(hydrometer) : No. 64 구부 부피(V_b) 37.0 cm^3 길이(L_2) 12.5 cm



실측 No.	γ g/cm^3	L_1 cm	L cm	γ^2	$\gamma \cdot L$
1	1.04	3.6	9.04	1.082	9.402
2	1.02	6.7	12.14	1.040	12.383
3	1.00	9.7	15.14	1.000	15.140
Sum	3.06	—	36.32	3.122	36.925

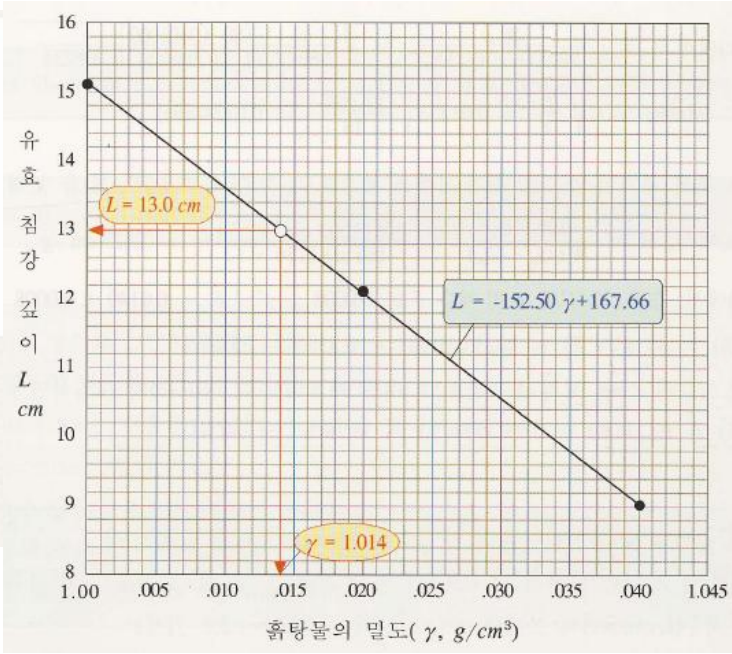
$$n = 3$$

$$L(cm) = L_1 + \tfrac{1}{2}\left(L_2 - \frac{V_b}{A}\right) = L_1 + \tfrac{1}{2}\left(12.5 - \frac{37.0}{22.78}\right) = 5.44 + L_1$$

$$a = \frac{n\Sigma\gamma L - \Sigma\gamma\,\Sigma L}{n\Sigma\gamma^2 - (\Sigma\gamma)^2} = \frac{3(36.9244) - (3.060)(36.320)}{3(3.1220) - (3.060)^2} = -152.50$$

$$b = \frac{\Sigma\gamma^2\,\Sigma L - \Sigma\gamma\,\Sigma\gamma L}{n\Sigma\gamma^2 - (\Sigma\gamma)^2} = \frac{(3.1220)(36.320) - (3.060)(36.9244)}{3(3.1220) - (3.060)^2} = 167.66$$

$$L = -a \cdot \gamma + b = -152.50\,\gamma + 167.66$$



1 Bản Chất Vật Lý của Đất

Ø Phần trăm của những hạt có đường kính nhỏ hơn D

$$\gamma_i = \frac{W}{V} = \frac{W_s + W_w}{V_s + V_w}$$

$$V_w = V - V_s = V - \frac{W_s}{G_s \gamma_w}$$

$$W_w = V_w \gamma_w = \left(V - \frac{W_s}{G_s \gamma_w}\right)\gamma_w$$

$$W = W_s + W_w = W_s + \left(V - \frac{W_s}{G_s \gamma_w}\right)\gamma_w$$

$$\gamma_i = \frac{W}{V} = \frac{W_s + \left(V - \frac{W_s}{G_s \gamma_w}\right)\gamma_w}{V} = \frac{W_s}{V} + \left(\gamma_w - \frac{W_s}{G_s V}\right)$$

$$\gamma_i = \gamma_w + \frac{W_s}{V}\left(\frac{G_s - 1}{G_s}\right)$$

ü Đặt P% là tỉ số giữa trọng lượng của những hạt có đường kính nhỏ hơn D và trọng lượng của tất cả các hạt của mẫu đất ban đầu

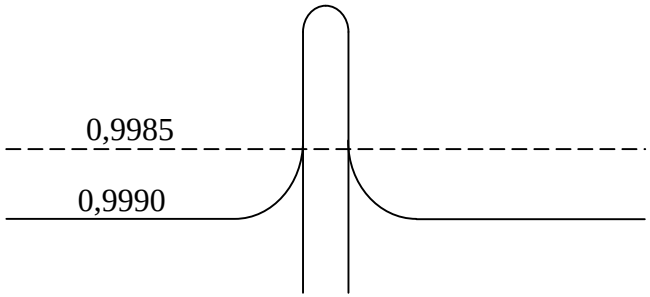
ü Trọng lượng của hạt đất trên đơn vị thể tích ở độ sâu z và thời gian t là PW/N và dung trọng là:

$$g = g_w + \frac{G_s - 1}{G}\frac{PW}{V} \Rightarrow \boxed{P = \frac{G}{G_s - 1}\frac{V}{W}(g - g_w)}$$

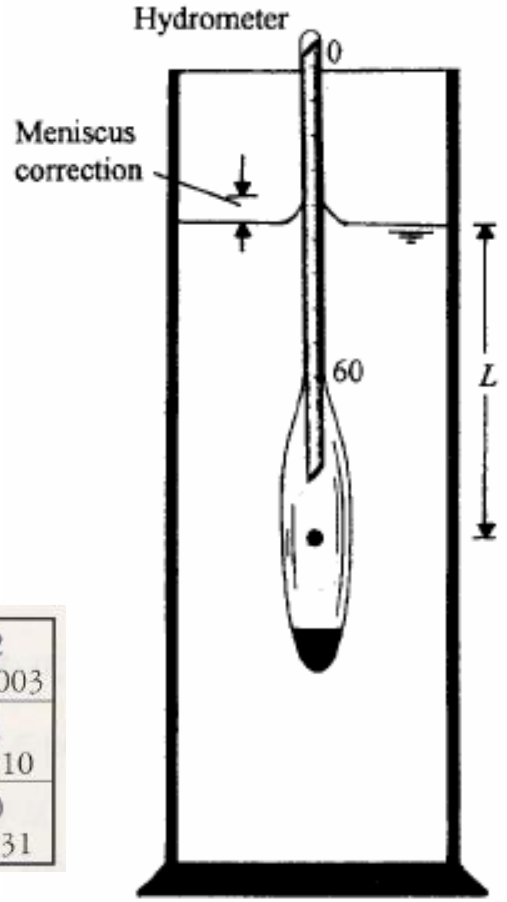
1 Bản Chất Vật Lý của Đất

Ø Điều chỉnh giá trị dung trọng của tỷ trọng kế

$$g = g_{đoc} + C_M + F$$



$$C_M = 0.9990 - 0.9985 = 0.0005$$



T °C	4	5	6	7	8	9	10	11	12
F	- 0.0006	- 0.0006	0.0006	0.0006	0.0006	0.0005	- 0.0005	- 0.0004	- 0.0003
T °C	13	14	15	16	17	18	19	20	21
F	- 0.0002	- 0.0001	0.0000	0.0001	0.0003	0.0004	0.0006	0.0008	0.0010
T °C	22	23	24	25	26	27	28	29	30
F	0.0012	0.0014	0.0016	0.0018	0.0020	0.0023	0.0025	0.0028	0.0031

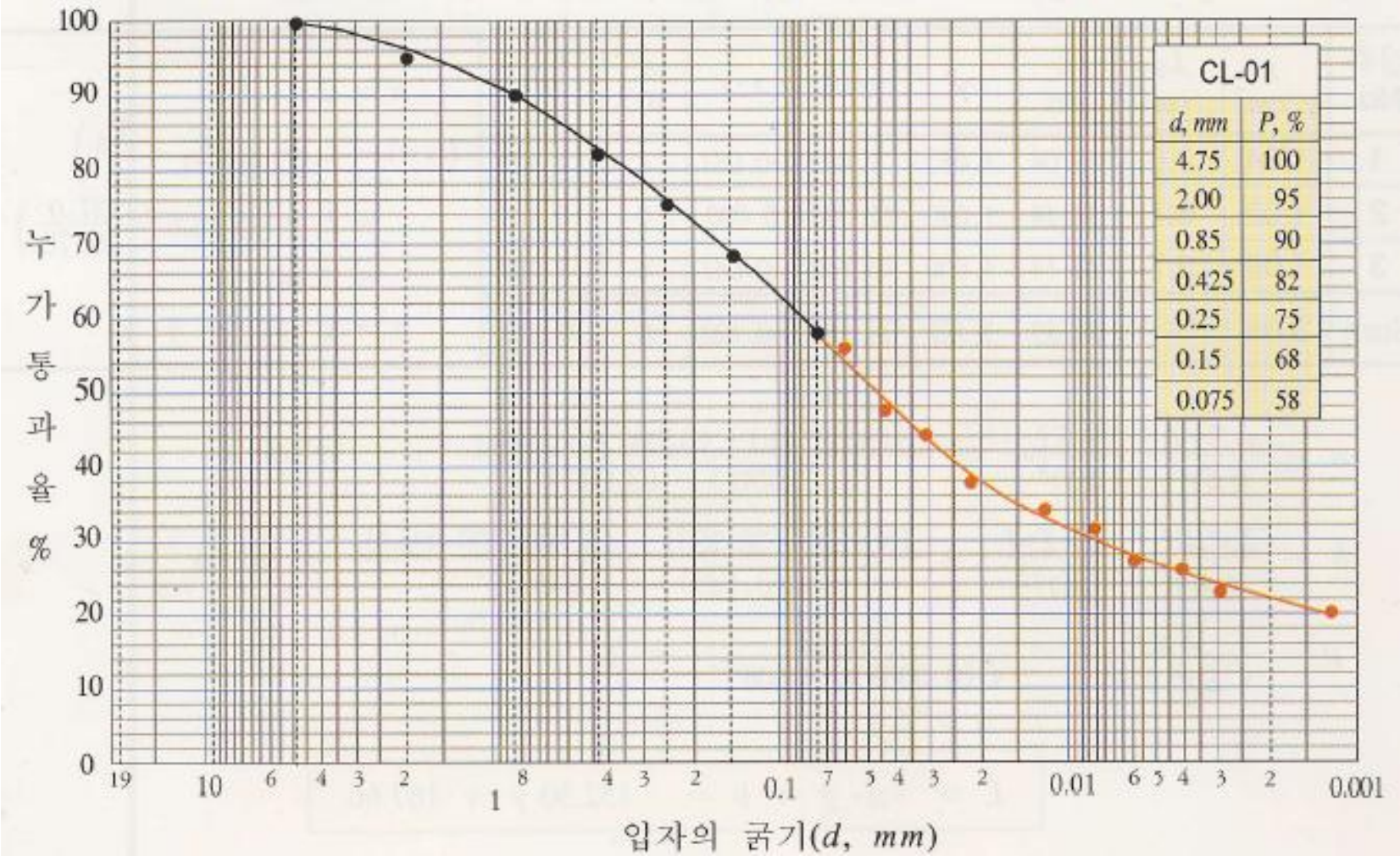
1 Bản Chất Vật Lý của Đất

- 흙 시료 : PI 15 % W_s 65 g G_s 2.74 $P_{2.0}$ 95 % 흙탕물 부피(V) 1000 cm^3
- 분산제 : 종류 ; calgon($NaPO_3$) - 용액 섞은 양 125 cc (47.5 g/l 용액), C_m 0.0005
- 수조 온도(T) 20 °C : μ 0.01009 $mm\ poise$, 수정 계수(F) 0.0008 , G_w 0.998234

$$M = \frac{100\,V\,G_s}{W_s(G_s - 1)} = 2423 \qquad C = \sqrt{\frac{30\,\mu}{980\,(G_s - G_w)\,\gamma_w}} = 0.01334$$

시간계획	종료시간 t, $min.$	읽음값 γ	γ' $\gamma - 1 + C_m$	침강깊이 L, cm	$C\sqrt{\frac{L}{t}}$ d, mm	⑦ $\gamma' + F$	누가 통과율, % $M \times$ ⑦	$P' \times P_{2.0}$
13/30/00	0.5	1.0230	0.0235	11.576	0.0642	0.0243	58.9	56
13/31	1	1.0195	0.0200	12.110	0.0464	0.0208	50.4	48
13/32	2	1.0180	0.0185	12.339	0.0331	0.0193	46.8	44
13/35	5	1.0150	0.0155	13.796	0.0222	0.0163	39.5	38
13/45	15	1.0135	0.0140	13.025	0.0124	0.0148	35.9	34
14/00	30	1.0125	0.0130	13.178	0.0088	0.0138	33.4	32
14/30	60	1.0105	0.0110	13.483	0.0064	0.0118	28.6	27
15/35	125	1.0100	0.0105	13.559	0.0044	0.0111	26.9	26
17/23	233	1.0090	0.0095	13.711	0.0032	0.0101	24.5	23
13/20	1430	1.0080	0.0085	13.864	0.0013	0.0088	21.3	20

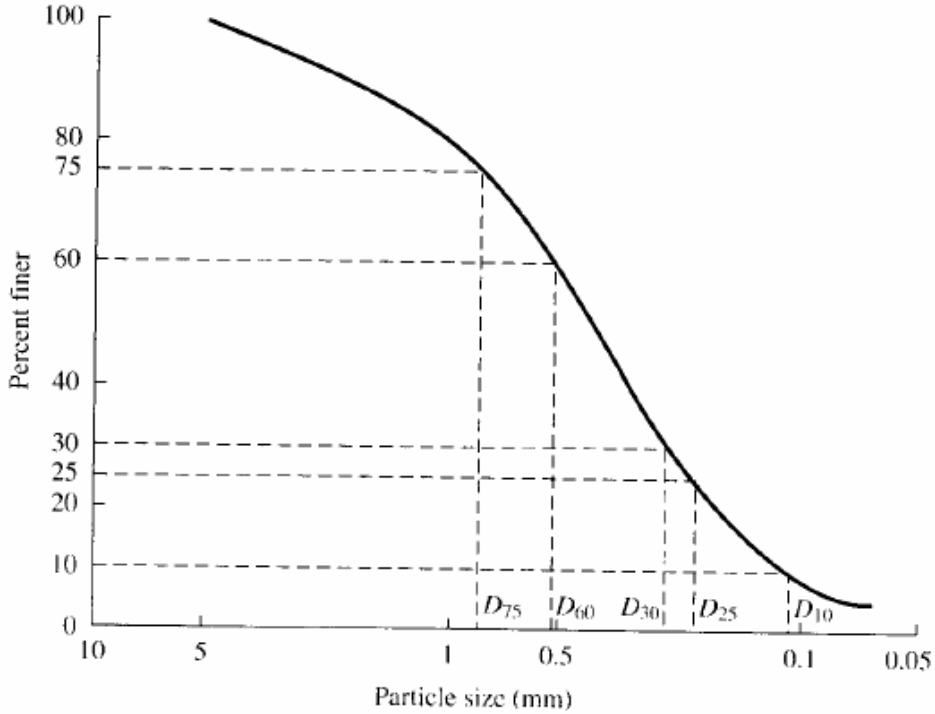
1 Bản Chất Vật Lý của Đất



1 Bản Chất Vật Lý của Đất

Đường cong cấp phối hạt

4 thông số được xác định từ đường cong cấp phối hạt



1. Đường kính hiệu quả D_{10} (effective size)
2. Hệ số đồng đều C_u (uniformity coefficient)

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

Cấp phối tốt khi $C_u > 4$: sỏi

$C_u > 6$: cát

3. Hệ số đường cong (coefficient of curvature)

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

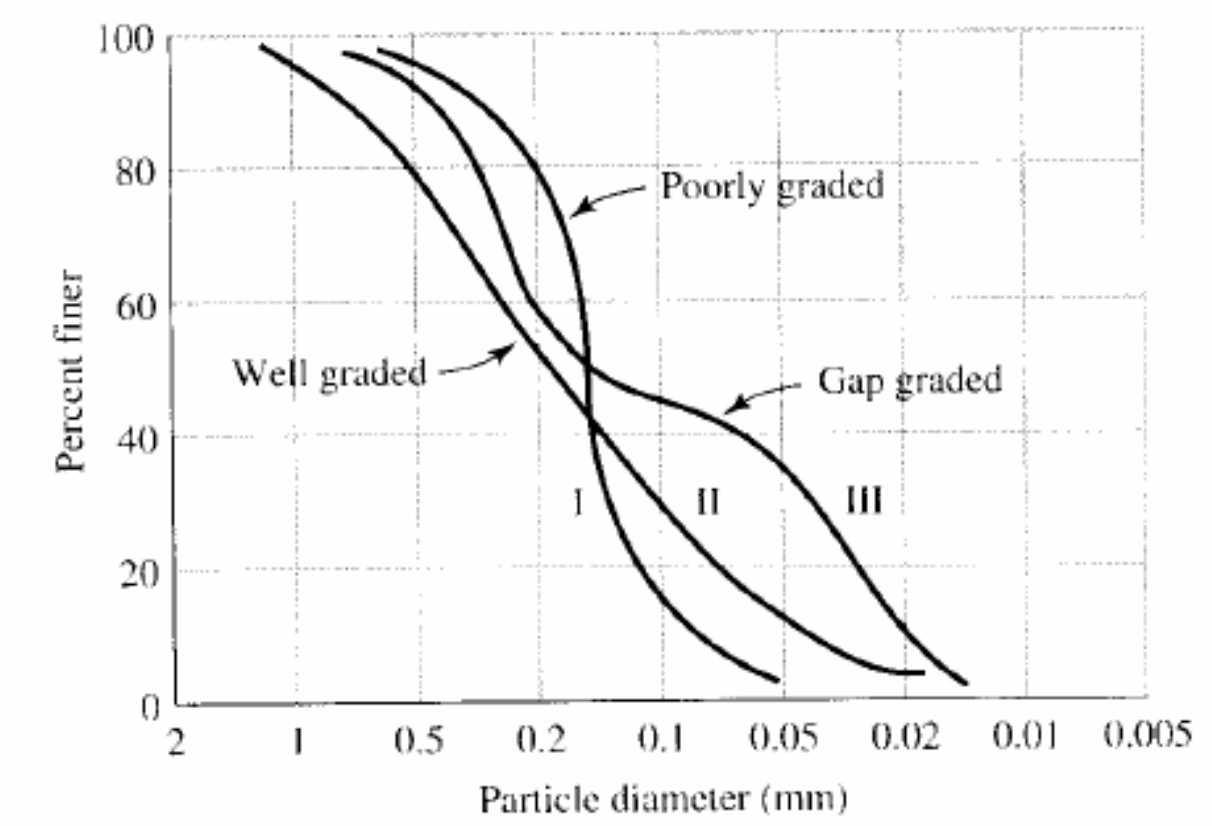
$1 < C_c < 3$: cấp phối hạt tốt

4. Terzaghi and Peck, D_{15} sử dụng để xác định cấp phối của vật liệu cho ổn định chống sối mòn

$$\frac{D_{15(F)}}{D_{85(BS)}} < 4-5$$ Ngăn ngừa bị xói mòn

$$\frac{D_{15(F)}}{D_{15(BS)}} > 4-5$$ Đãm bảo chịu được dòng nước chảy với tốc độ lớn

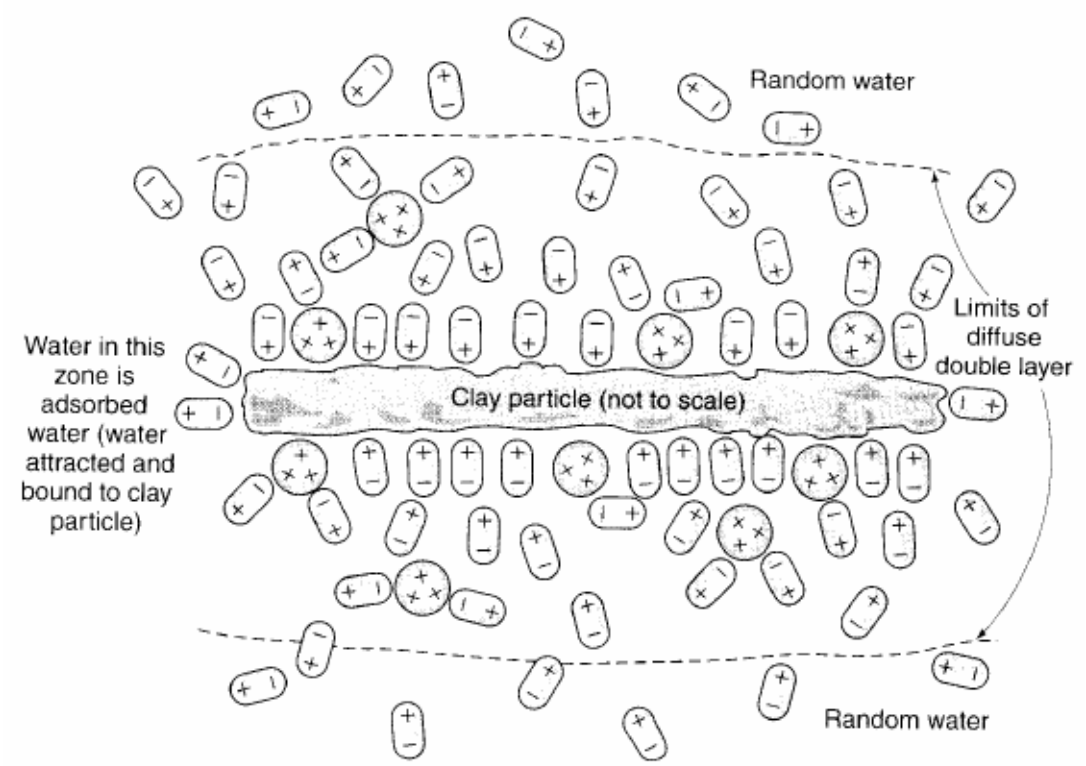
1 Bản Chất Vật Lý của Đất

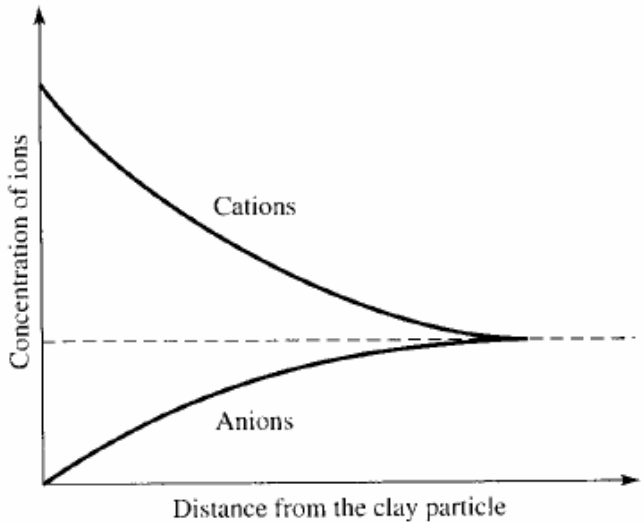


1 Bản Chất Vật Lý của Đất

1.2.2 Nước trong đất

- Ø Nước hút bám
- Ø Nước tự do
- Ø Nước mao dẫn





1 Bản Chất Vật Lý của Đất

1.3 Xác định các chỉ tiêu cơ bản của đất

- Độ ẩm $w = \frac{W_w}{W_s} \times 100\% = \frac{M_w}{M_s} \times 100\%$

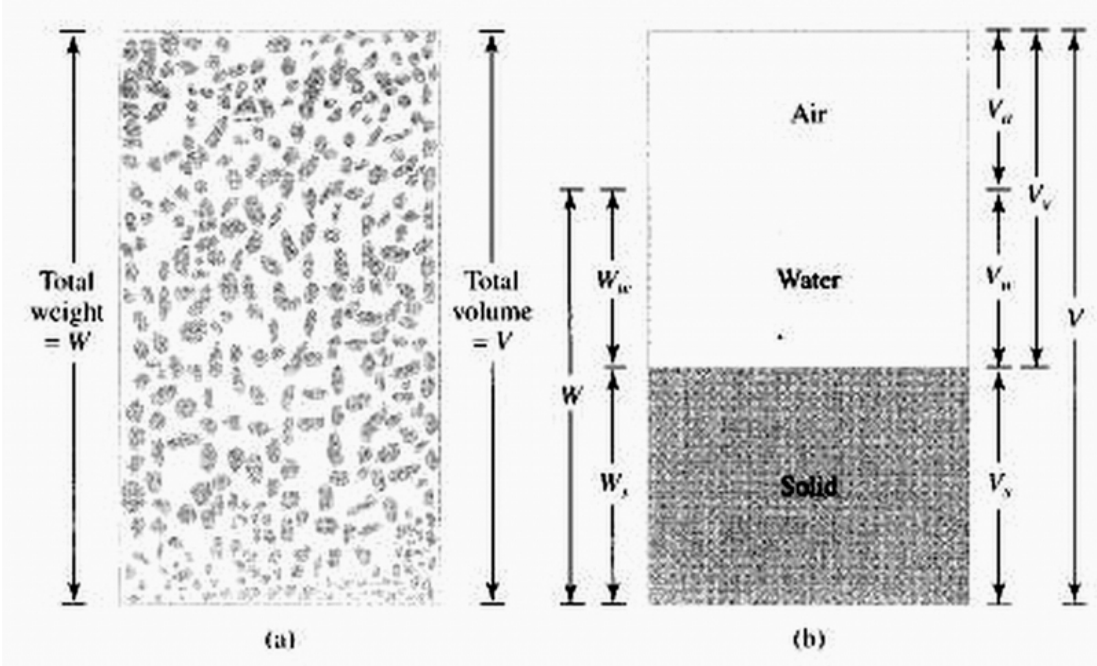
- Trọng lượng riêng (kN/m³)

$$g = \frac{W}{V} \qquad g_d = \frac{W_s}{V} \qquad g' = g_{sat} - g_w$$

- Khối lượng riêng (T/m³)

$$r = \frac{M}{V} \qquad r_d = \frac{M_s}{V}$$

$$\Rightarrow \quad g = r \times g$$



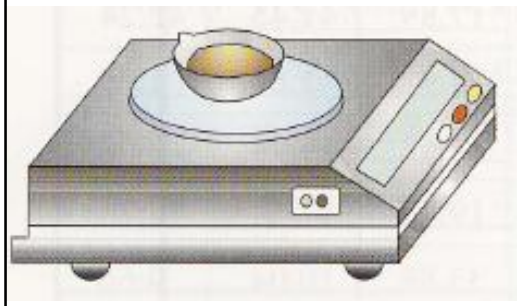
- Tỷ trọng

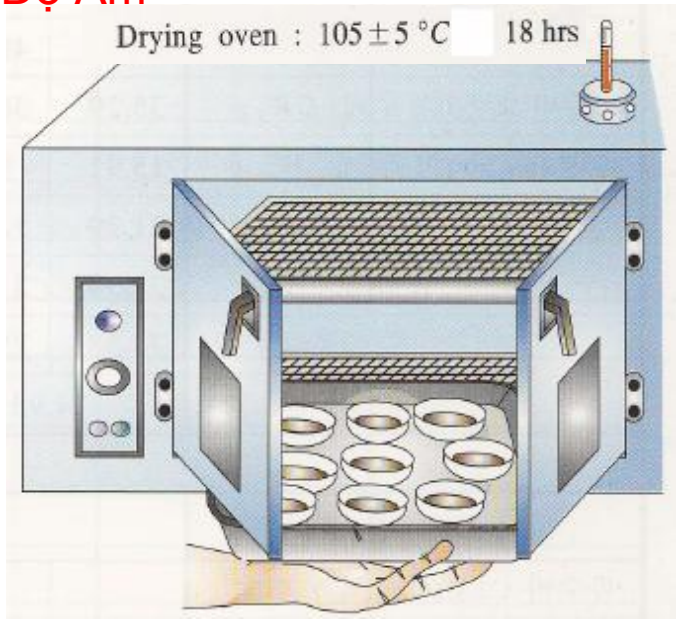
$$G_s = \frac{r_s}{r_w} = \frac{g_s}{g_w}$$

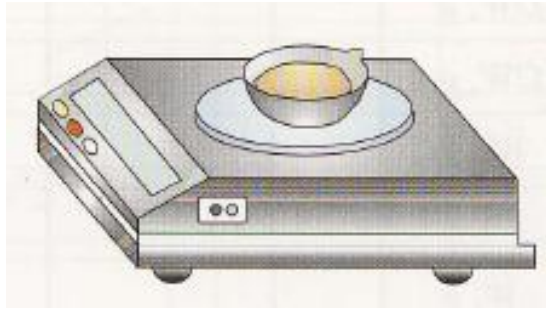
- Hệ số rỗng $e = \frac{V_v}{V_s}$
- Độ rỗng $n = \frac{V_v}{V}$
- Hàm lượng khí $A_v = \frac{V_a}{V}$
- Độ bảo hòa $S = \frac{V_w}{V_v} \times 100\%$

1 Bản Chất Vật Lý của Đất

- Thí Nghiệm Xác Định Độ Ẩm





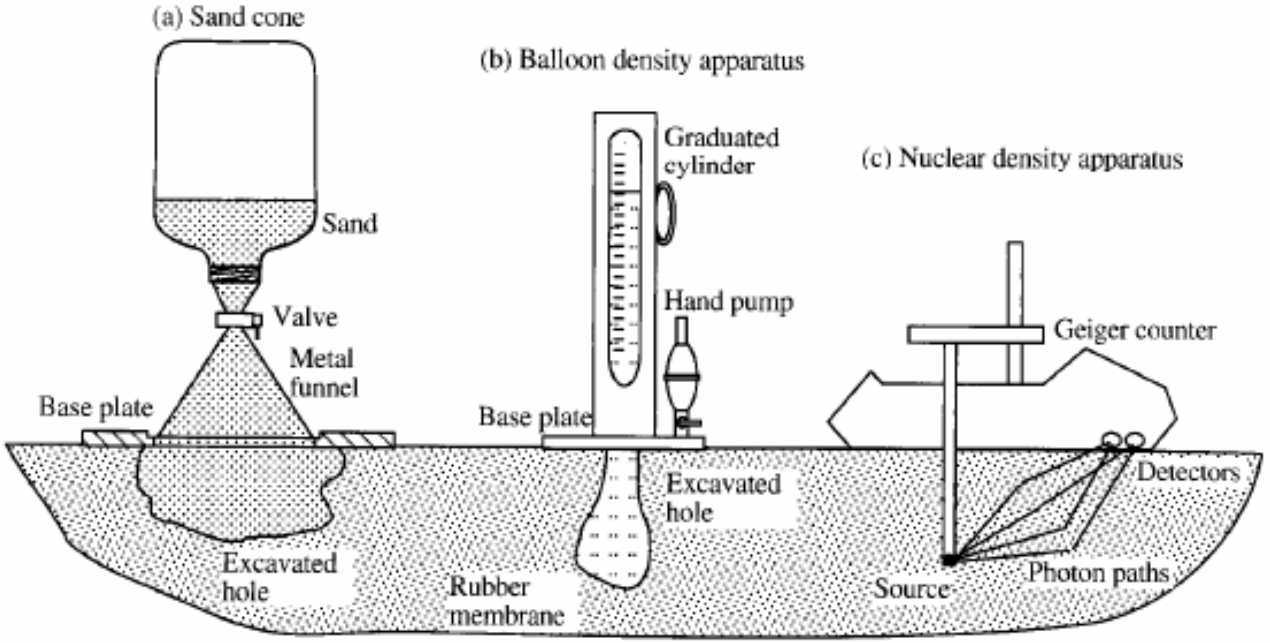


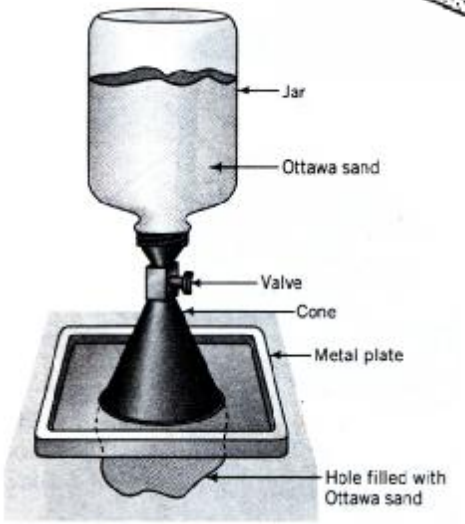
Item	Test No.		
	1	2	3
Can No.	42	31	54
Mass of can, W_1 (g)	17.31	18.92	16.07
Mass of can + wet soil, W_2 (g)	43.52	52.19	39.43
Mass of can + dry soil, W_3 (g)	39.86	47.61	36.13
Mass of moisture, $W_2 - W_3$ (g)	3.66	4.58	3.30
Mass of dry soil, $W_3 - W_1$ (g)	22.55	28.69	20.06
Moisture content, $w(\%) = \frac{W_2 - W_3}{W_3 - W_1} \times 100$	16.2	16.0	16.5

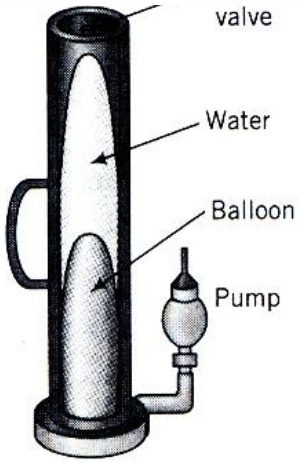
Average moisture content, w 16.2 %

1 Bản Chất Vật Lý của Đất

- Thí Nghiệm Xác Định Khối Lượng Riêng Ngoài Hiện Trường







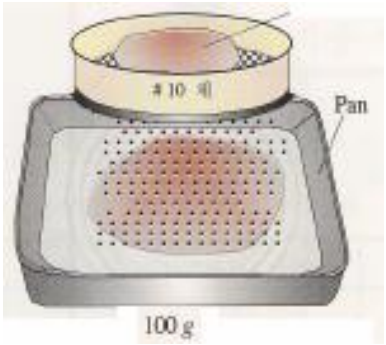
1 Bản Chất Vật Lý của Đất

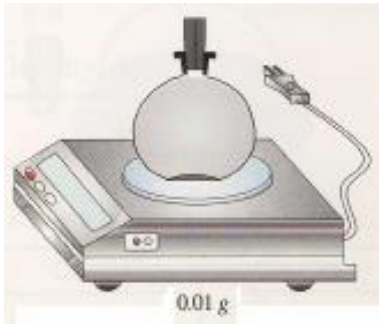
Field Unit Weight–Sand Cone Method

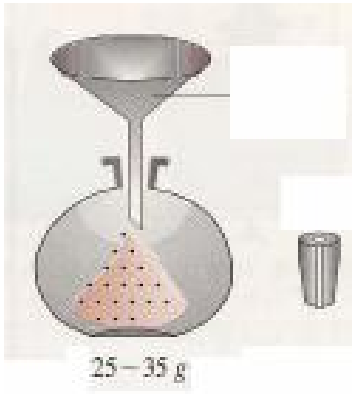
Item	Quantity
Calibration of Unit Weight of Ottawa Sand	
1. Weight of Proctor mold, W_1	10.35 lb
2. Weight of Proctor mold + sand, W_2	13.66 lb
3. Volume of mold, V_1	$1/30\ ft^3$
4. Dry unit weight, $\gamma_{d\,(sand)} = \dfrac{W_2 - W_1}{V_1}$	99.3 lb/ft^3
Calibration Cone	
5. Weight of bottle + cone + sand (before use), W_3	15.17 lb
6. Weight of bottle + cone + sand (after use), W_4	14.09 lb
7. Weight of sand to fill the cone, $W_c = W_4 - W_3$	1.08 lb
Results from Field Tests	
8. Weight of bottle + cone + sand (before use), W_6	15.42 lb
9. Weight of bottle + cone + sand (after use), W_8	11.74 lb
10. Volume of hole, $V_2 = \dfrac{W_6 - W_8 - W_c}{\gamma_{d\,(sand)}}$	0.0262 ft^3
11. Weight of gallon can, W_5	0.82 lb
12. Weight of gallon can + moist soil, W_7	3.92 lb
13. Weight of gallon can + dry soil, W_9	3.65 lb
14. Moist unit weight of soil in field, $\gamma = \dfrac{W_7 - W_5}{V_2}$	118.32 lb/ft^3
15. Moisture content in the field, $w\,(\%) = \dfrac{W_7 - W_9}{W_9 - W_5} \times 100$	9.54%
16. Dry unit weight in the field, $\gamma_{d\,(sand)} = \dfrac{\gamma}{1 + \dfrac{w\,(\%)}{100}}$	108.11 lb/ft^3

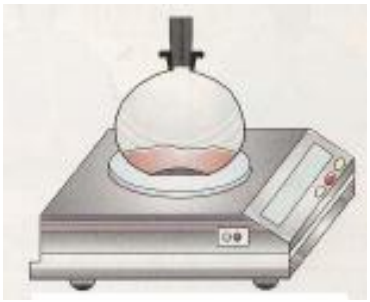
1 Bản Chất Vật Lý của Đất

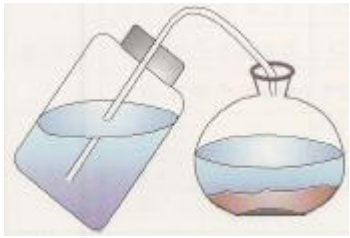
- Thí Nghiệm Xác Định Tỷ Trọng

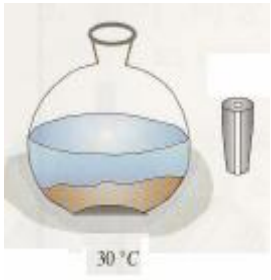


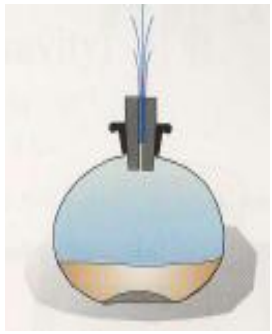


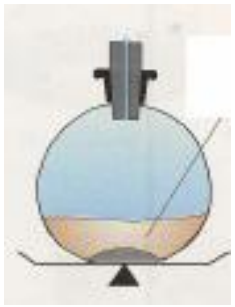


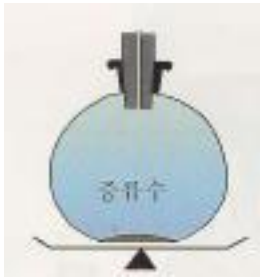












1 Bản Chất Vật Lý của Đất

$$G_s = \frac{\text{mass of soil, } W_s}{\text{mass of equal volume of soil}}$$

mass of equal volume of water, $W_w = (W_1 + W_s) - W_2$

$$G_{s(\text{at } T_1\,^\circ\text{C})} = \frac{W_s}{W_w}$$

W_1 (g) Mass of flask + water filled to mark,

W_2 (g) Mass of flask + soil + water filled to mark,

$$G_{s(\text{at } 20^\circ\text{c})} = G_{s(\text{at } T_1\,^\circ\text{C})}\left[\frac{\rho_{w(\text{at } T_1\,^\circ\text{C})}}{\rho_{w(\text{at } 20^\circ\text{C})}}\right] = G_{s(\text{at } T_1\,^\circ\text{C})}\, A$$

$$A = \frac{\rho_{w(\text{at } T_1\,^\circ\text{C})}}{\rho_{w(\text{at } T_{20}\,^\circ\text{C})}}$$

Temperature (T_1°C)	A	Temperature (T_1°C)	A
16	1.0007	24	0.9991
17	1.0006	25	0.9988
18	1.0004	26	0.9986
19	1.0002	27	0.9983
20	1.0000	28	0.9980
21	0.9998	29	0.9977
22	0.9996	30	0.9974
23	0.9993		

1 Bản Chất Vật Lý của Đất

Description of soil *Light brown sandy silt* Sample No. *23*

Volume of flask at 20°C *500* ml Temperature of test *23* °C *A* *0.9993*

Location _____

Tested by _____ Date _____

Item	Test No.		
	1	2	3
Volumetric flask No.	*6*	*8*	*9*
Mass of flask + water filled to mark, W_1 (g)	*666.0*	*674.0*	*652.0*
Mass of flask + soil + water filled to mark, W_2 (g)	*722.0*	*738.3*	*709.93*
Mass of dry soil, W_s (g)	*99.0*	*103.0*	*92.0*
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1 + W_s) - W_2$	*37.0*	*38.7*	*34.07*
$G_{s(T_1°C)} = W_s / W_w$	*2.68*	*2.66*	*2.70*
$G_{s(20°C)} = G_{s(T_1°C)} \times A$	*2.68*	*2.66*	*2.70*

Average G_s $\dfrac{(2.68 + 2.66 + 2.70)}{3} = 2.68$

1 Bản Chất Vật Lý của Đất

Type of soil	Void ratio, e	Natural moisture content in a saturated state (%)	Dry unit weight, γ_d	
			lb/ft^3	kN/m^3
Loose uniform sand	0.8	30	92	14.5
Dense uniform sand	0.45	16	115	18
Loose angular-grained silty sand	0.65	25	102	16
Dense angular-grained silty sand	0.4	15	121	19
Stiff clay	0.6	21	108	17
Soft clay	0.9–1.4	30–50	73–93	11.5–14.5
Loess	0.9	25	86	13.5
Soft organic clay	2.5–3.2	90–120	38–51	6–8
Glacial till	0.3	10	134	21

Specific Gravities of Soils

Sand	2.65
Silty Sand	2.66 - 2.68
Silt	2.67 - 2.68
Silty Clay	2.70 - 2.72
Clay	2.70 - 2.80

Gs > 2.80 - likely metals present

Gs < 2.70 - likely organics present

Average Gs for sand = 2.65

Average Gs for well mixed soil = 2.70

1 Bản Chất Vật Lý của Đất

- Mối quan hệ giữa các chỉ tiêu

$$e = \frac{V_v}{V_s} = \frac{n}{1-n} \Rightarrow n = \frac{e}{1+e}$$

$$\gamma = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{G_s\gamma_w + wG_s\gamma_w}{1+e} = \frac{(1+w)G_s\gamma_w}{1+e}$$

$$\gamma_d = \frac{W_s}{V} = \frac{G_s\gamma_w}{1+e} \qquad \gamma_d = \frac{\gamma}{1+w}$$

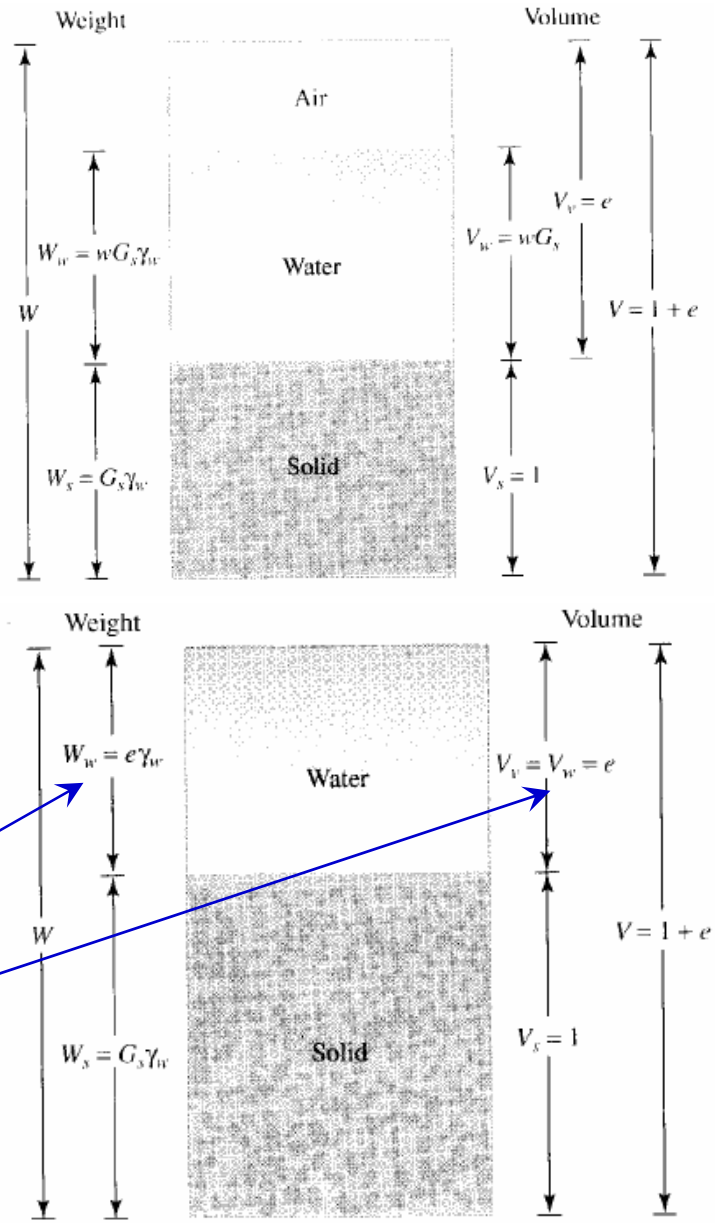
$$\gamma_{sat} = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{G_s\gamma_w + e\gamma_w}{1+e} = \frac{(G_s+e)\gamma_w}{1+e}$$

$$\rho_d = \frac{G_s\rho_w(1-A_v)}{1+wG_s}$$

$$S = \frac{V_w}{V_v} = \frac{wG_s}{e} \Rightarrow Se = wG_s$$

Ø **Khi đất bảo hòa: S=1**

$$e = wG_s$$



1 Bản Chất Vật Lý của Đất

Moist unit weight (γ)		Dry unit weight (γ_d)		Saturated unit weight (γ_{sat})	
Given	Relationship	Given	Relationship	Given	Relationship
w, G_s, e	$\dfrac{(1+w)G_s\gamma_w}{1+e}$	γ, w	$\dfrac{\gamma}{1+w}$	G_s, e	$\dfrac{(G_s+e)\gamma_w}{1+e}$
S, G_s, e	$\dfrac{(G_s+Se)\gamma_w}{1+e}$	G_s, e	$\dfrac{G_s\gamma_w}{1+e}$	G_s, n	$[(1-n)G_s+n]\gamma_w$
w, G_s, S	$\dfrac{(1+w)G_s\gamma_w}{1+\dfrac{wG_s}{S}}$	G_s, n	$G_s\gamma_w(1-n)$	G_s, w_{sat}	$\left(\dfrac{1+w_{sat}}{1+w_{sat}G_s}\right)G_s\gamma_w$
w, G_s, n	$G_s\gamma_w(1-n)(1+w)$	G_s, w, S	$\dfrac{G_s\gamma_w}{1+\left(\dfrac{wG_s}{S}\right)}$	e, w_{sat}	$\left(\dfrac{e}{w_{sat}}\right)\left(\dfrac{1+w_{sat}}{1+e}\right)\gamma_w$
S, G_s, n	$G_s\gamma_w(1-n)+nS\gamma_w$	e, w, S	$\dfrac{eS\gamma_w}{(1+e)w}$	n, w_{sat}	$n\left(\dfrac{1+w_{sat}}{w_{sat}}\right)\gamma_w$
		γ_{sat}, e	$\gamma_{sat}-\dfrac{e\gamma_w}{1+e}$	γ_d, e	$\gamma_d+\left(\dfrac{e}{1+e}\right)\gamma_w$
		γ_{sat}, n	$\gamma_{sat}-n\gamma_w$	γ_d, n	$\gamma_d+n\gamma_w$
		γ_{sat}, G_s	$\dfrac{(\gamma_{sat}-\gamma_w)G_s}{(G_s-1)}$	γ_d, S	$\left(1-\dfrac{1}{G_s}\right)\gamma_d+\gamma_w$
				γ_d, w_{sat}	$\gamma_d(1+w_{sat})$

1 Bản Chất Vật Lý của Đất

Thí dụ 1

The mass of a moist soil sample having a volume of 0.0057 m^3 is 10.5 kg. The moisture content (w) and the specific gravity of soil solids (G_s) were determined to be 13% and 2.68, respectively. Determine

a. Moist density, ρ (kg/m^3)
b. Dry density, ρ_d (kg/m^3)
c. Void ratio, e
d. Porosity, n
e. Degree of saturation, S (%)

1 Bản Chất Vật Lý của Đất

Solution

a.
$$\rho = \frac{M}{V} = \frac{10.5}{0.0057} = \mathbf{1842\ kg/m^3}$$

b.
$$\rho_d = \frac{\rho}{1 + w} = \frac{1842}{1 + \frac{13}{100}} = \mathbf{1630\ kg/m^3}$$

c.
$$e = \frac{G_s \gamma_w}{\rho_d} - 1 = \frac{(2.68)(1000)}{1630} - 1 = \mathbf{0.64}$$

d.
$$n = \frac{e}{1 + e} = \frac{0.64}{1 + 0.64} = \mathbf{0.39}$$

e.
$$S(\%) = \frac{wG_s}{e} \times 100 = \frac{(0.13)(2.68)}{0.64} \times 100 = \mathbf{54.4\%}$$

1 Bản Chất Vật Lý của Đất

Thí dụ 2

The saturated unit weight, γ_{sat}, of a soil is 19.5 kN/m^3, and the specific gravity of soil solids is 2.65.

a. Derive an expression for γ_d in terms of γ_{sat}, γ_w, and G_s.
b. Using the expression derived in part (a), determine the dry unit weight of the soil.

1 Bản Chất Vật Lý của Đất

Solution

a.

$$\gamma_{sat} = \frac{G_s\gamma_w + e\gamma_w}{1 + e}$$

$$\gamma_{sat} - \gamma_w = \frac{G_s\gamma_w + e\gamma_w}{1 + e} - \gamma_w = \frac{G_s\gamma_w + e\gamma_w - \gamma_w - e\gamma_w}{1 + e} = \frac{\gamma_w(G_s - 1)}{1 + e}$$

$$\gamma_{sat} - \gamma_w = \frac{\gamma_w(G_s - 1)G_s}{(1 + e)G_s} = \frac{\gamma_d(G_s - 1)}{G_s}$$

or

$$\gamma_d = \frac{(\gamma_{sat} - \gamma_w)G_s}{G_s - 1}$$

b. Given that $\gamma_{sat} = 19.5\ \text{kN/m}^3$ and $G_s = 2.65$,

$$\gamma_d = \frac{(\gamma_{sat} - \gamma_w)G_s}{G_s - 1} = \frac{(19.5 - 9.81)(2.65)}{2.65 - 1} = 15.56\ \text{kN/m}^3$$

1 Bản Chất Vật Lý của Đất

Thí dụ 3

In its natural state, a moist soil has a volume of 0.33 ft^3 and weighs 39.93 lb. The oven-dried weight of the soil is 34.54 lb. If $G_s = 2.67$, calculate

a. Moisture content (%)
b. Moist unit weight (lb/ft^3)
c. Dry unit weight (lb/ft^3)
d. Void ratio
e. Porosity
f. Degree of saturation (%)

1 Bản Chất Vật Lý của Đất

Solution

a. $$w = \frac{W_w}{W_s} = \frac{39.93 - 34.54}{34.54}(100) = \mathbf{15.6\%}$$

b. $$\gamma = \frac{W}{V} = \frac{39.93}{0.33} = \mathbf{121\ lb/ft^3}$$

c. $$\gamma_d = \frac{W_s}{V} = \frac{34.54}{0.33} = \mathbf{104.7\ lb/ft^3}$$

d. The volume of solids is

$$V_s = \frac{W_s}{G_s\gamma_w} = \frac{34.54}{(2.67)(62.4)} = 0.207\ \text{ft}^3$$

Thus,

$$V_v = V - V_s = 0.33 - 0.207 = 0.123\ \text{ft}^3$$

The volume of water is

$$V_w = \frac{W_w}{\gamma_w} = \frac{39.93 - 34.54}{62.4} = 0.086\ \text{ft}^3$$

$$e = \frac{V_v}{V_s} = \frac{0.123}{0.207} = \mathbf{0.59}$$

e. $$n = \frac{V_v}{V} = \frac{0.123}{0.33} = \mathbf{0.37}$$

f. $$S = \frac{V_w}{V_v} = \frac{0.086}{0.123} = 0.699 = \mathbf{69.9\%}$$

1 Bản Chất Vật Lý của Đất

Thí dụ 4

For a saturated soil, given $w = 40\%$ and $G_s = 2.71$, determine the saturated and dry unit weights in lb/ft^3 and kN/m^3.

1 Bản Chất Vật Lý của Đất

Solution

For saturated soil,

$$e = wG_s = (0.4)(2.71) = 1.084$$

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1 + e} = \frac{(2.71 + 1.084)62.4}{1 + 1.084} = \mathbf{113.6\ lb/ft^3}$$

Also,

$$\gamma_{sat} = (113.6)\left(\frac{9.81}{62.4}\right) = \mathbf{17.86\ kN/m^3}$$

$$\gamma_d = \frac{G_s\gamma_w}{1 + e} = \frac{(2.71)(62.4)}{1 + 1.084} = \mathbf{81.1\ lb/ft^3}$$

Also,

$$\gamma_d = (81.1)\left(\frac{9.81}{62.4}\right) = \mathbf{12.75\ kN/m^3}$$

1 Bản Chất Vật Lý của Đất

Thí dụ 5

The mass of a moist soil sample collected from the field is 465 grams, and its oven dry mass is 405.76 grams. The specific gravity of the soil solids was determined in the laboratory to be 2.68. If the void ratio of the soil in the natural state is 0.83, find the following:

a. The moist density of the soil in the field (kg/m^3)
b. The dry density of the soil in the field (kg/m^3)
c. The mass of water, in kilograms, to be added per cubic meter of soil in the field for saturation

1 Bản Chất Vật Lý của Đất

Solution

Part a

$$w = \frac{M_w}{M_s} = \frac{465 - 405.76}{405.76} = \frac{59.24}{405.76} = 14.6\%$$

$$\rho = \frac{G_s\rho_w + wG_s\rho_w}{1 + e} = \frac{G_s\rho_w(1 + w)}{1 + e} = \frac{(2.68)(1000)(1.146)}{1.83}$$

$$= \mathbf{1678.3\ kg/m^3}$$

Part b

$$\rho_d = \frac{G_s\rho_w}{1 + e} = \frac{(2.68)(1000)}{1.83} = \mathbf{1468.48\ kg/m^3}$$

Part c

Mass of water to be added = $\rho_{sat} - \rho$

$$\rho_{sat} = \frac{G_s\rho_w + e\rho_w}{1 + e} = \frac{\rho_w(G_s + e)}{1 + e} = \frac{(1000)(2.68 + 0.83)}{1.83} = 1918\ \text{kg/m}^3$$

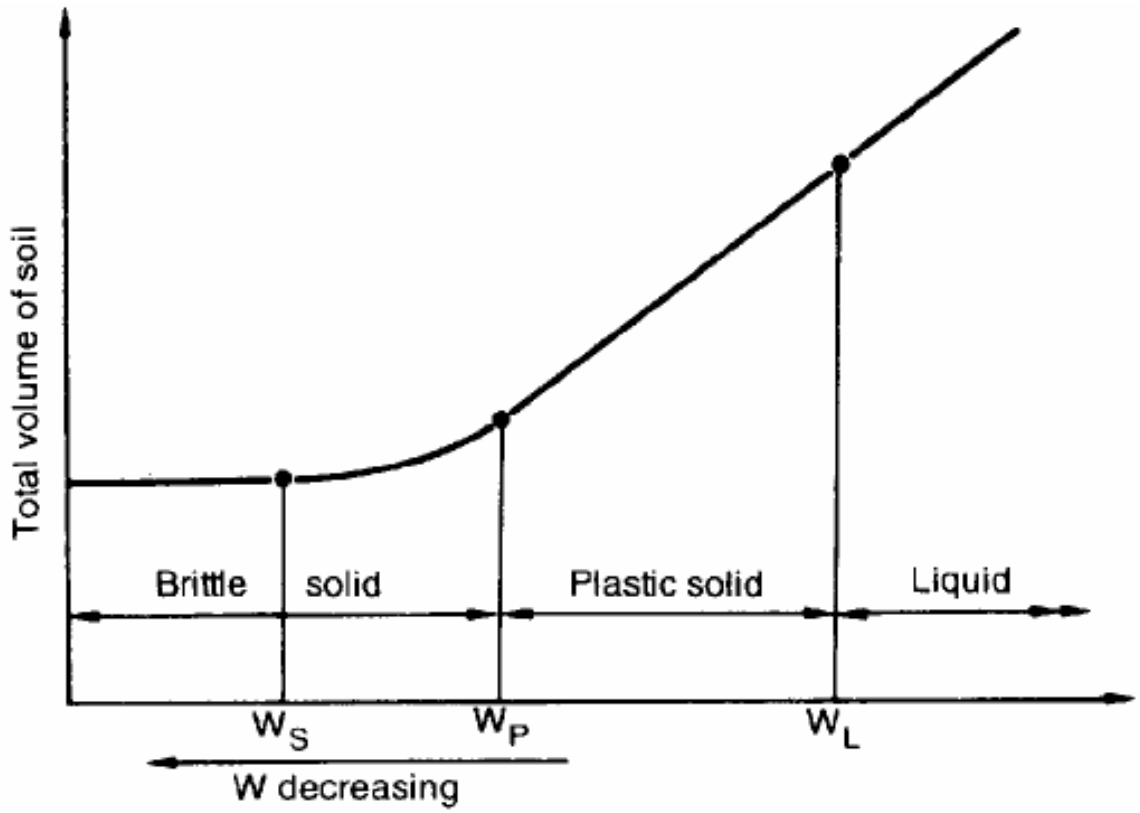
So the mass of water to be added = 1918 − 1678.3 = **239.7 kg/m³**.

1 Bản Chất Vật Lý của Đất

1.4 Xác định các chỉ tiêu đánh giá trạng thái của đất

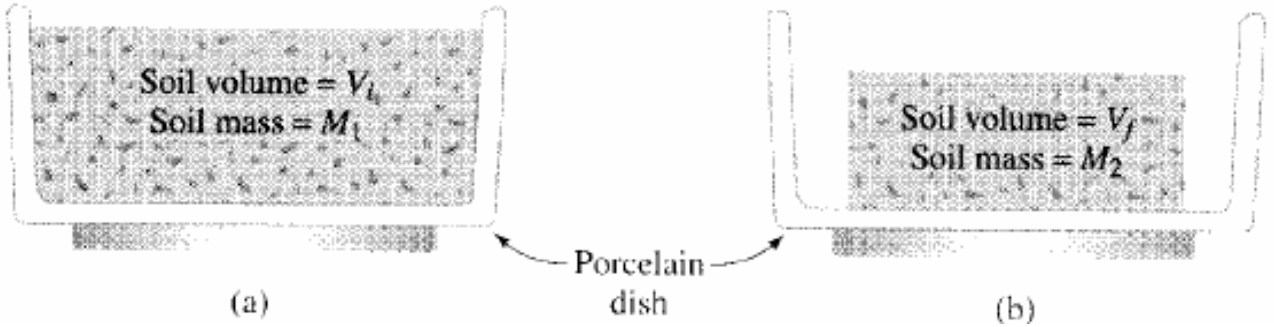
1.4.1 Trạng thái của đất dính

Cac giới hạn Atterbert



1 Bản Chất Vật Lý của Đất

- **Giới hạn co (SL, W_S)**



$$SL = w_i(\%) - \Delta w(\%)$$

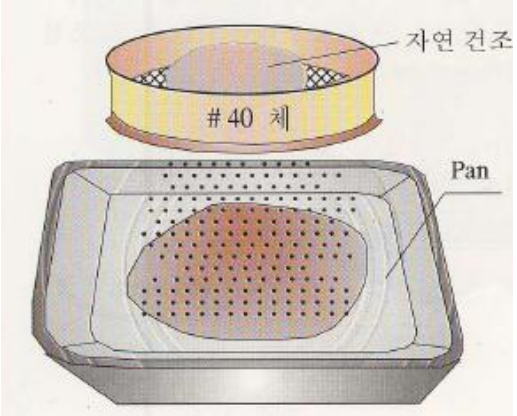
$$\Delta w(\%) = \frac{(V_i - V_f)\rho_w}{M_2} \times 100$$

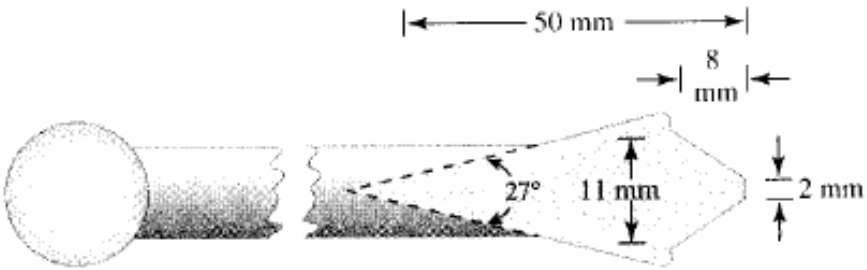
$$w_i(\%) = \frac{M_1 - M_2}{M_2} \times 100$$

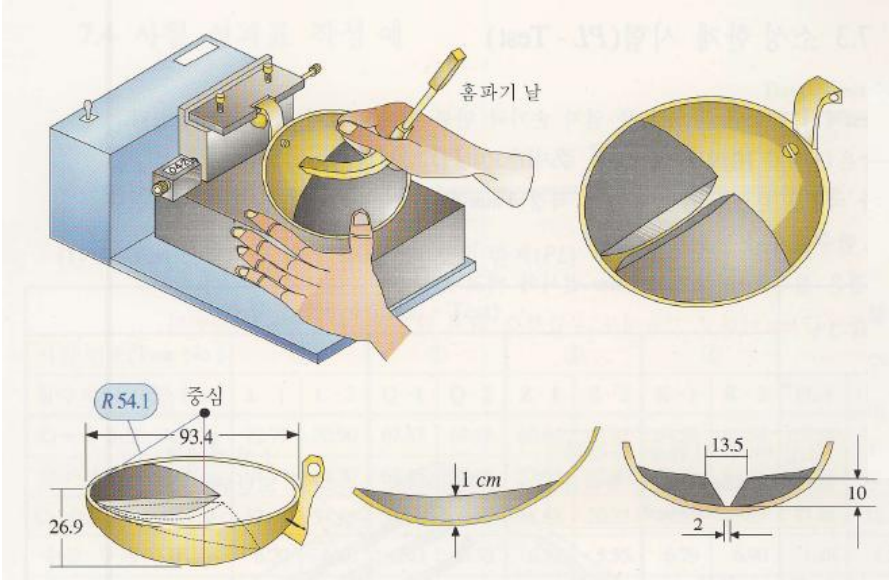
$$SL = \left(\frac{M_1 - M_2}{M_2}\right)(100) - \left(\frac{V_i - V_f}{M_2}\right)(\rho_w)(100)$$

1 Bản Chất Vật Lý của Đất

Giới hạn nhảo (LL, W_L)

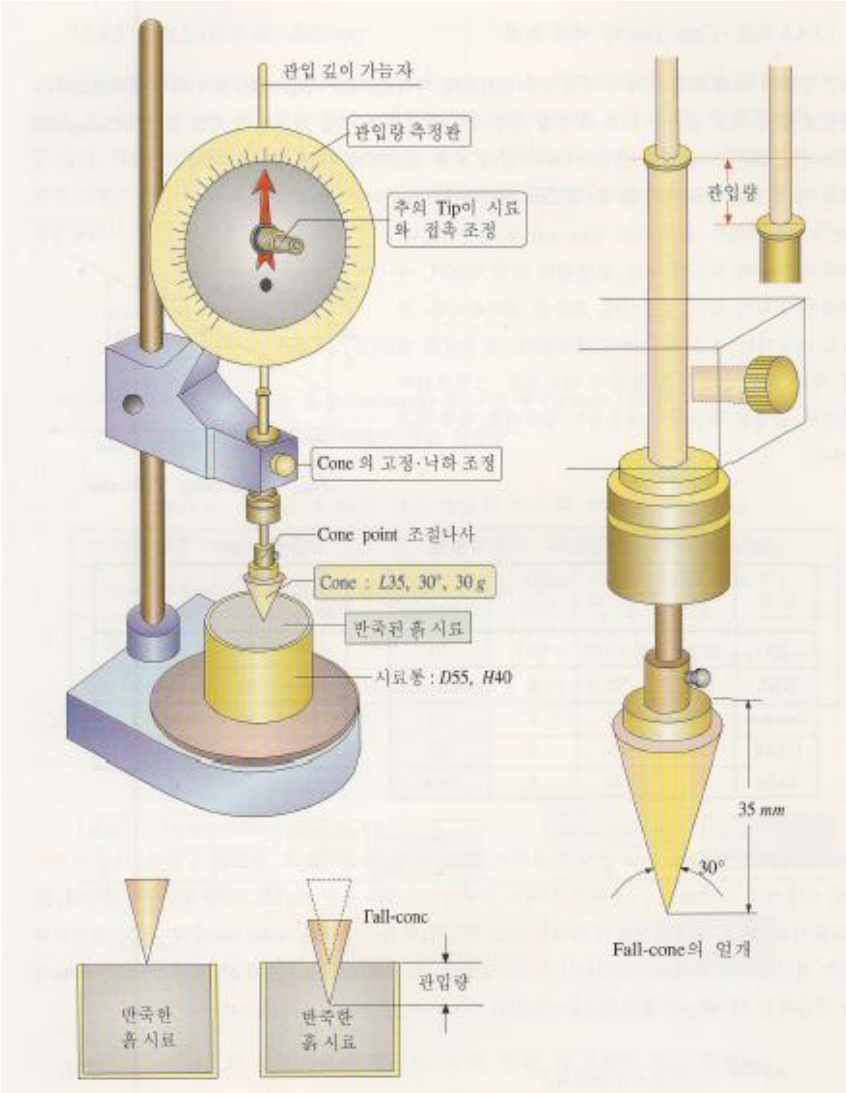




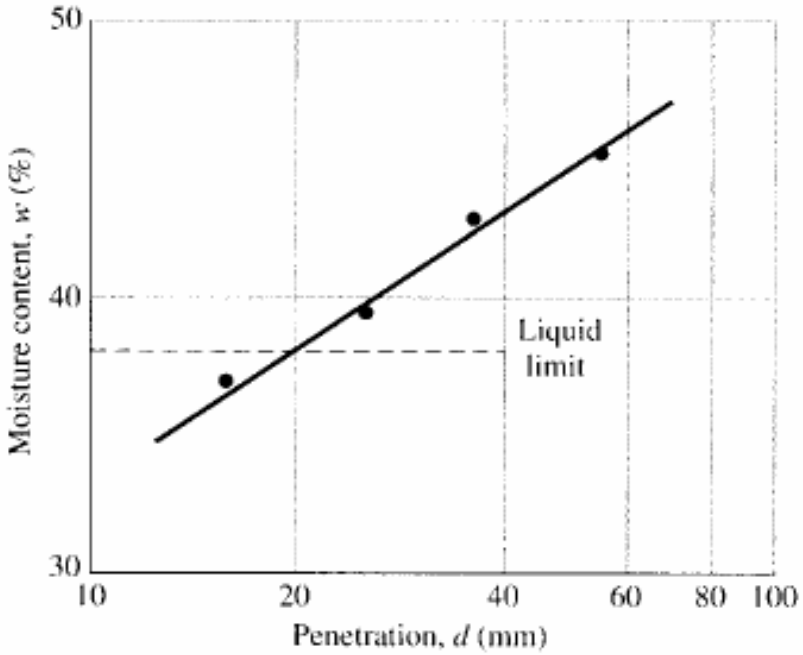


1 Bản Chất Vật Lý của Đất

Giới hạn nhảo (2)



문헌	Cone 크기		관입시간	LL 대응 관입량,mm
	θ, °	W, g	sec	
BS	30±1	80±0.05	5±1	20
USA	30	75	5	10
Sweden	60	60	5	10
USSR	30	76	5	10
India	31	148	5	25.4

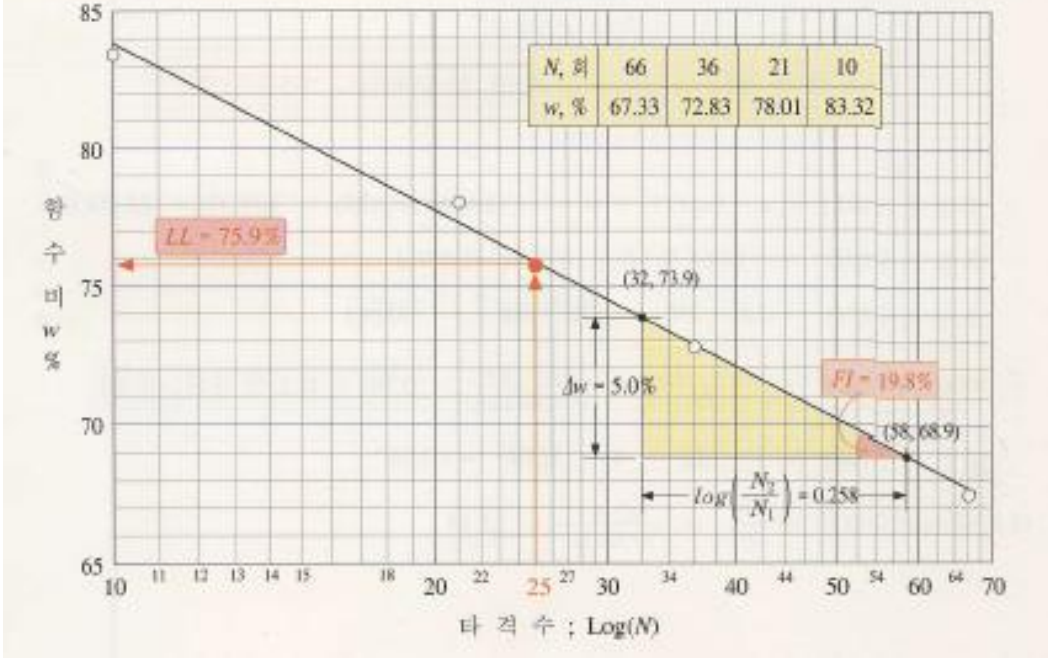


1 Bản Chất Vật Lý của Đất

- **Giới hạn dẻo (PL, W_P)**

1 Bản Chất Vật Lý của Đất

액성 한계 시험(*LL* - Test)										*PL*-Test	
시험 번호(Test No.)		①		②		③		④			
함수비 풍'Ⓒ' No.		L - 1	L - 2	Q - 1	Q - 2	Z - 1	Z - 2	K - 1	K - 2	PL-1	PL-2
Ⓒ+습윤토 *WW*, *g*		72.77	70.90	67.87	64.18	60.64	62.85	64.58	61.38	23.36	23.33
Ⓒ+건조토 *DW*, *g*		64.57	64.30	61.45	57.65	57.65	57.30	57.79	54.48	21.88	22.01
Can(Ⓒ), *CW*, *g*		52.45	54.45	52.64	48.68	48.68	50.22	49.59	46.25	17.44	18.13
수분 무게 W_w, *g*		8.20	6.60	6.42	6.53	6.53	5.55	6.79	6.90	1.48	1.32
건조토 무게 W_s, *g*		12.12	9.85	8.81	8.97	9.97	7.08	8.20	8.23	4.44	3.88
함수비 *w*, %	각각	67.66	67.01	72.87	62.80	77.562	78.39	82.80	83.84	33.33	34.02
	평균	67.33		72.83		78.01		83.32		33.68	
Brass-cup 낙하수(*N*)		66		36		21		10			



1 Bản Chất Vật Lý của Đất

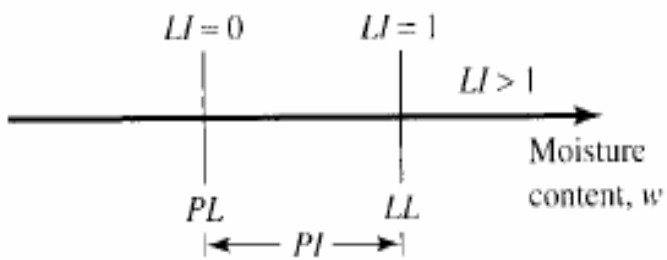
- **Chỉ số dẻo**

$$PI = LL - PL$$

PI	Description
0	Nonplastic
1–5	Slightly plastic
5–10	Low plasticity
10–20	Medium plasticity
20–40	High plasticity
>40	Very high plasticity

- **Chỉ số nhão**

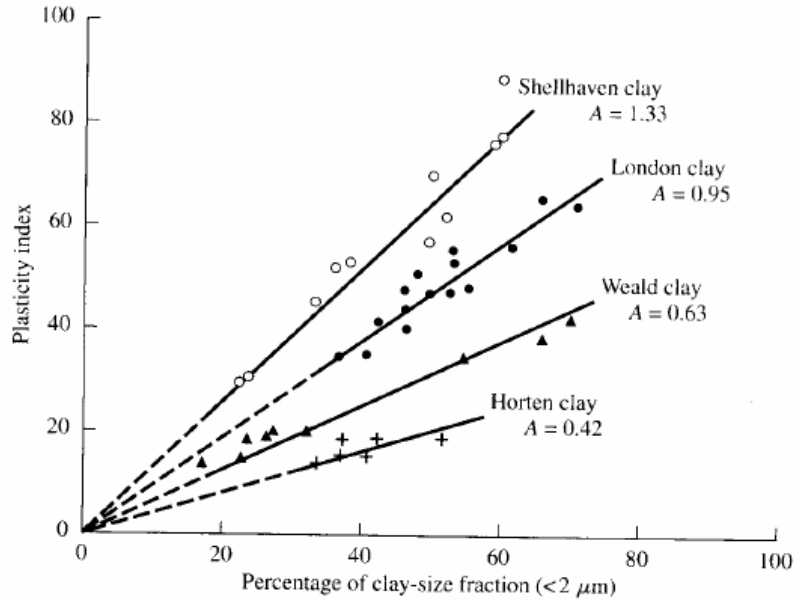
$$LI = \frac{w - PL}{LL - P}$$



- **Độ hoạt động (Skempton)**

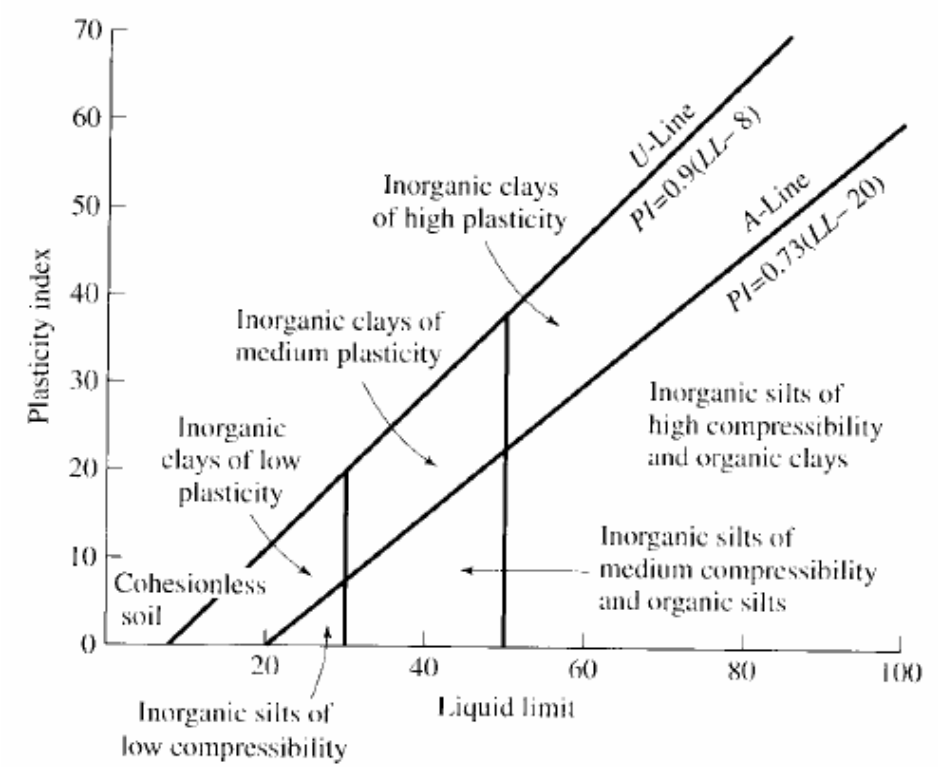
$$A = \frac{PI}{(\%\text{ of clay-size fraction, by weight})}$$

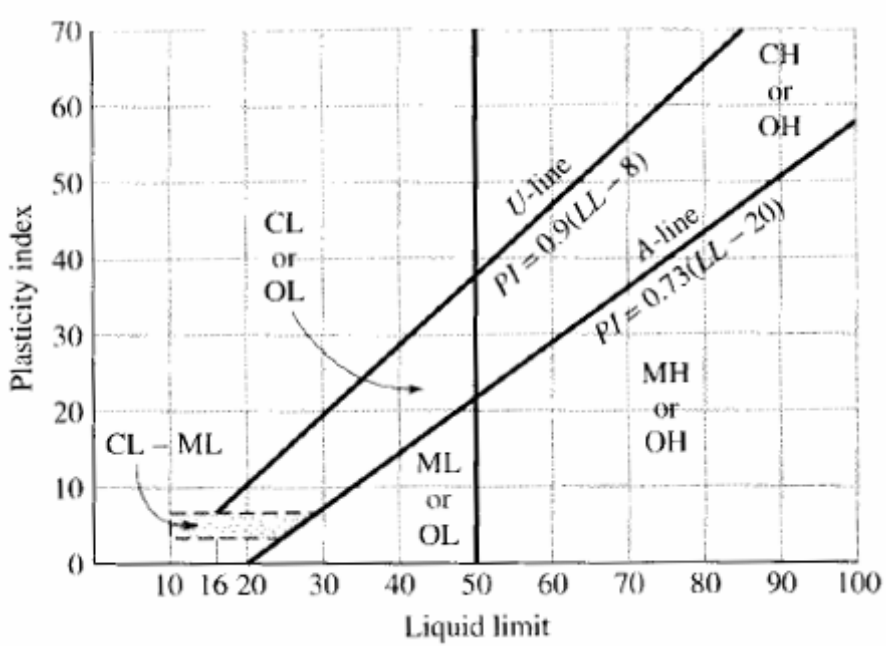
Activity	*Classification*
<0.75	Inactive clays
0.75–1.25	Normal clays
>1.25	Active clays



1 Bản Chất Vật Lý của Đất

Biểu đồ dẻo





1 Bản Chất Vật Lý của Đất

1.4.2 Trạng thái của đất rời

- **Độ chặt tương đối**

$$D_R\% = \frac{e_{max} - e_0}{e_{max} - e_{min}} \times 100\%$$

$$D_R\% = \frac{\frac{1}{\gamma_{min}} - \frac{1}{\gamma_0}}{\frac{1}{\gamma_{min}} - \frac{1}{\gamma_{max}}}(100\%)$$

$$D_R\% = \frac{\frac{1}{\rho_{min}} - \frac{1}{\rho_0}}{\frac{1}{\rho_{min}} - \frac{1}{\rho_{max}}}(100\%)$$

Relative density (%)	Description of soil deposit
0–15	Very loose
15–50	Loose
50–70	Medium
70–85	Dense
85–100	Very dense

1 Bản Chất Vật Lý của Đất

Thí dụ

An undisturbed sample of fine sand is tested in the laboratory and found to have a dry mass of 3.63 kg (dry weight of 8 lb), a total volume of 0.00198 m^3 (0.07 ft^3), and a specific gravity G_s of 2.70. Other laboratory tests are performed to determine the maximum and minimum density for the sand. At the maximum density, it is determined that the void ratio is 0.35; at the minimum density, the void ratio is 0.95. Determine the relative density of the undisturbed sample.

1 Bản Chất Vật Lý của Đất

Solution

Void ratio of undisturbed sample e_0:

$$V_T = .00198\ \text{m}^3$$

$$V_S = \frac{M_S}{G_S \rho_W} = \frac{3.63\ \text{kg}}{(2.70)(10^3\ \text{kg/m}^3)} = .00134\ \text{m}^3$$

$$V_V = V_T - V_S = 0.00198\ \text{m}^3 - 0.00134\ \text{m}^3 = 0.000636\ \text{m}^3$$

$$e_0 = \frac{V_V}{V_S} = \frac{0.636 \times 10^{-3}\ \text{m}^3}{1.34 \times 10^{-3}\ \text{m}^3} = .475$$

$$D_R\% = \frac{e_{\max} - e_0}{e_{\max} - e_{\min}}(100\%) = \frac{(0.95 - 0.475)}{(0.95 - 0.35)}(100\%) = 79\%$$

$$\text{Dry density} = \frac{M_S}{V_T} = \frac{3.63\ \text{kg}}{0.00198\ \text{m}^3} = 1.83\ \text{Mg/m}^3$$

1 Bản Chất Vật Lý của Đất

1.5 Phân loại đất

Unified Soil Classification System

$F_{200} < 50$	Gravels	GW	$F_{200} < 5$; $C_u \geq 4$; $1 \leq C_z \leq 3$
		GP	$F_{200} < 5$; Not meeting the GW criteria of C_u and C_z
	$\frac{R_4}{R_{200}} > 0.5$	GM	$F_{200} > 12$; $PI < 4$ or plots *below* A-line (Fig. 4.2)
		GC	$F_{200} > 12$; $PI > 7$ and plots *on or above* A-line (Fig. 4.2)
		GM-GC	$F_{200} > 12$; PI plots in the hatched area (Fig. 4.2)
		GW-GM	$5 \leq F_{200} \leq 12$; satisfies C_u and C_z criteria of GW and meets the PI criteria for GM
		GW-GC	$5 \leq F_{200} \leq 12$; satisfies C_u and C_z criteria of GW and meets the PI criteria for GC
		GP-GM	$5 \leq F_{200} \leq 12$; does not satisfy C_u and C_z criteria of GW and meets the PI criteria for GM
		GP-GC	$5 \leq F_{200} \leq 12$; does not satisfy C_u and C_z criteria of GW and meets the PI criteria for GC
	Sands	SW	$F_{200} < 5$; $C_u \geq 6$; $1 \leq C_z \leq 3$
		SP	$F_{200} < 5$; Not meeting the SW criteria of C_u and C_z
	$\frac{R_4}{R_{200}} \leq 0.5$	SM	$F_{200} > 12$; $PI < 4$ or plots *below* A-line (Fig. 4.2)
		SC	$F_{200} > 12$; $PI > 7$ and plots *on or above* A-line (Fig. 4.2)
		SM-SC	$F_{200} > 12$; PI plots in the hatched area (Fig. 4.2)
		SW-SM	$5 \leq F_{200} \leq 12$; satisfies C_u and C_z criteria of SW and meets the PI criteria for SM
		SW-SC	$5 \leq F_{200} \leq 12$; satisfies C_u and C_z criteria of SW and meets the PI criteria for SC
		SP-SM	$5 \leq F_{200} \leq 12$; does not satisfy C_u and C_z criteria of SW and meets the PI criteria for SM
		SP-SC	$5 \leq F_{200} \leq 12$; does not satisfy C_u and C_z criteria of SW and meets the PI criteria for SC

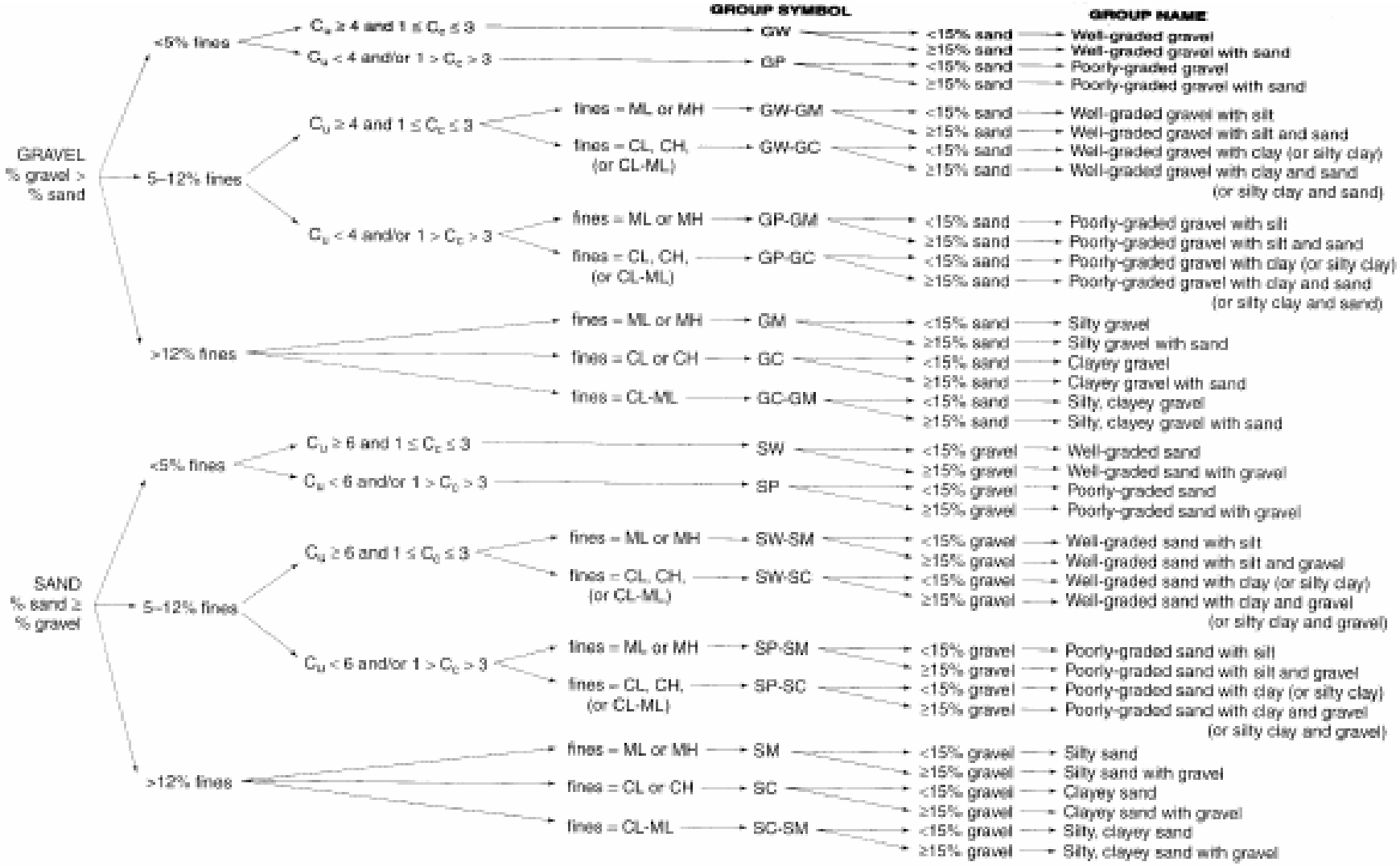
1 Bản Chất Vật Lý của Đất

$F_{200} \geq 50$	Silts and Clays $LL < 50$	ML	$PI < 4$ or plots *below* A-line (Fig. 4.2)
		CL	$PI > 7$ and plots *on or above* A-line (Fig. 4.2)
		CL-ML	PI plots in the hatched area (Fig. 4.2)
		OL	$\frac{LL_{(\text{oven dried})}}{LL_{(\text{not dried})}} < 0.75$; PI plots in the OL area in Fig. 4.2
	Silts and Clays $LL \geq 50$	MH	PI plots *below* A-line (Fig. 4.2)
		CH	PI plots *on or above* A-line (Fig. 4.2)
		OH	$\frac{LL_{(\text{oven dried})}}{LL_{(\text{not dried})}} < 0.75$; PI plots in the OH area in Fig. 4.2
	Highly organic matter	Pt	Peat

- W — well graded
- P — poorly graded
- L — low plasticity
- H — high plasticity

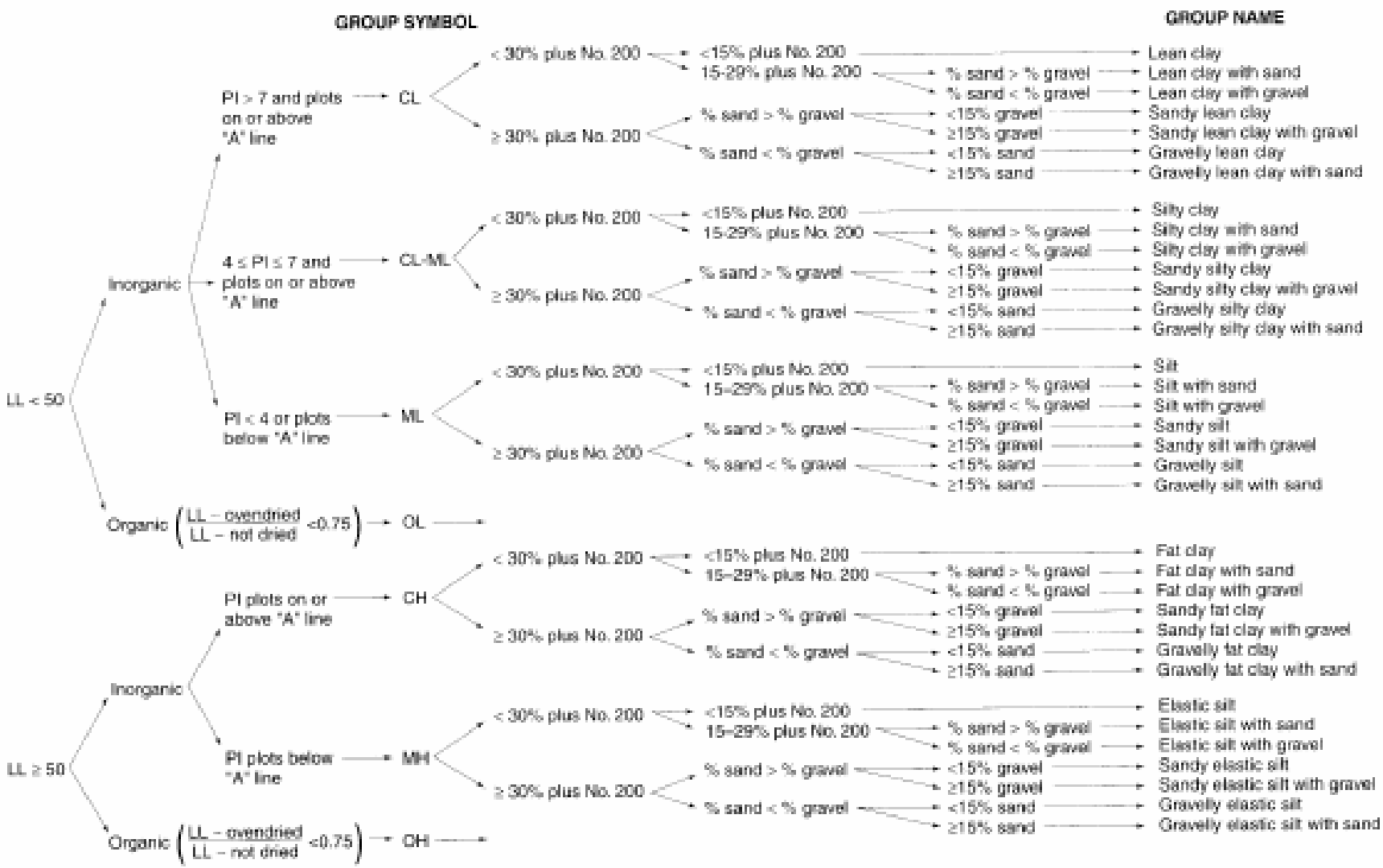
1 Bản Chất Vật Lý của Đất

ASTM



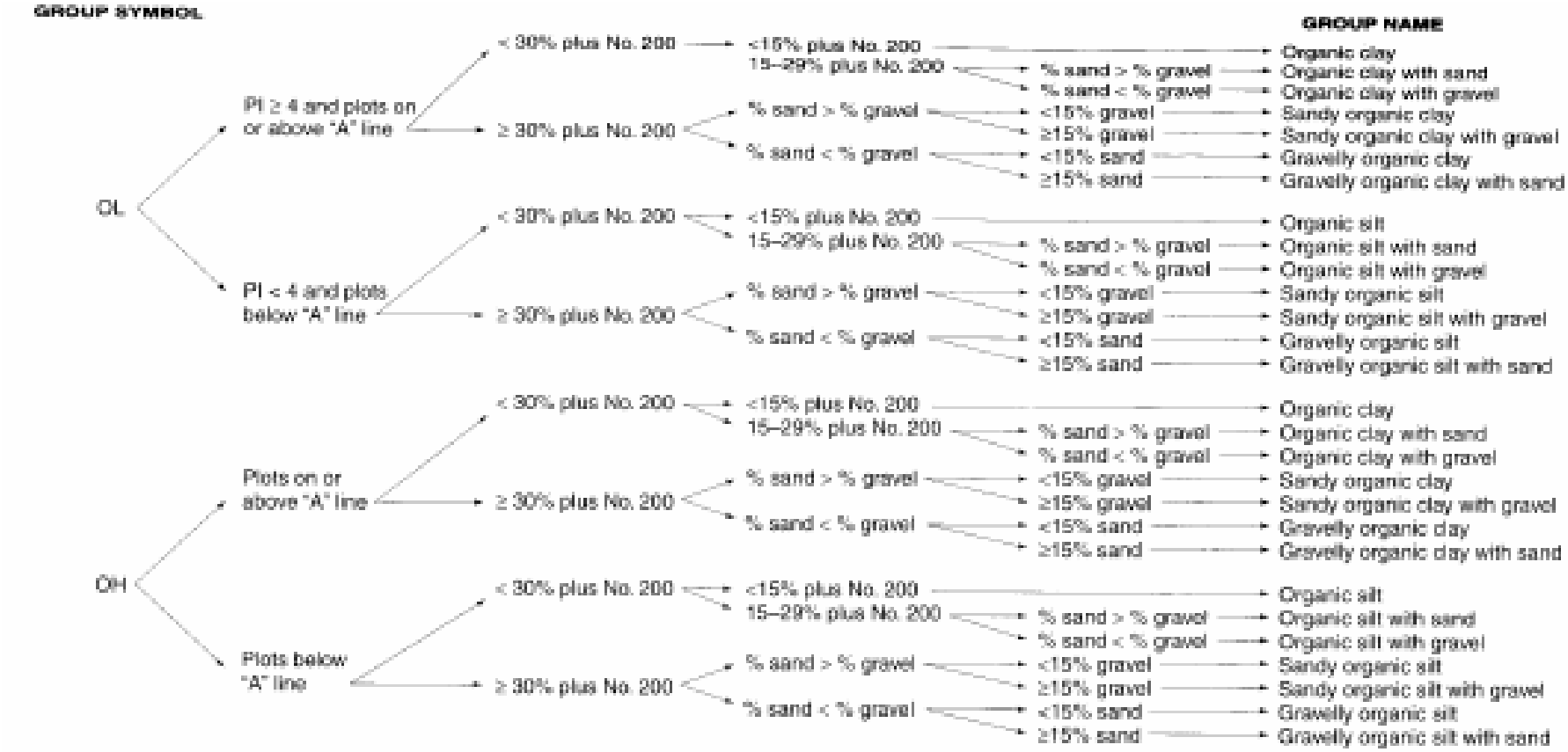
Flow chart for classifying coarse-grained soils (more than 50 percent retained on No. 200 sieve).

1 Bản Chất Vật Lý của Đất



Flow chart for classifying fine-grained soil (50 percent or more passes No. 200 sieve).

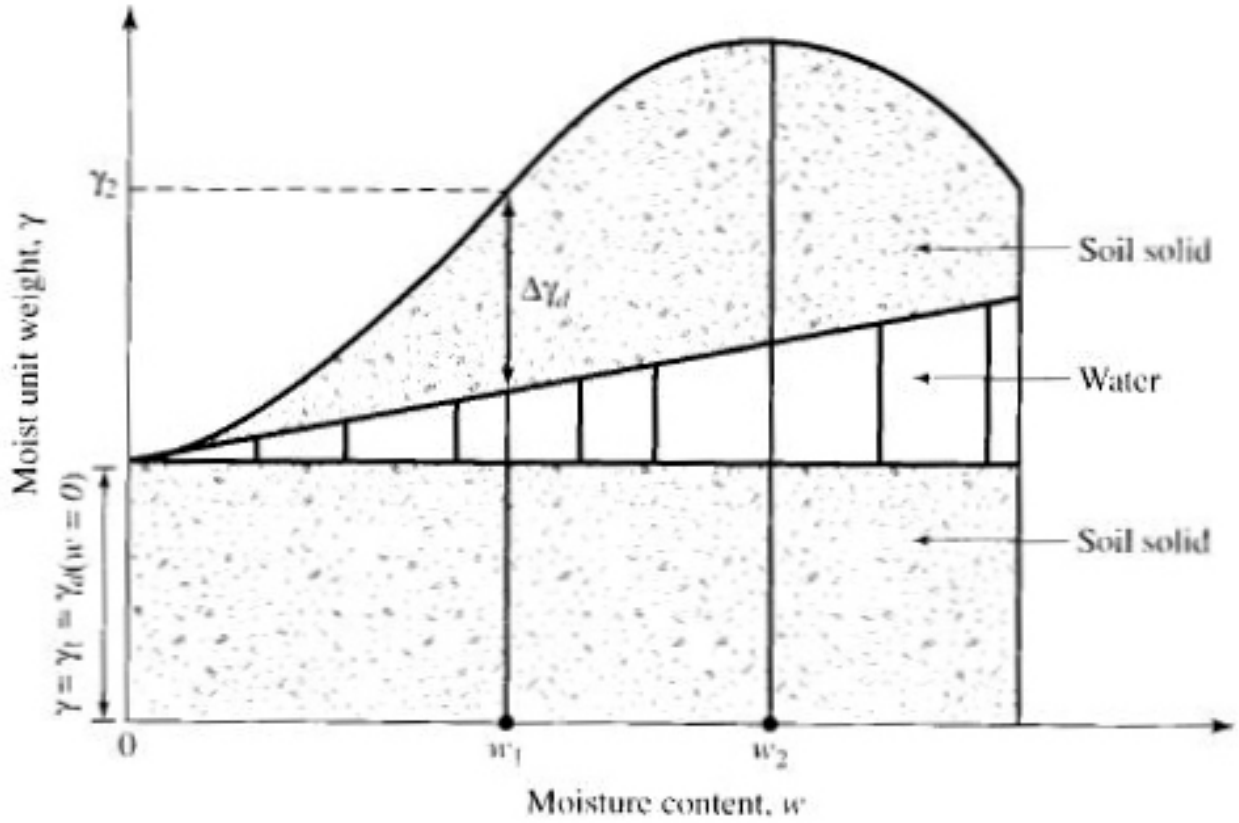
1 Bản Chất Vật Lý của Đất



Flow chart for classifying organic fine-grained soil (50 percent or more passes No. 200 sieve).

1 Bản Chất Vật Lý của Đất

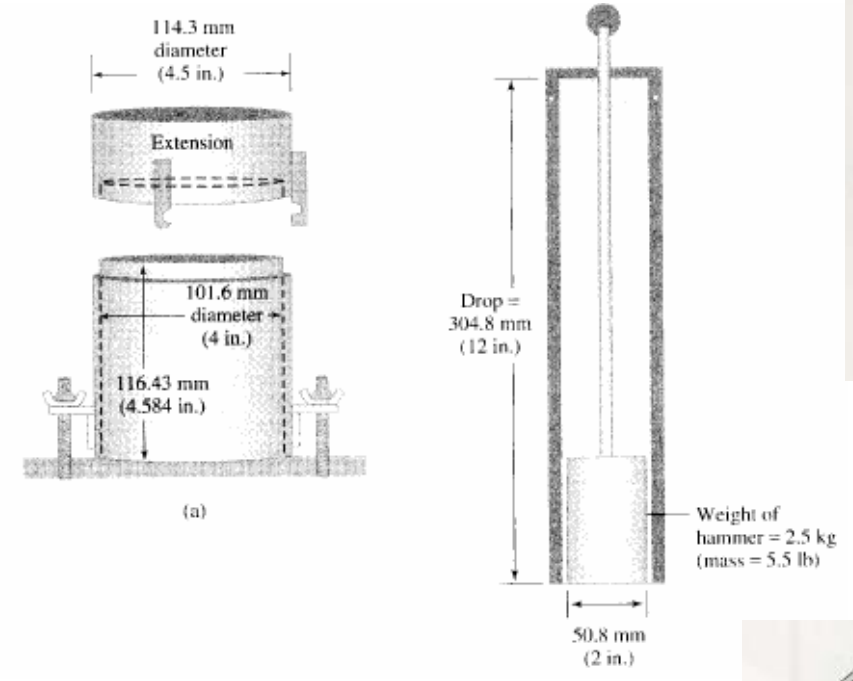
1.6 Đầm chặt đất

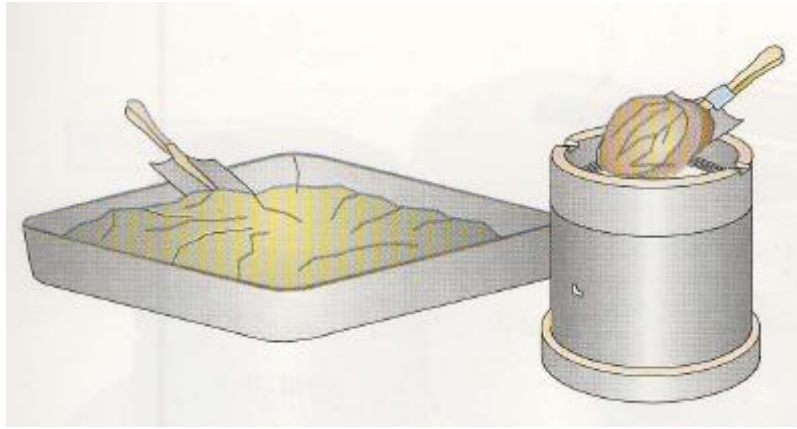


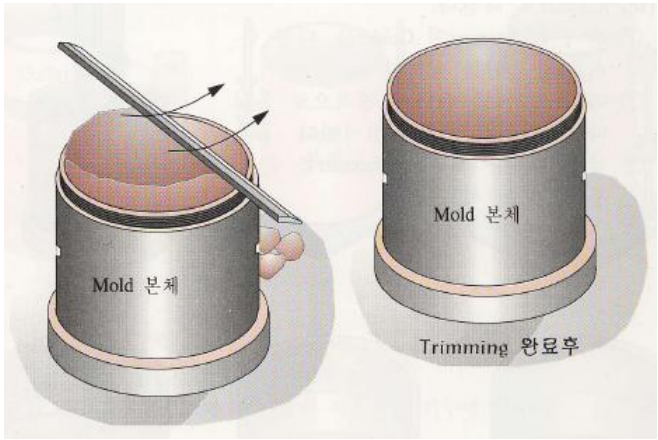
- Khi w% < w_{opt}: tăng w% ⟹ hạt trượt và sắp xếp chặt hơn
- Khi w% > w_{opt}: tăng w% ⟹ nước chiếm chỗ không gian của hạt

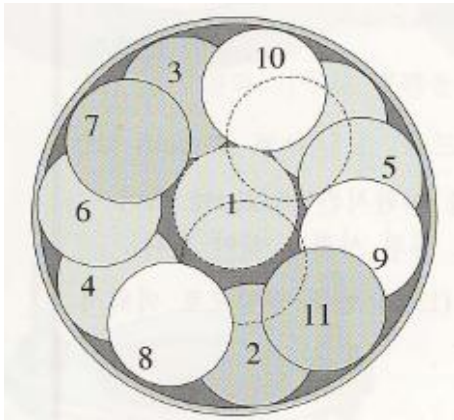
1 Bản Chất Vật Lý của Đất

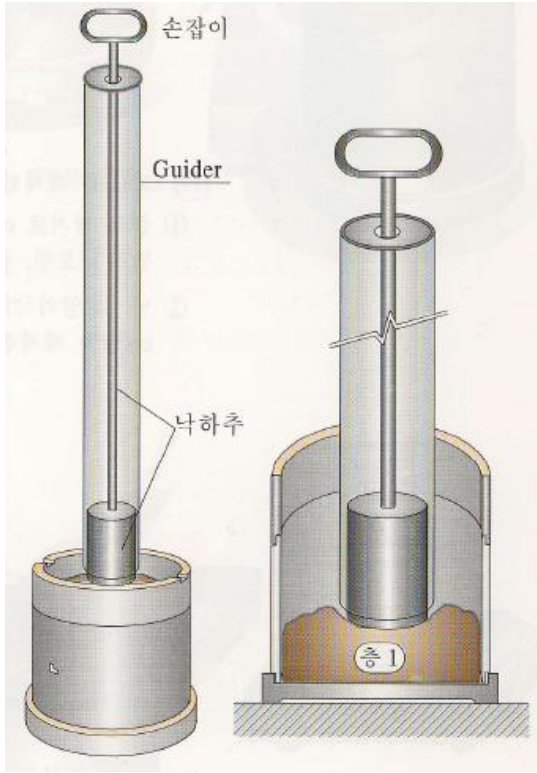
- Thí nghiệm đầm chặt



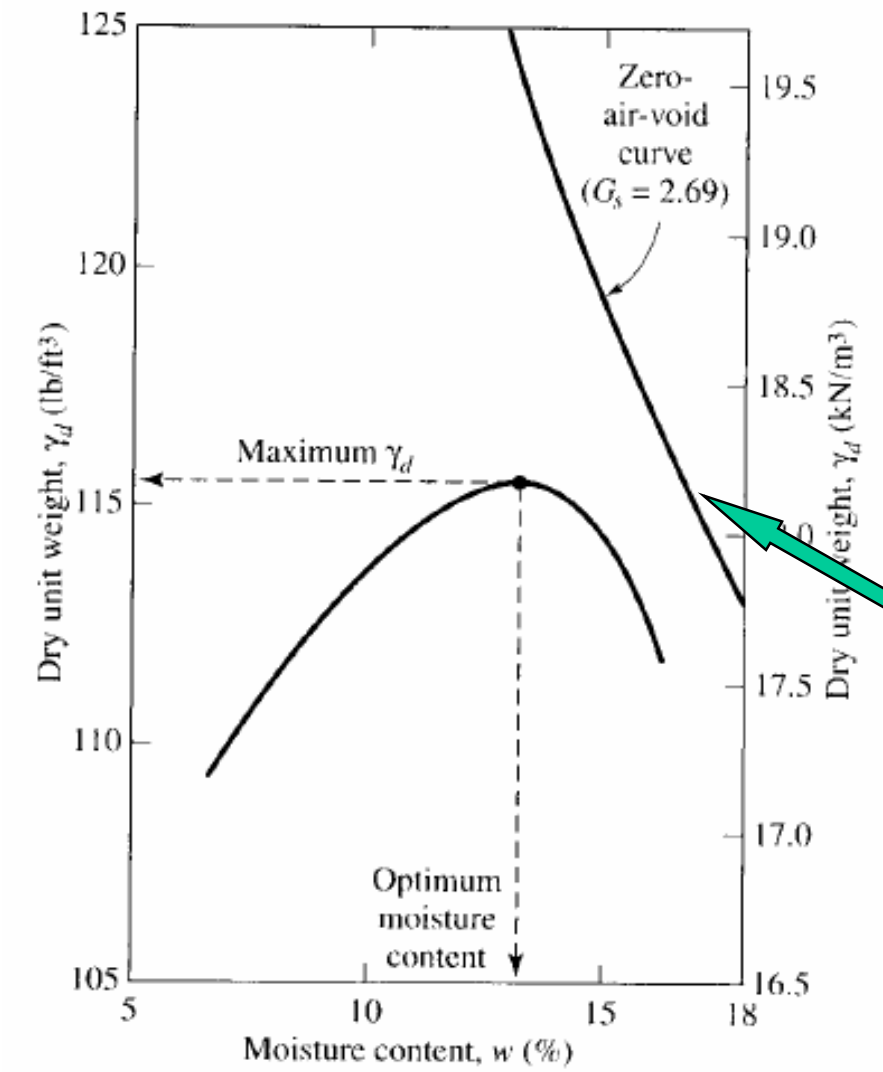








1 Bản Chất Vật Lý của Đất



$$g_d = \frac{G_s g_w (1 - A_v)}{1 + wG_s}$$

$$\gamma_d = \frac{G_s \gamma_w}{1 + \frac{G_s w}{S}}$$

- Khi S = 1 or A_v = 0

$$\gamma_{zav} = \frac{G_s \gamma_w}{1 + wG_s} = \frac{\gamma_w}{w + \frac{1}{G_s}}$$

1 Bản Chất Vật Lý của Đất

Description of soil *Light brown clayey silt* Sample No. *2*

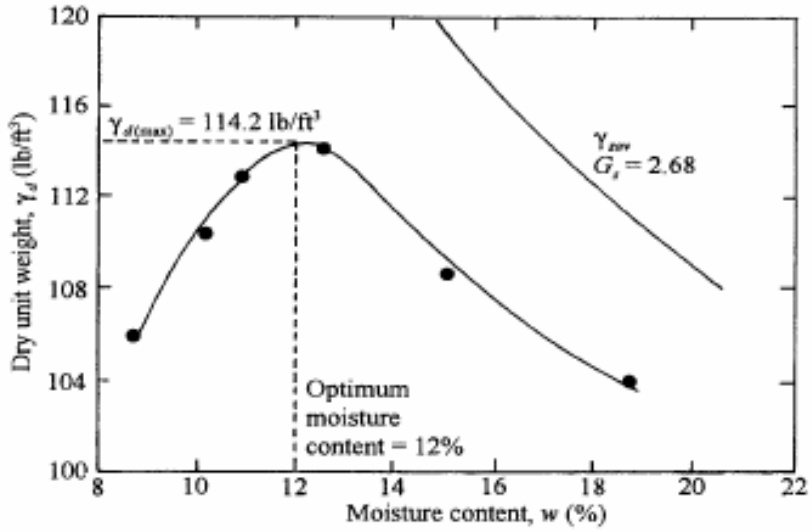
Location

Volume of mold *1/30* ft³ Weight of hammer *5.5* lb Number of blows/layer *25* Number of layers *3*

Tested by Date

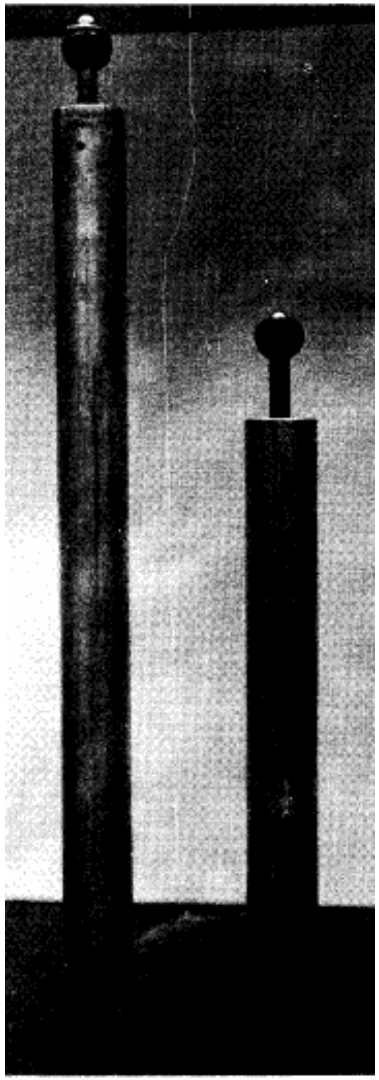
Test	1	2	3	4	5	6
1. Weight of mold, W_1 (lb)	10.35	10.35	10.35	10.35	10.35	10.35
2. Weight of mold + moist soil, W_2 (lb)	14.19	14.41	14.53	14.63	14.51	14.47
3. Weight of moist soil, $W_2 - W_1$ (lb)	3.84	4.06	4.18	4.28	4.16	4.12
4. Moist unit weight, $\gamma = \frac{W_2 - W_1}{1/30}$ (lb/ft³)	115.2	121.8	125.4	128.4	124.8	123.8
5. Moisture can number	202	212	222	242	206	504
6. Mass of moisture can, W_3 (g)	54.0	53.3	53.3	54.0	54.8	40.8
7. Mass of can + moist soil, W_4 (g)	253.0	354.0	439.0	490.0	422.8	243.0
8. Mass of can + dry soil, W_5 (g)	237.0	326.0	401.0	441.5	374.7	211.1
9. Moisture content, $w(\%) = \frac{W_4 - W_5}{W_5 - W_3} \times 100$	8.7	10.3	10.9	12.5	15.0	18.8
10. Dry unit weight of compaction γ_d (lb/ft³) $= \frac{\gamma}{1 + \frac{w(\%)}{100}}$	106.0	110.4	113.0	114.1	108.5	104.2

Specific gravity of soil solids, G_s	Assumed moisture content, w (%)	Unit weight of water, γ_w (lb/ft³)	γ_{zav} [a] (lb/ft³)
2.68	10	62.4	131.9
2.68	12	62.4	126.5
2.68	14	62.4	121.6
2.68	16	62.4	117.0
2.68	18	62.4	112.8
2.68	20	62.4	108.7



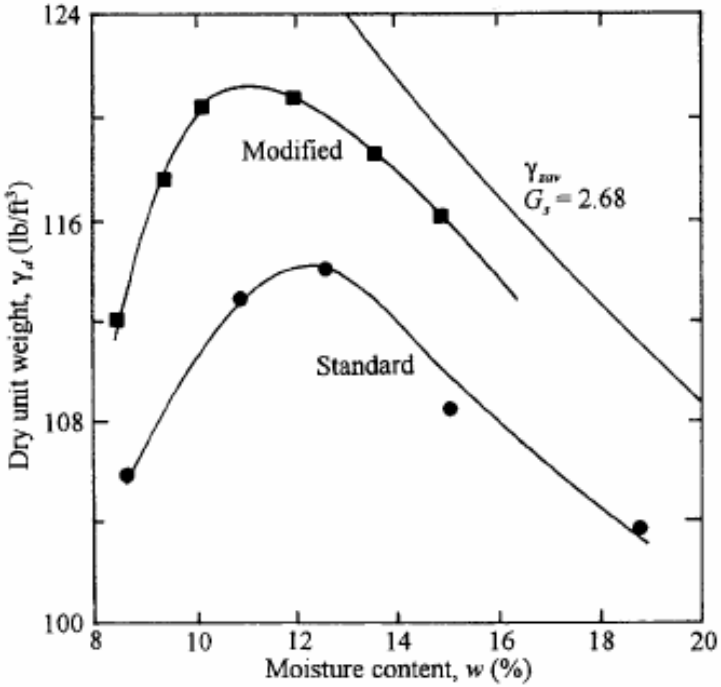
1 Bản Chất Vật Lý của Đất

- Thí nghiệm đầm chặt thay đổi



Summary of Modified Proctor Compaction Test Specifications
(ASTM D-1557, AASHTOT-180)

Description	Method A	Method B	Method C	Method D
Mold:				
Volume (ft^3)	$^1/_{30}$	$^1/_{13.33}$	$^1/_{30}$	$^1/_{13.33}$
Height (in.)	4.58	4.58	4.58	4.58
Diameter (in.)	4	6	4	6
Weight of hammer (lb)	10	10	10	10
Height of drop of hammer (in.)	18	18	18	18
Number of layers of soil	5	5	5	5
Number of blows per layer	25	56	25	56
Test on soil fraction passing sieve	No. 4	No. 4	¾ in.	¾ in.



1 Bản Chất Vật Lý của Đất

Thí dụ

For a soil with $G_s = 2.65$, the following results were obtained from a standard compaction test:

Sample number	1	2	3	4	5
Moisture content (%)	16.2	16.7	19.0	20.4	21.6
Dry density (Mg/m^3)	1.580	1.620	1.647	1.605	1.566

To obtain two extra points close to the maximum dry density two standard compaction tests were performed and tabulated. (a) Determine ρ_{dmax} and w_{opt} and plot the zero air curve, (b) a 0.3 m layer of this soil is compacted in the field to its maximum dry density. After some time the natural moisture content of the layer is measured to be 16%. How much water in terms of m/m^2 is needed to make the layer fully saturated?

Sample number	6	7
Mass of mould + compacted wet soil (kg)	8.966	8.974
Mass of mould (kg)	7.0	7.0
Volume of mould (cm^3)	1000	1000
Mass of sub-sample taken from mould (g)	178.8	155.8
Mass of sub-sample after drying (g)	152.3	131.8

1 Bản Chất Vật Lý của Đất

Solution

a) Cho ĐK: $A_v = 0$

$$\gamma_{zav} = \frac{G_s\gamma_w}{1 + wG_s} = \frac{\gamma_w}{w + \frac{1}{G_s}}$$

Test points	W (%)	ρ_d (Mg/m^3) $A = 0\%$	Test	Test points	W (%)	ρ_d (Mg/m^3) $A = 0\%$	Test
1	16.2	1.854	1.580	3	19.0	1.762	1.647
2	16.7	1.837	1.620	4	20.4	1.720	1.605
6	17.4	1.814	1.675	5	21.6	1.685	1.566
7	18.2	1.788	1.670				

(b) $\rho_d = G_s\rho_w/(1 + wG_s)$

$= 1.68,\ 2.65\times1.0/(1 + 2.65w) = 1.68$

$\rightarrow w = 21.8\%.$

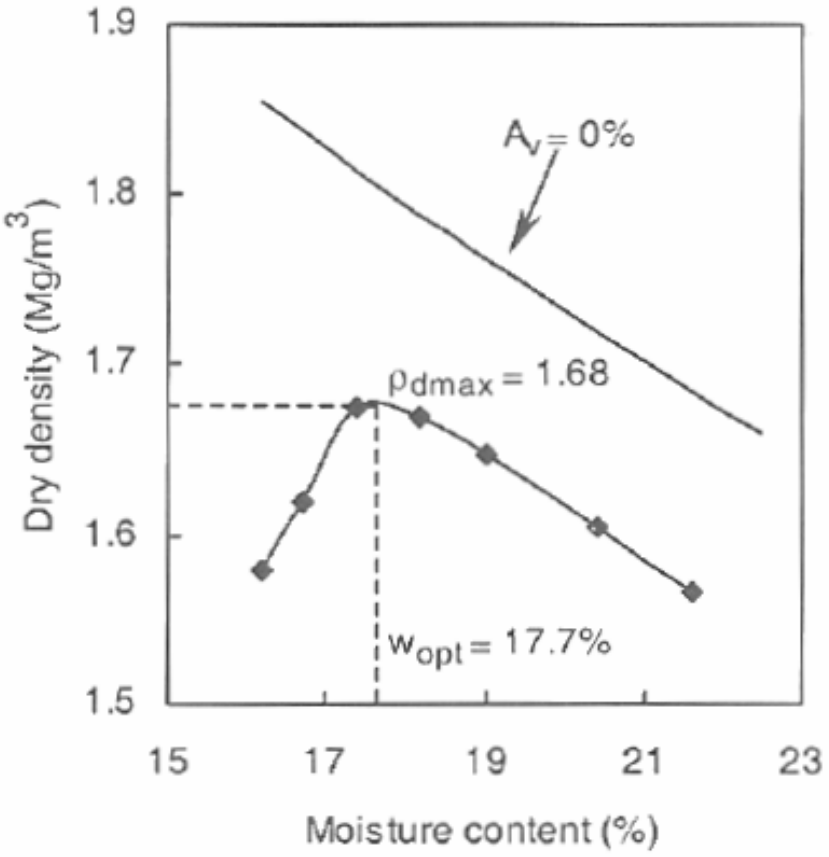
$\Delta w = 21.8\text{-}16.0 = 5.8\%,$

$\Delta M_w = 1.68\times0.058 = 0.097\ \text{Mg/m}^3$

$\Delta V_w = 0.097\ \text{m}^3/\text{m}^3.$

$\Delta V_w(0.3\ \text{m layer}) = 0.097\times0.3 = 0.029\ \text{m}^3/\text{m}^2,$

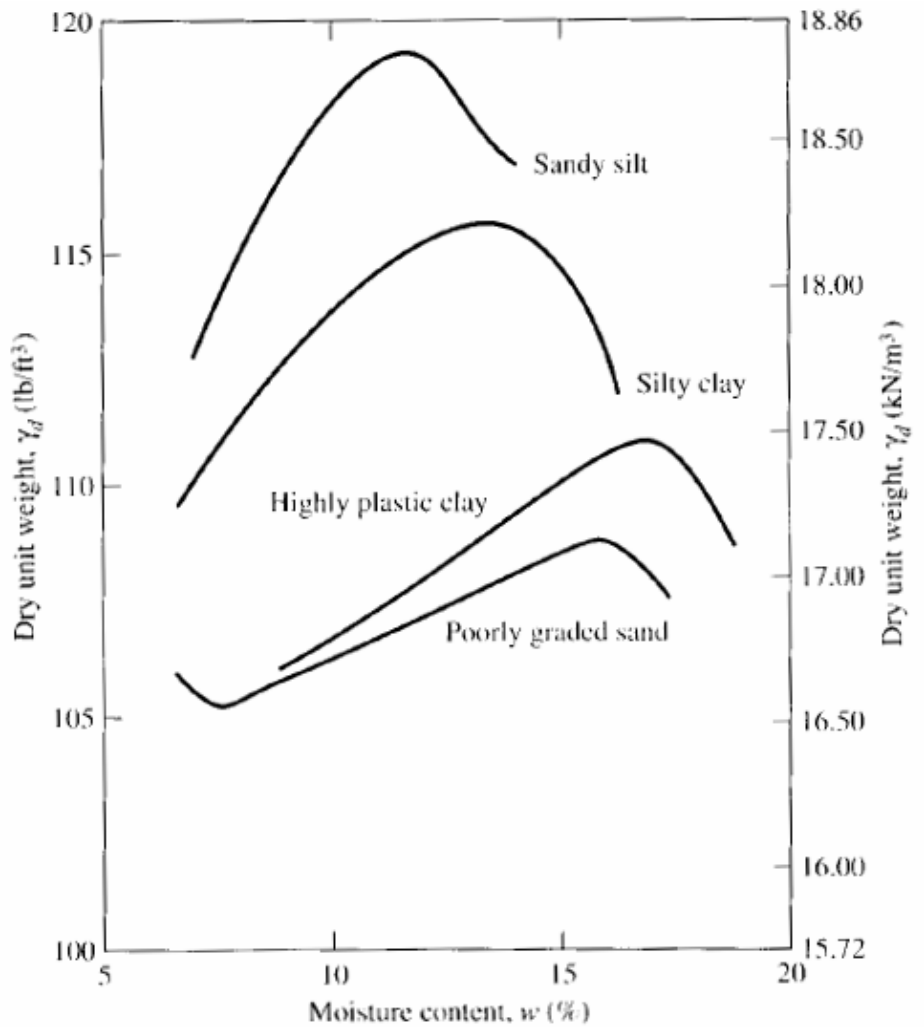
$h_w = 0.029/1.0 = 0.029\ \text{m/m}^2.$



1 Bản Chất Vật Lý của Đất

- Những hệ số quan trọng ảnh hưởng đến đầm chặt

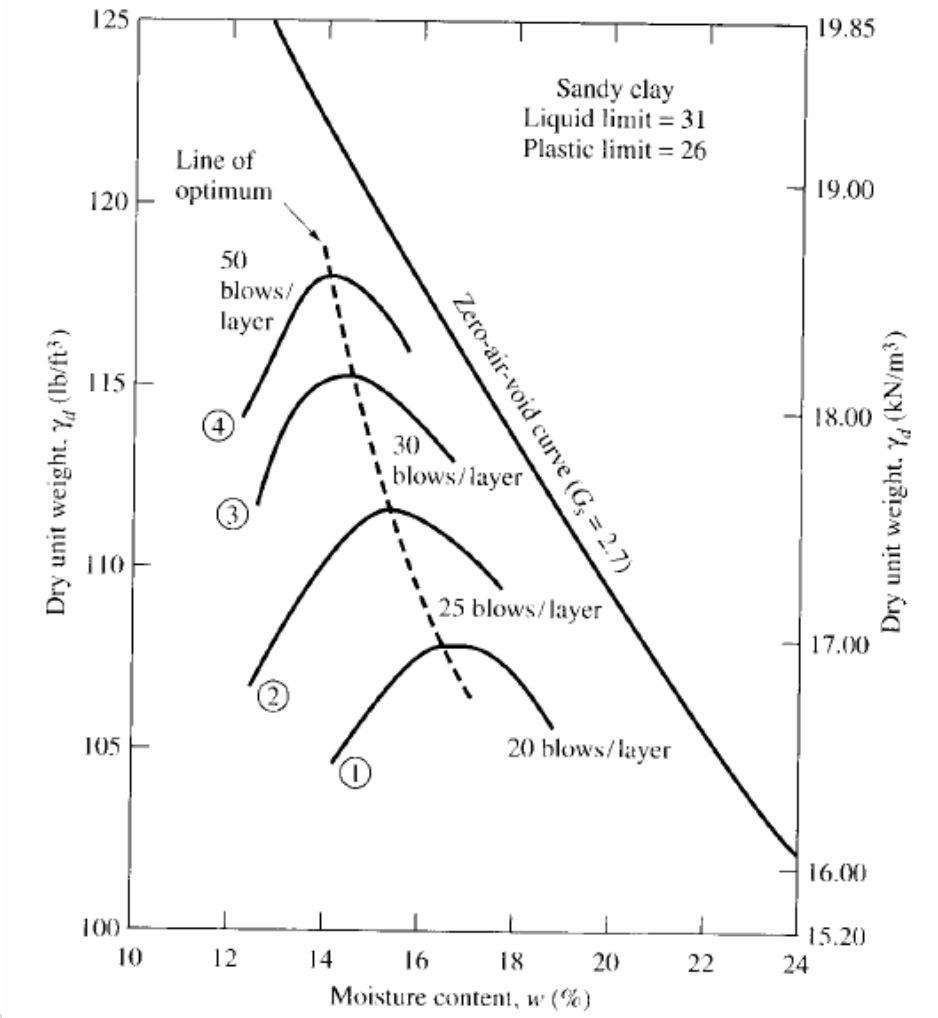
Ø Lọai đất



1 Bản Chất Vật Lý của Đất

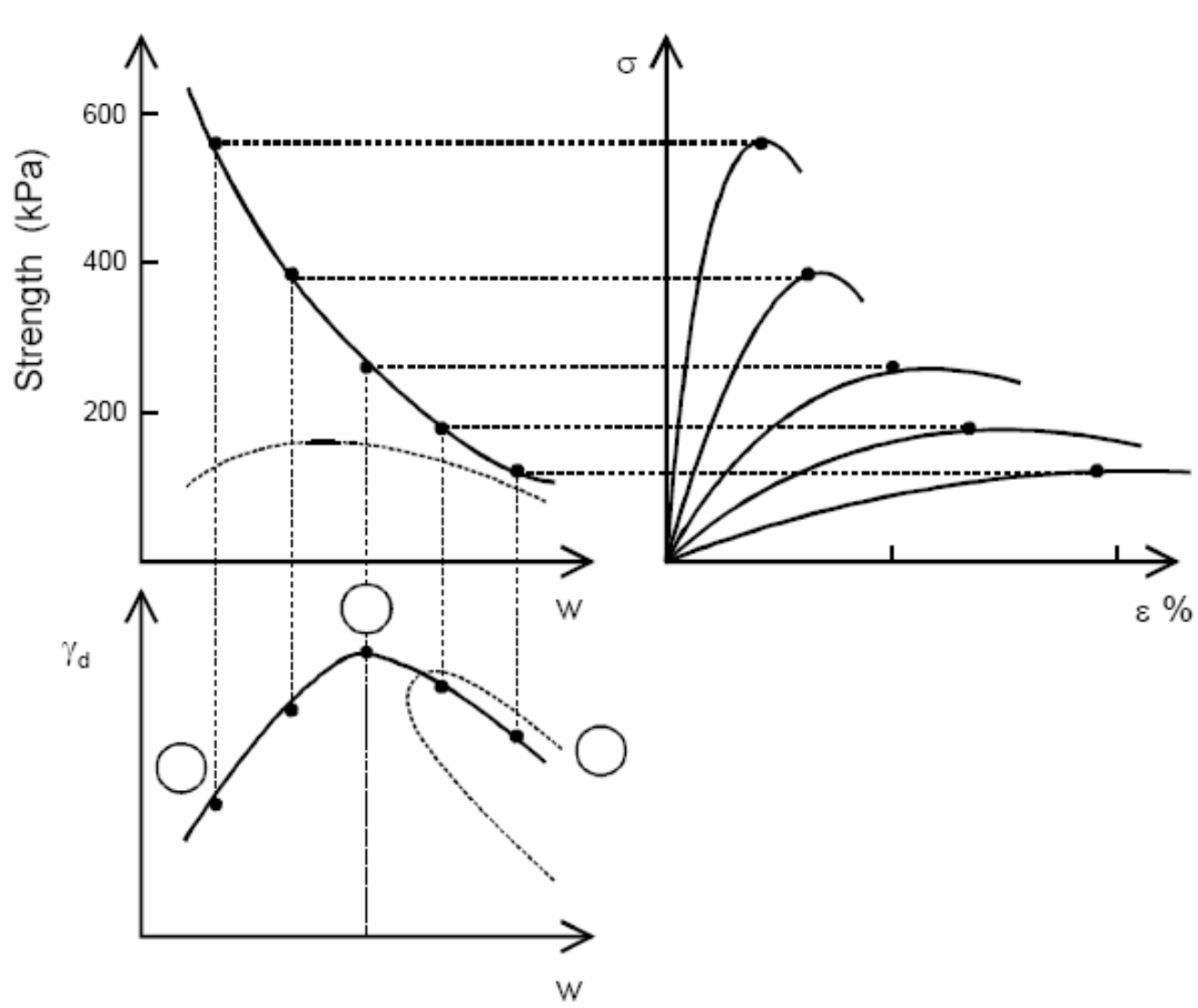
Ø Năng lượng đầm chặt

$$E = \frac{\begin{pmatrix}\text{Number}\\ \text{of blows}\\ \text{per layer}\end{pmatrix} \times \begin{pmatrix}\text{Number}\\ \text{of}\\ \text{layers}\end{pmatrix} \times \begin{pmatrix}\text{Weight}\\ \text{of}\\ \text{hammer}\end{pmatrix} \times \begin{pmatrix}\text{Height of}\\ \text{drop of}\\ \text{hammer}\end{pmatrix}}{\text{Volume of mold}}$$



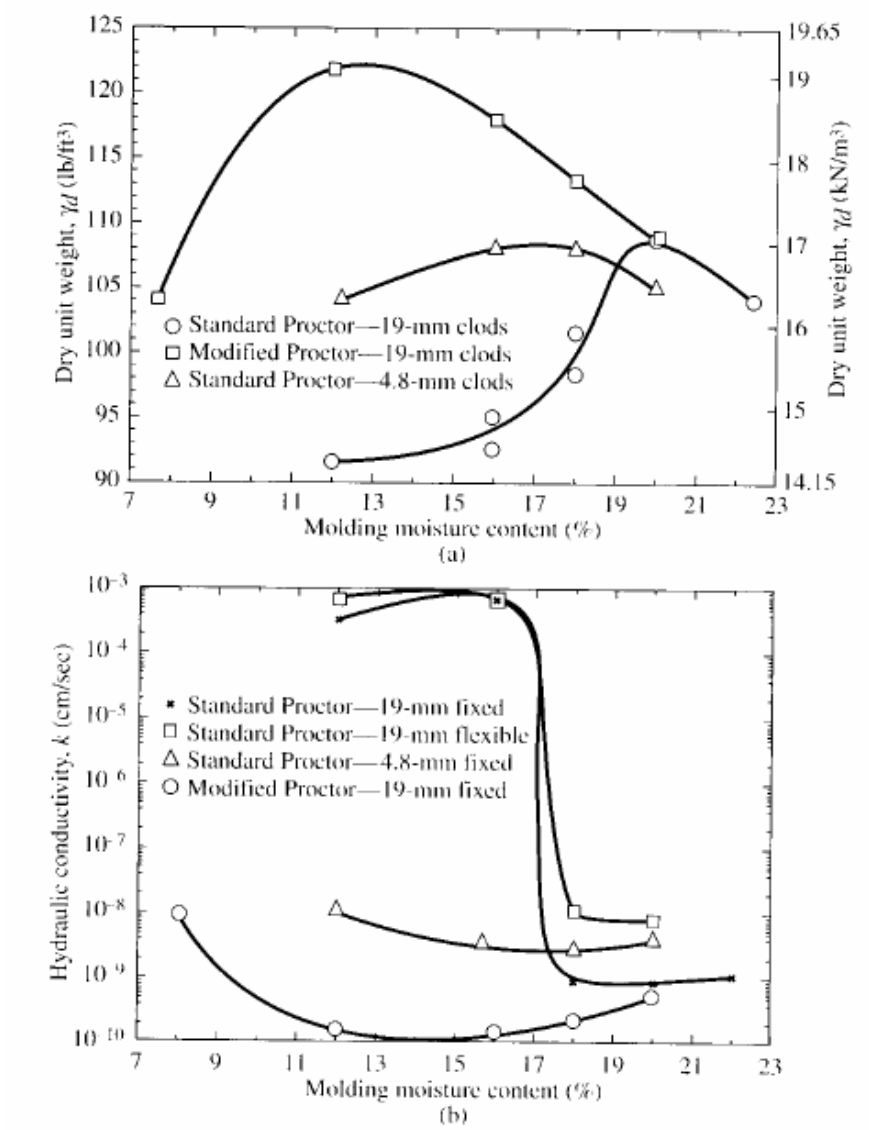
1 Bản Chất Vật Lý của Đất

Ø Cường độ của mẫu đất được đầm chặt



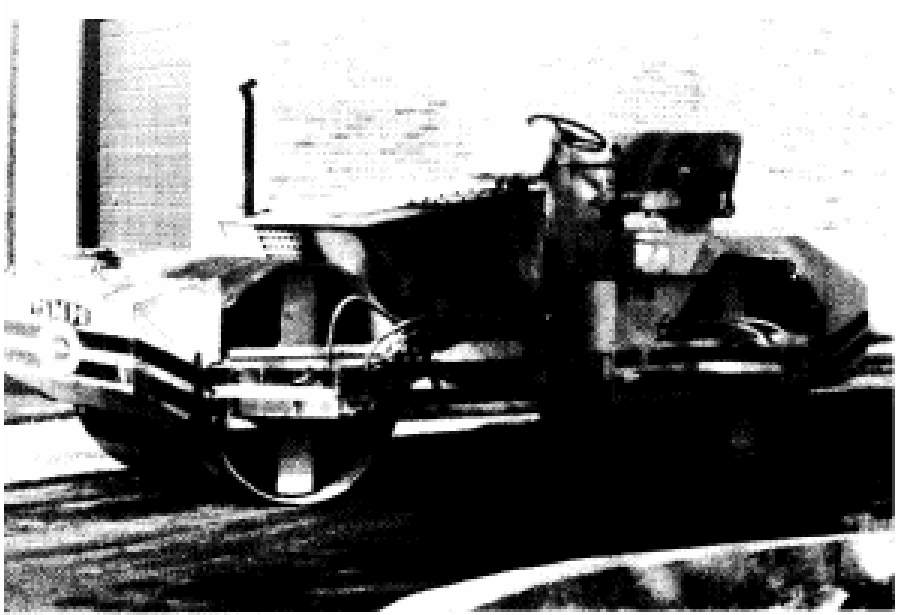
1 Bản Chất Vật Lý của Đất

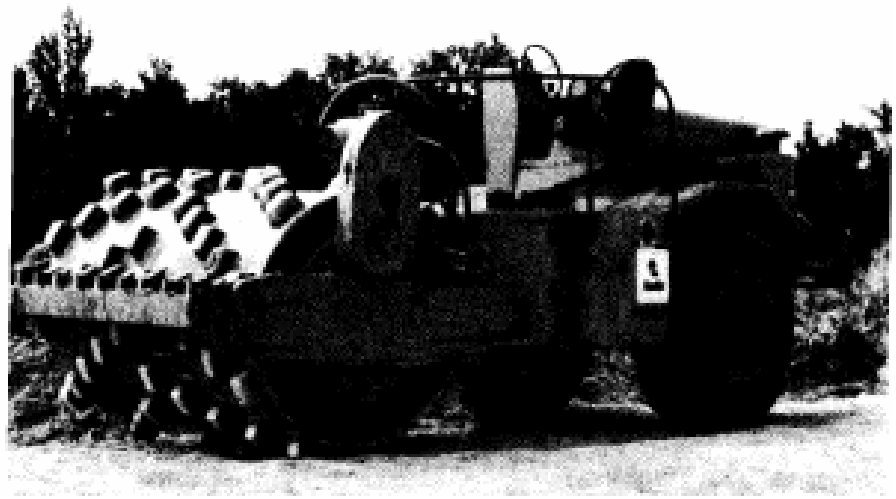
Ø Hệ số thấm của mẫu đất được đầm chặt



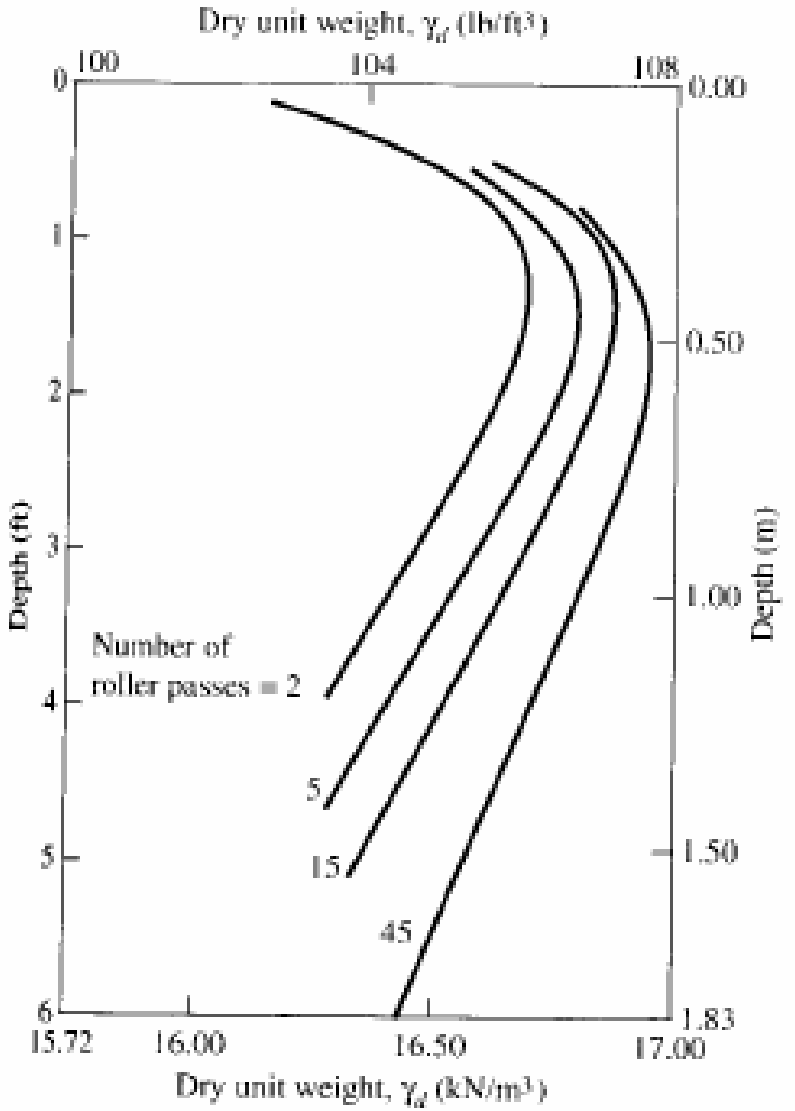
1 Bản Chất Vật Lý của Đất

- Đầm chặt ngoài hiện trường

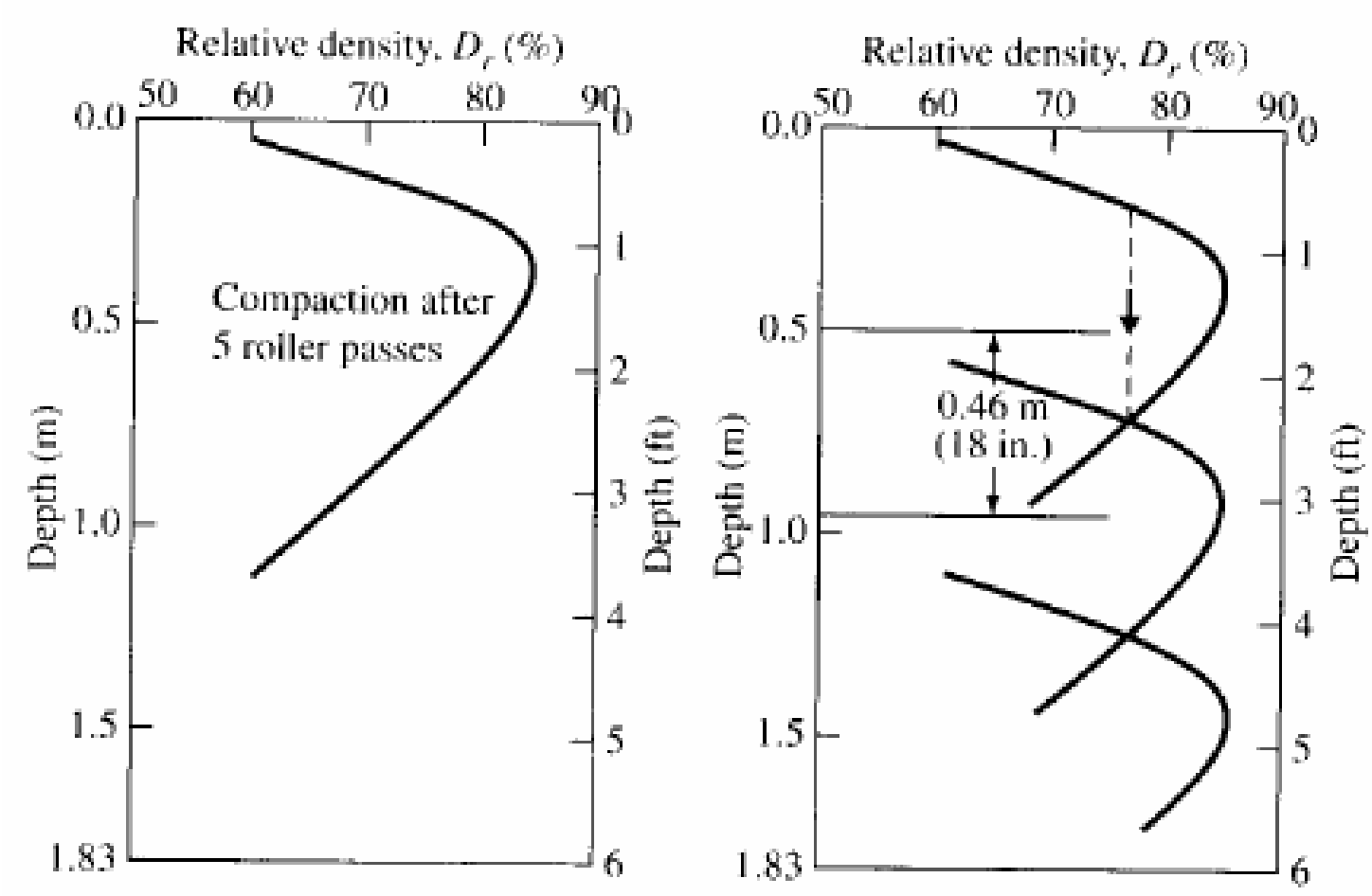




1 Bản Chất Vật Lý của Đất



1 Bản Chất Vật Lý của Đất



1 Bản Chất Vật Lý của Đất

Ø Hệ số đầm chặt

$$R(\%) = \frac{\gamma_{d(\text{field})}}{\gamma_{d(\text{max}-\text{lab})}} \times 100$$

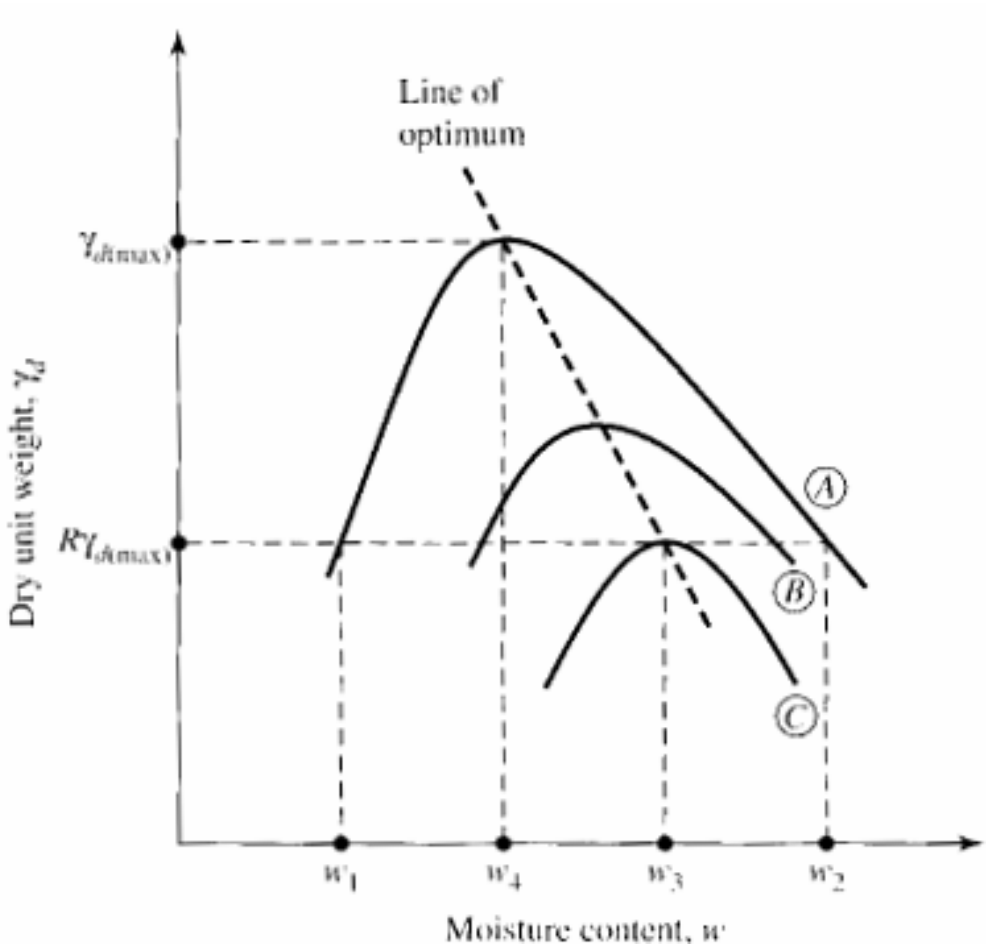
$$D_r = \left[\frac{\gamma_{d(\text{field})} - \gamma_{d(\text{min})}}{\gamma_{d(\text{max})} - \gamma_{d(\text{min})}}\right]\left[\frac{\gamma_{d(\text{max})}}{\gamma_{d(\text{field})}}\right]$$

$$R = \frac{R_0}{1 - D_r(1 - R_0)}$$

$$R_0 = \frac{\gamma_{d(\text{min})}}{\gamma_{d(\text{max})}}$$

Lee and Singh (1971)

$$R = 80 + 0.2D_r$$



1 Bản Chất Vật Lý của Đất

Thí dụ

Laboratory compaction test results for a clayey silt are given in the following table:

Moisture content (%)	Dry unit weight (kN/m^3)
6	14.80
8	17.45
9	18.52
11	18.9
12	18.5
14	16.9

Following are the results of a field unit weight determination test performed on the same soil by means of the sand-cone method:

- Calibrated dry density of Ottawa sand = 1570 kg/m^3
- Calibrated mass of Ottawa sand to fill the cone = 0.545 kg
- Mass of jar + cone + sand (before use) = 7.59 kg
- Mass of jar + cone + sand (after use) = 4.78 kg
- Mass of moist soil from hole = 3.007 kg
- Moisture content of moist soil = 10.2%

Determine

a. Dry unit weight of compaction in the field
b. Relative compaction in the field

Solution

a. In the field,

Mass of sand used to fill the hole and cone = 7.59 kg − 4.78 kg = 2.81 kg

Mass of sand used to fill the hole = 2.81 kg − 0.545 kg = 2.265 kg

$$\text{Volume of the hole } (V) = \frac{2.265 \text{ kg}}{\text{Dry density of Ottawa sand}}$$

$$= \frac{2.265 \text{ kg}}{1570 \text{ kg/m}^3} = 0.0014426 \text{ m}^3$$

$$\text{Moist density of compacted soil} = \frac{\text{Mass of moist soil}}{\text{Volume of hole}}$$

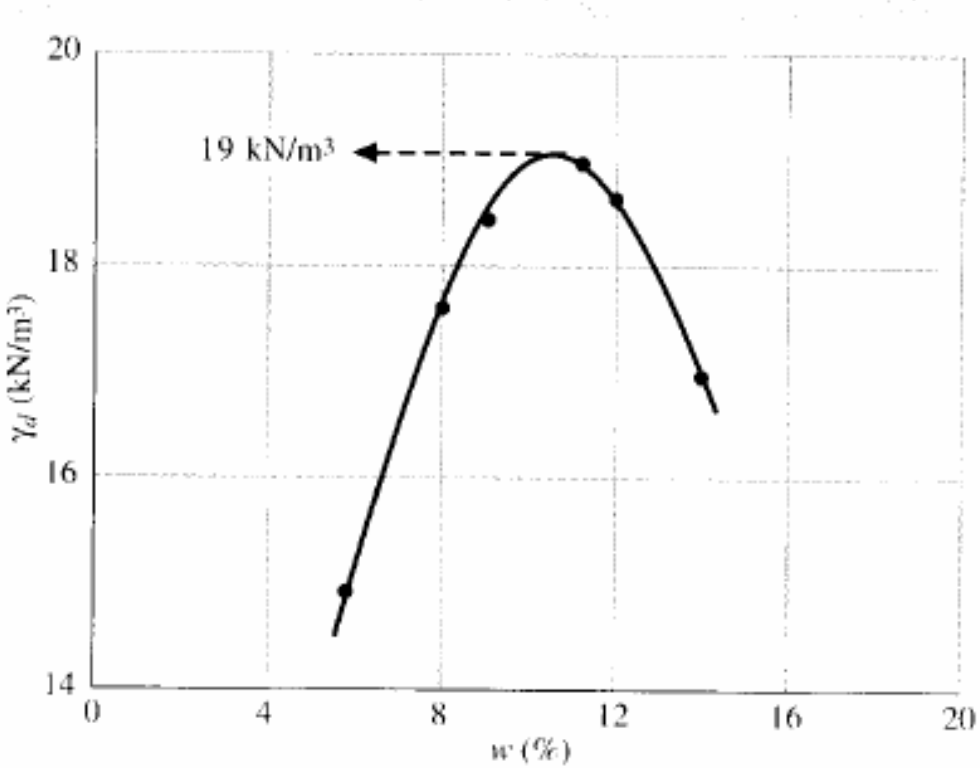
$$= \frac{3.007}{0.0014426} = 2084.4 \text{ kg/m}^3$$

$$\text{Moist unit weight of compacted soil} = \frac{(2084.4)(9.81)}{1000} = 20.45 \text{ kN/m}^3$$

Hence,

$$\gamma_d = \frac{\gamma}{1 + \frac{w(\%)}{100}} = \frac{20.45}{1 + \frac{10.2}{100}} = \mathbf{18.56 \text{ kN/m}^3}$$

1 Bản Chất Vật Lý của Đất



b. The results of the laboratory compaction test are plotted From the plot, we see that $\gamma_{d(\max)} = 19\ \text{kN/m}^3$.

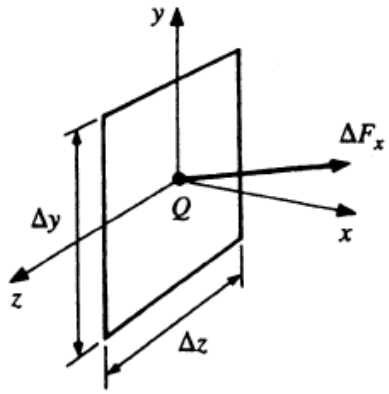
$$R = \frac{\gamma_{d(\text{field})}}{\gamma_{d(\max)}} = \frac{18.56}{19.0} = \mathbf{97.7\%}$$

Chapter 2 Phân bố ứng suất trong đất

2

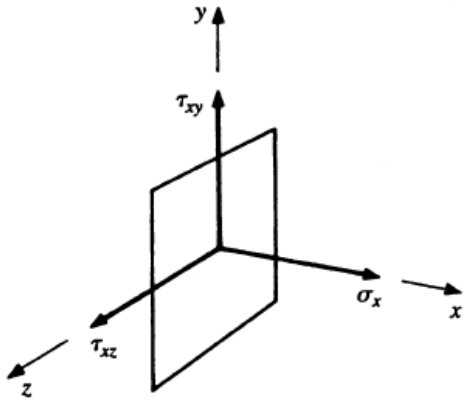
2 Ứng suất

2.1 Khái niệm



$$\bar{\sigma}_{xx} = \frac{\Delta F_{xx}}{\Delta A_x}$$

$$\sigma_{xx} = \frac{dF_{xx}}{dA_x}$$

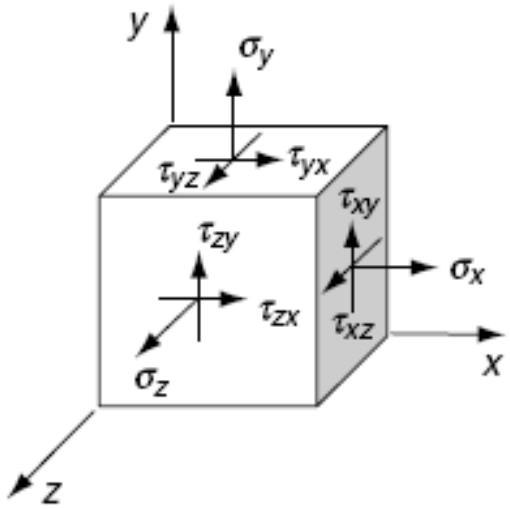


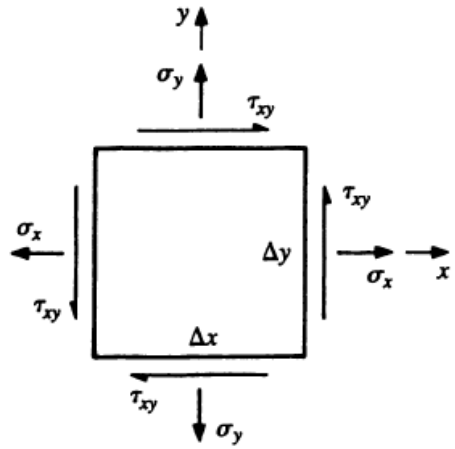
$$\tau_{xy} = \frac{dF_{xy}}{dA_x}$$

$$\tau_{xz} = \frac{dF_{xz}}{dA_x}$$

2 Ứng suất

2.1.1 Các thành phần ứng suất





$$\boldsymbol{\sigma} = [\boldsymbol{\sigma}] = \begin{bmatrix} \sigma_x & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z \end{bmatrix}$$

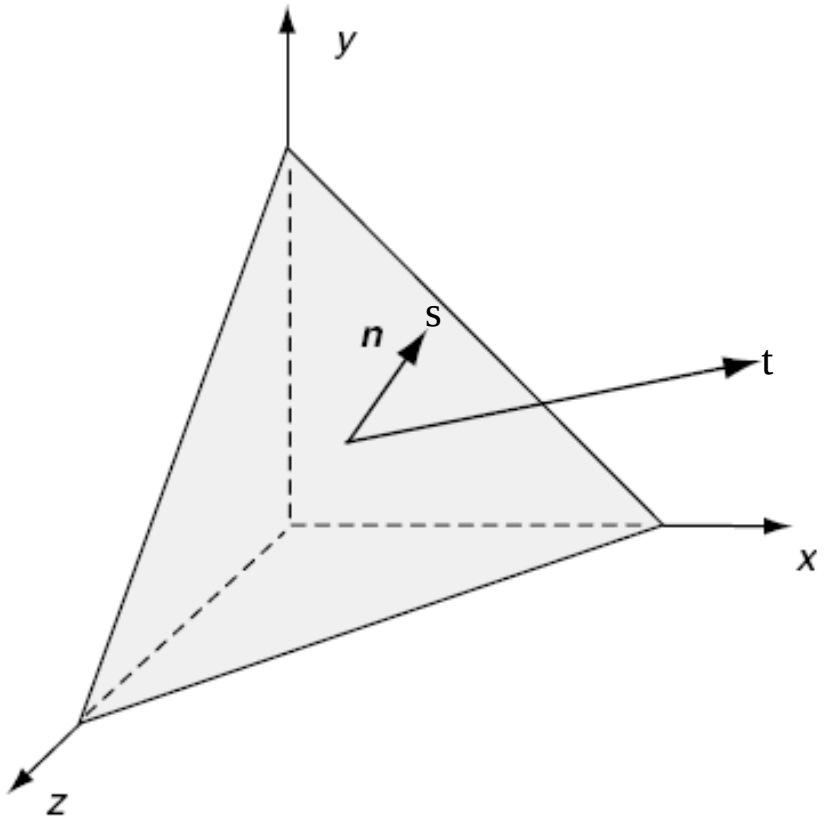
$$[\boldsymbol{\sigma}] = \begin{bmatrix} \sigma_x & \tau_{xy} \\ \tau_{xy} & \sigma_y \end{bmatrix}$$

$$[s] = \begin{bmatrix} p & 0 & 0 \\ 0 & p & 0 \\ 0 & 0 & p \end{bmatrix} + \begin{bmatrix} s_x - p & t_{xy} & t_{xz} \\ t_{yx} & s_y - p & t_{yz} \\ t_{zx} & t_{zy} & s_z - p \end{bmatrix}$$

$$p = \frac{s_x + s_y + s_z}{3}$$

2 Ứng suất

- **Ứng suất trên mặt phẳng**

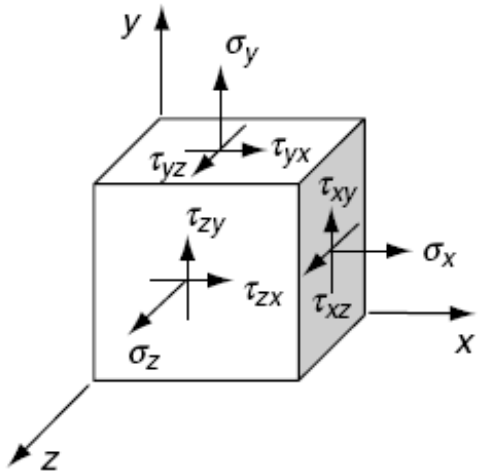


$$\sigma = \sigma_x l^2 + \sigma_y m^2 + \sigma_z n^2 + 2\tau_{xy} lm + 2\tau_{yz} mn + 2\tau_{zx} nl$$

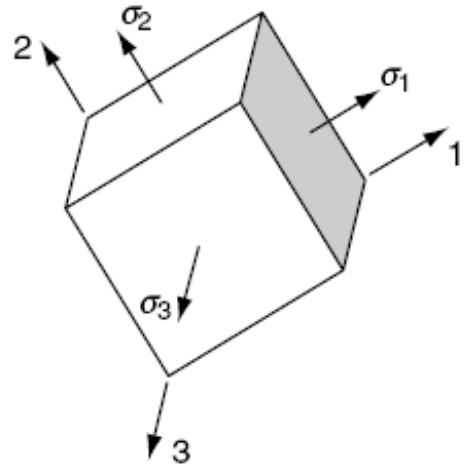
$$\tau = [(\sigma_x l + \tau_{xy} m + \tau_{zx} n)^2 + (\tau_{xy} l + \sigma_y m + \tau_{yz} n)^2 + (\tau_{zx} l + \tau_{yz} m + \sigma_z n)^2 - \sigma^2]^{1/2}$$

2 Ứng suất

Ứng suất chính



(General Coordinate System)



(Principal Coordinate System)

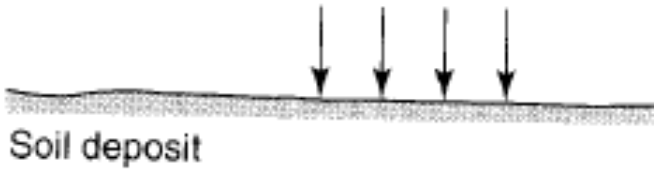
$$s^3-\left(s_x+s_y+s_z\right)s^2+\left(s_xs_y+s_ys_z+s_xs_z-t_{xy}^2-t_{yz}^2-t_{xz}^2\right)s$$
$$-\left(s_xs_ys_z+2t_{xy}t_{yz}t_{xz}-s_xt_{yz}^2-s_yt_{xz}^2-s_zt_{xy}^2\right)=0$$

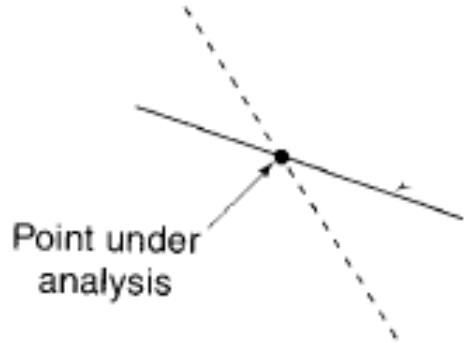
$$\boxed{s^3-I_1s^2+I_2s-I_3=0}$$

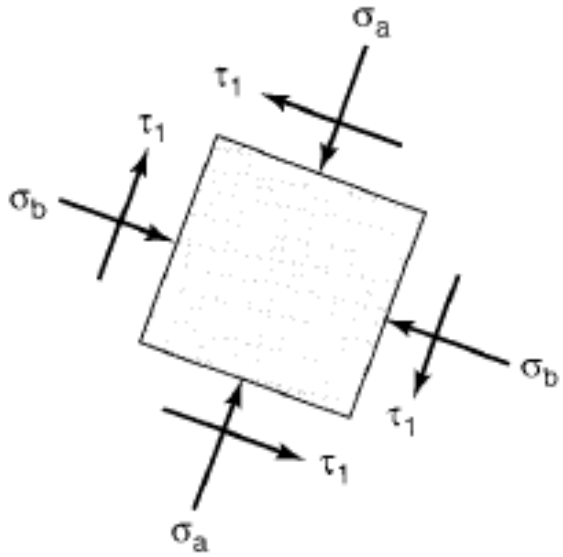
$$\begin{cases} I_1=s_x+s_y+s_z \\ I_2=s_xs_y+s_ys_z+s_xs_z-t_{xy}^2-t_{yz}^2-t_{xz}^2 \\ I_3=s_xs_ys_z+2t_{xy}t_{yz}t_{xz}-s_xt_{yz}^2-s_yt_{xz}^2-s_zt_{xy}^2 \end{cases}$$

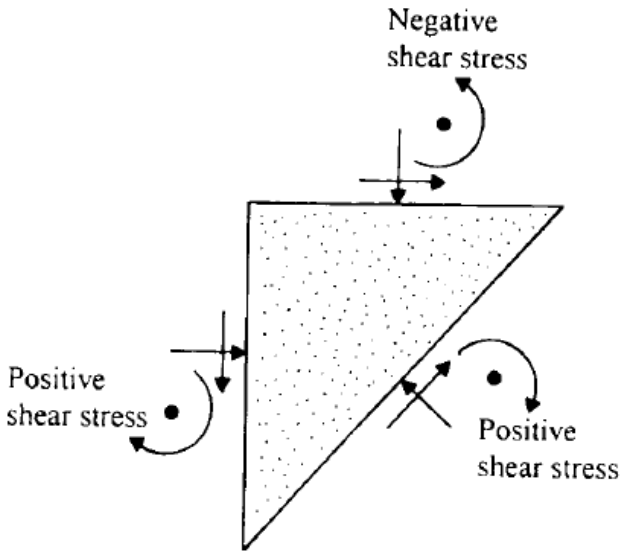
2 Ứng suất

2.1.2 Ứng suất trên mặt phẳng

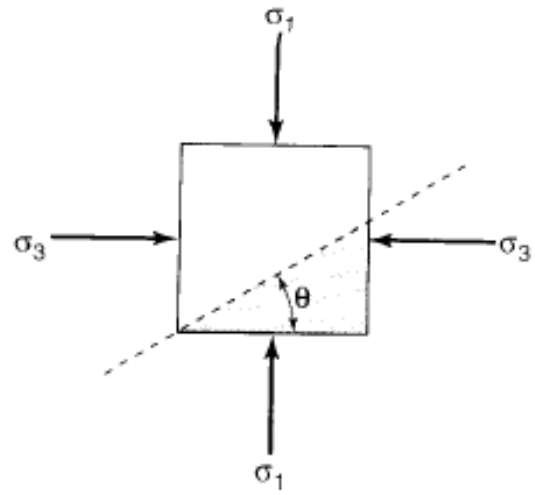


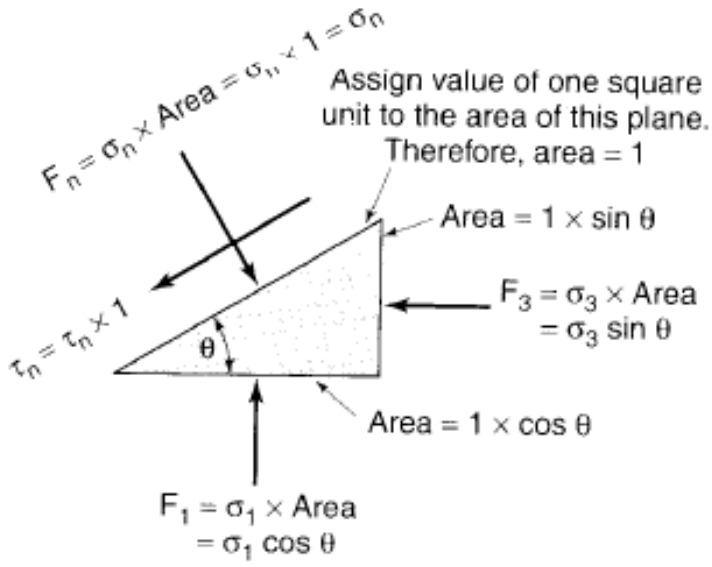


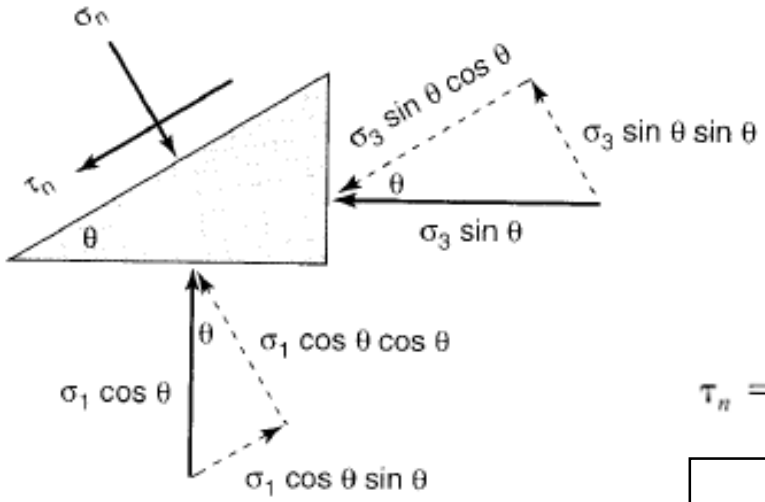




2 Ứng suất







$$\sigma_n = \sigma_1 \cos\theta \cos\theta + \sigma_3 \sin\theta \sin\theta$$

$$= \sigma_1 \cos^2\theta + \sigma_3 \sin^2\theta$$

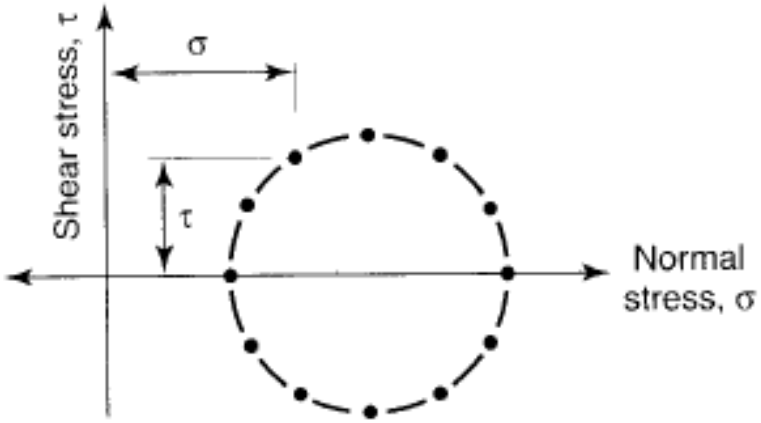
$$\boxed{\sigma_n = \sigma_1 \cos^2\theta + \sigma_3 \sin^2\theta = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2} \cos 2\theta}$$

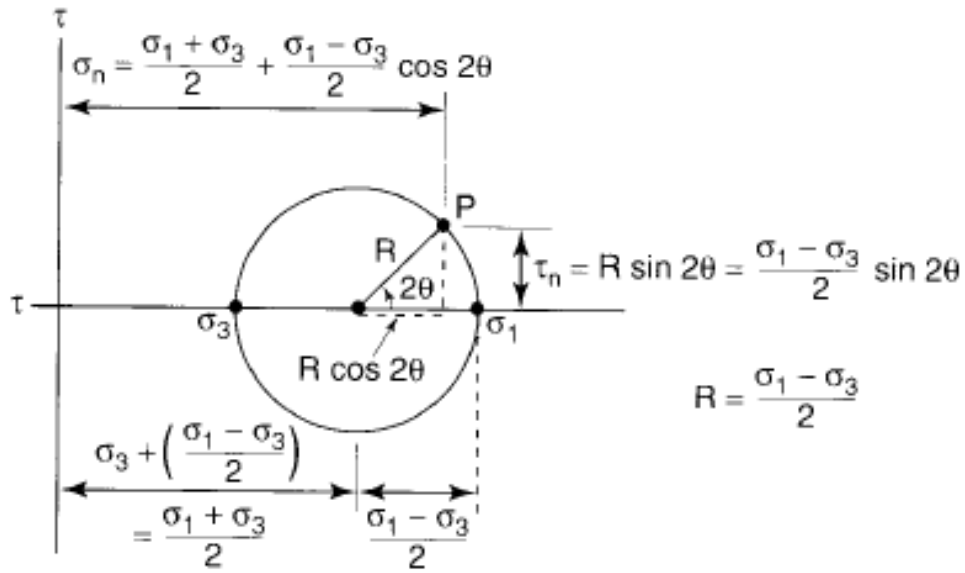
$$\tau_n = \sigma_1 \cos\theta \sin\theta - \sigma_3 \sin\theta \cos\theta = (\sigma_1 - \sigma_3) \sin\theta \cos\theta$$

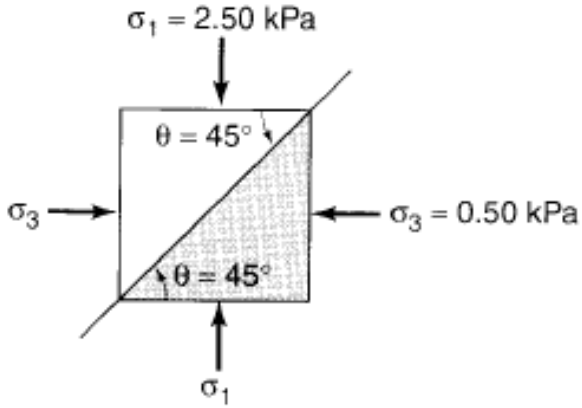
$$\boxed{\tau_n = (\sigma_1 - \sigma_3) \sin\theta \cos\theta = \left(\frac{\sigma_1 - \sigma_3}{2}\right) \sin 2\theta}$$

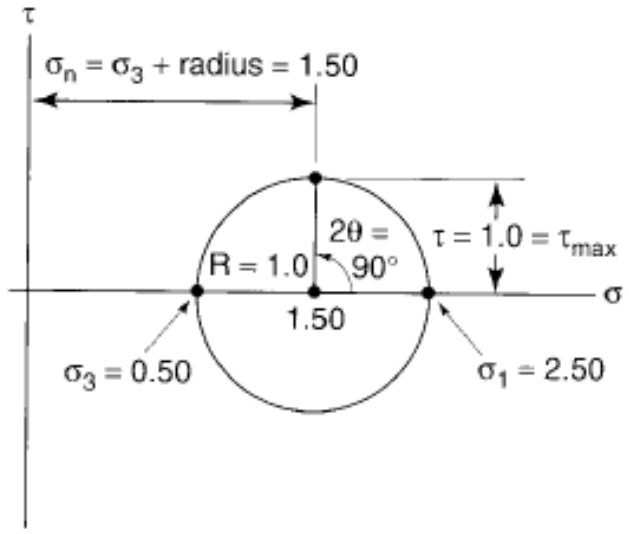
2 Ứng suất

Vòng tròn Mohr



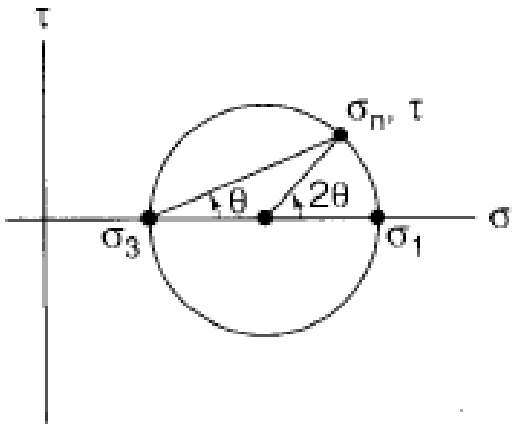


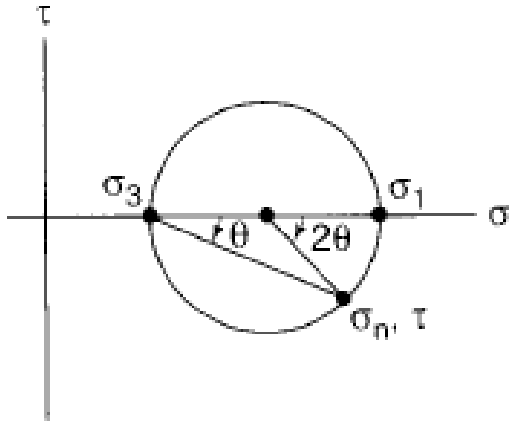


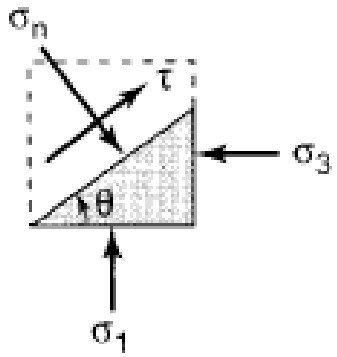


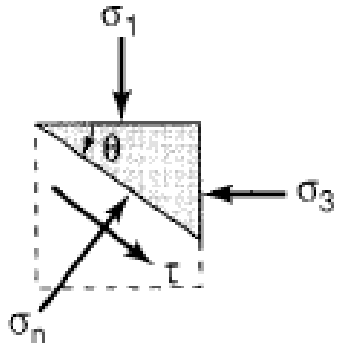
2 Ứng suất

Ø **Cực Vòng tròn Mohr ứng suất là điểm nắm trên vòng tròn Mohr sao cho từ điểm đó vẽ đường song song với mặt phẳng cần xác định ứng suất, đường thẳng này cắt vòng tròn Mohr tại giá trị s, t cần tìm**



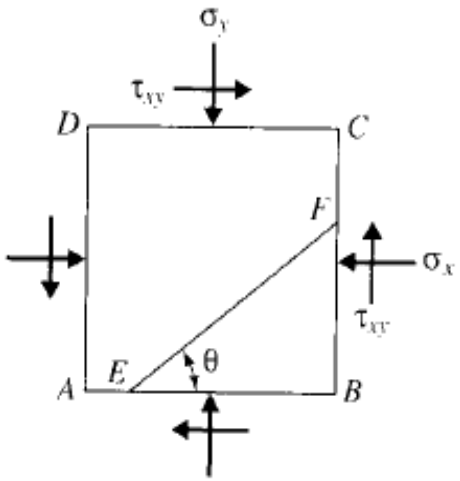


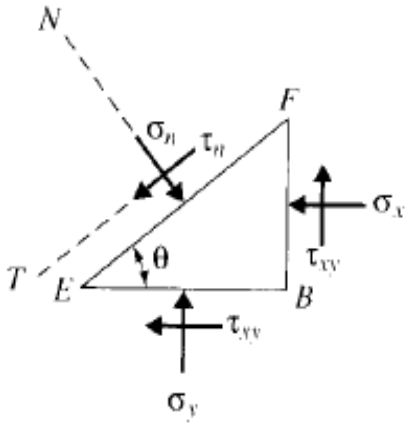




2 Ứng suất

Tổng quát





Major principal stress:

$$\sigma_n = \sigma_1 = \frac{\sigma_y + \sigma_x}{2} + \sqrt{\left[\frac{(\sigma_y - \sigma_x)}{2}\right]^2 + \tau_{xy}^2}$$

Minor principal stress:

$$\sigma_n = \sigma_3 = \frac{\sigma_y + \sigma_x}{2} - \sqrt{\left[\frac{(\sigma_y - \sigma_x)}{2}\right]^2 + \tau_{xy}^2}$$

$$\sigma_n = \sigma_x \sin^2\theta + \sigma_y \cos^2\theta + 2\tau_{xy} \sin\theta \cos\theta$$

$$\sigma_n = \frac{\sigma_y + \sigma_x}{2} + \frac{\sigma_y - \sigma_x}{2} \cos 2\theta + \tau_{xy} \sin 2\theta$$

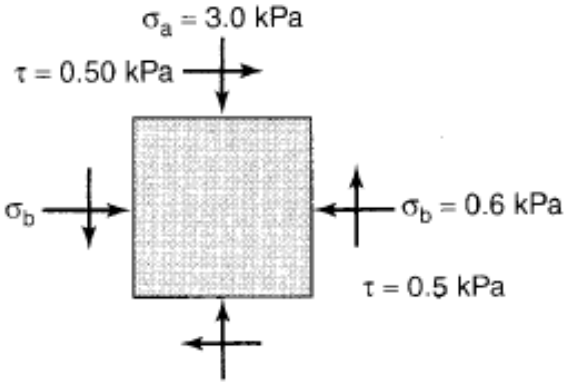
$$\tau_n(\overline{EF}) = -\sigma_x(\overline{EF}) \sin\theta \cos\theta + \sigma_y(\overline{EF}) \sin\theta \cos\theta - \tau_{xy}(\overline{EF}) \cos^2\theta + \tau_{xy}(\overline{EF}) \sin^2\theta$$

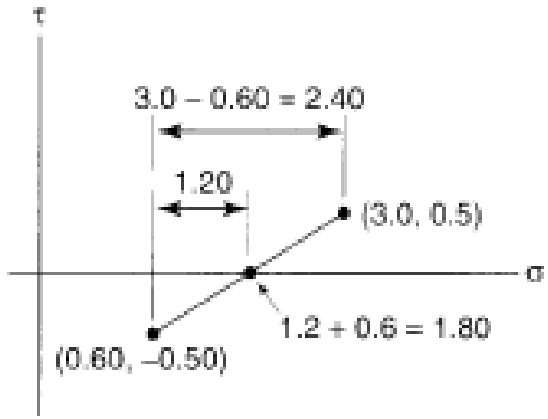
$$\tau_n = \sigma_y \sin\theta \cos\theta - \sigma_x \sin\theta \cos\theta - \tau_{xy}(\cos^2\theta - \sin^2\theta)$$

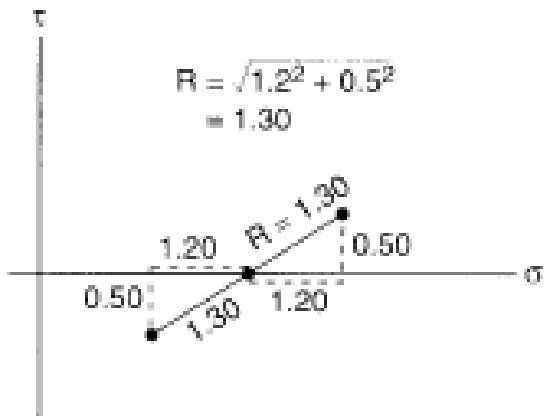
$$\tau_n = \frac{\sigma_y - \sigma_x}{2} \sin 2\theta - \tau_{xy} \cos 2\theta$$

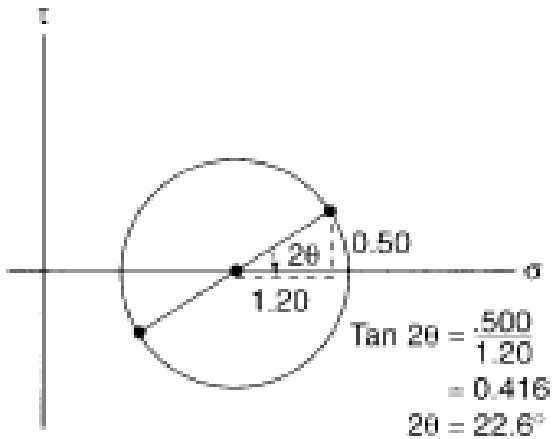
$$\tan 2\theta = \frac{2\tau_{xy}}{\sigma_y - \sigma_x}$$

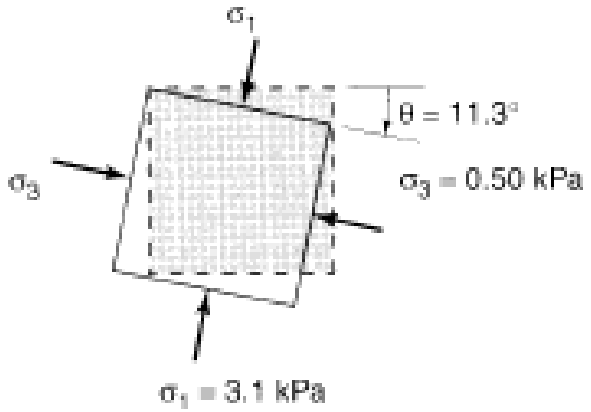
2 Ứng suất











2 Ứng suất

Thí dụ

A soil element is shown in Figure 9.4. The magnitudes of stresses are $\sigma_x = 120\ \text{kN/m}^2$, $\tau = 40\ \text{kN/m}^2$, $\sigma_y = 300\ \text{kN/m}^2$, and $\theta = 20°$. Determine

a. Magnitudes of the principal stresses
b. Normal and shear stresses on plane AB. Use Eqs. (9.3), (9.4), (9.6), and (9.7).

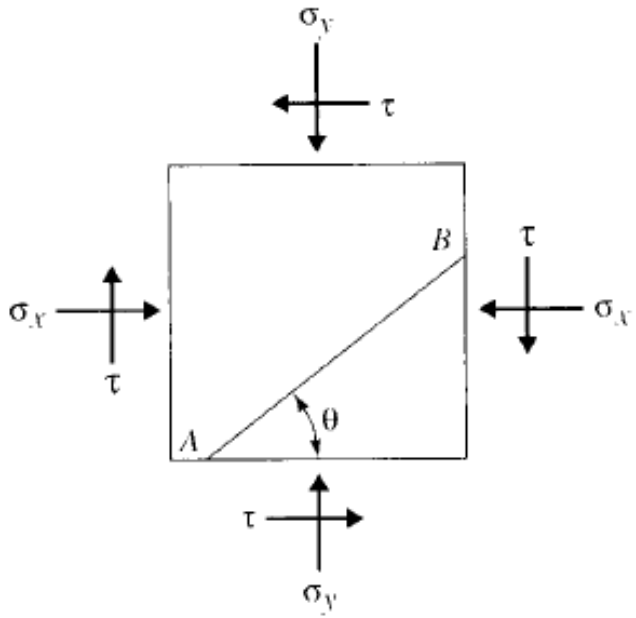


Figure 9.4 Soil element with stresses acting on it

2 Ứng suất

Solution

a.

$$\left.\begin{matrix}\sigma_3\\ \sigma_1\end{matrix}\right\} = \frac{\sigma_y + \sigma_x}{2} \pm \sqrt{\left[\frac{\sigma_y - \sigma_x}{2}\right]^2 + \tau_{xy}^2}$$

$$= \frac{300 + 120}{2} \pm \sqrt{\left[\frac{300 - 120}{2}\right]^2 + (-40)^2}$$

$$\sigma_1 = \mathbf{308.5\ kN/m^2}$$

$$\sigma_3 = \mathbf{111.5\ kN/m^2}$$

b.

$$\sigma_n = \frac{\sigma_y + \sigma_x}{2} + \frac{\sigma_y - \sigma_x}{2}\cos 2\theta + \tau \sin 2\theta$$

$$= \frac{300 + 120}{2} + \frac{300 - 120}{2}\cos(2 \times 20) + (-40)\sin(2 \times 20)$$

$$= \mathbf{252.23\ kN/m^2}$$

$$\tau_n = \frac{\sigma_y - \sigma_x}{2}\sin 2\theta - \tau \cos 2\theta$$

$$= \frac{300 - 120}{2}\sin(2 \times 20) - (-40)\cos(2 \times 20)$$

$$= \mathbf{88.49\ kN/m^2}$$