CONSTRUCTION AND QUALITY CONTROL OF FLEXIBLE AND RIGID PAVEMENTS

PROPERTIES OF SOILS FOR PAVEMENT DESIGN

National Rural Infrastructure Development Agency

Ministry of Rural Development

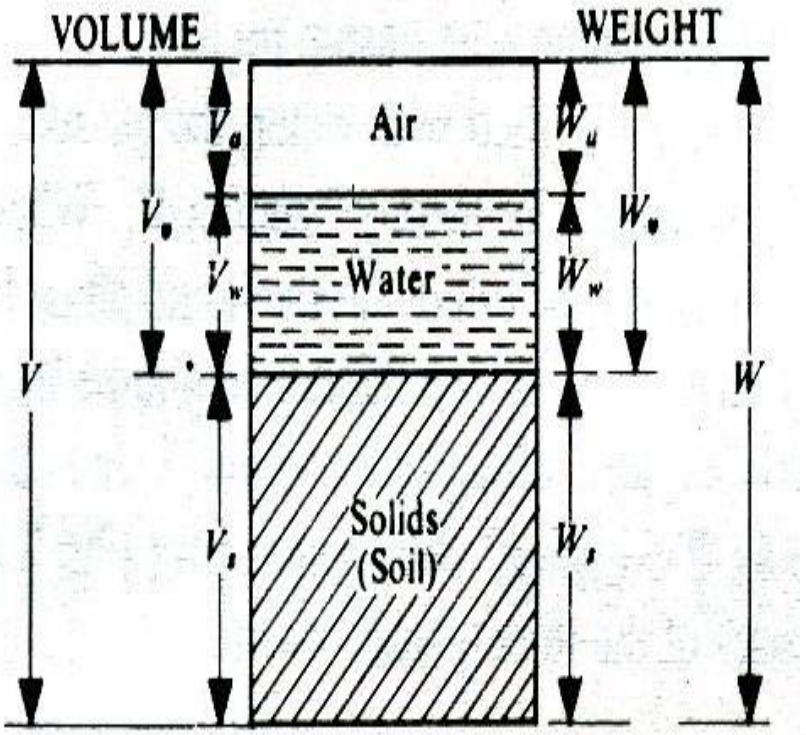
National Institute of Technology

Warangal, Hyderabad

Lecture-5

PROPERTIES OF SOILS FOR PAVEMENT DESIGN

• Engineering Geology + Mechanics ⟶ Soil Mechanics



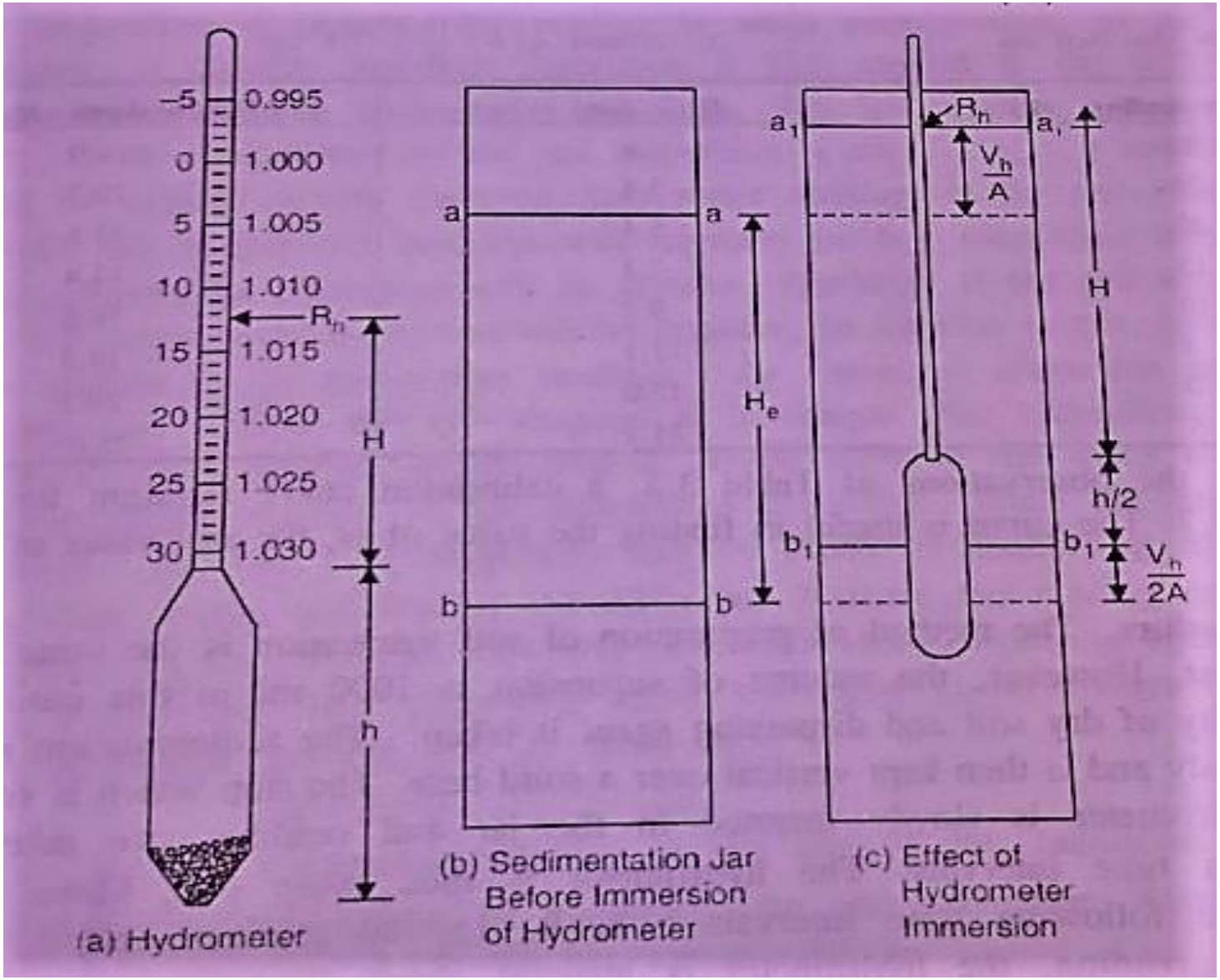
THREE PHASE SOIL SYSTEM

•Terzaghi's Effective Stress Principle $\sigma' = \sigma - u$

- Grain Size

Sieve Analysis - Calculations

Size of sieve	Wt. of soil retained, g	Cumulative Wt. retained, g	Cum. % wt. retained	Percent finer
4.75 mm				
2.36 mm				
1.18 mm				
600µ				
425µ				
300µ				
212µ				
150µ				
75µ				
Pan				

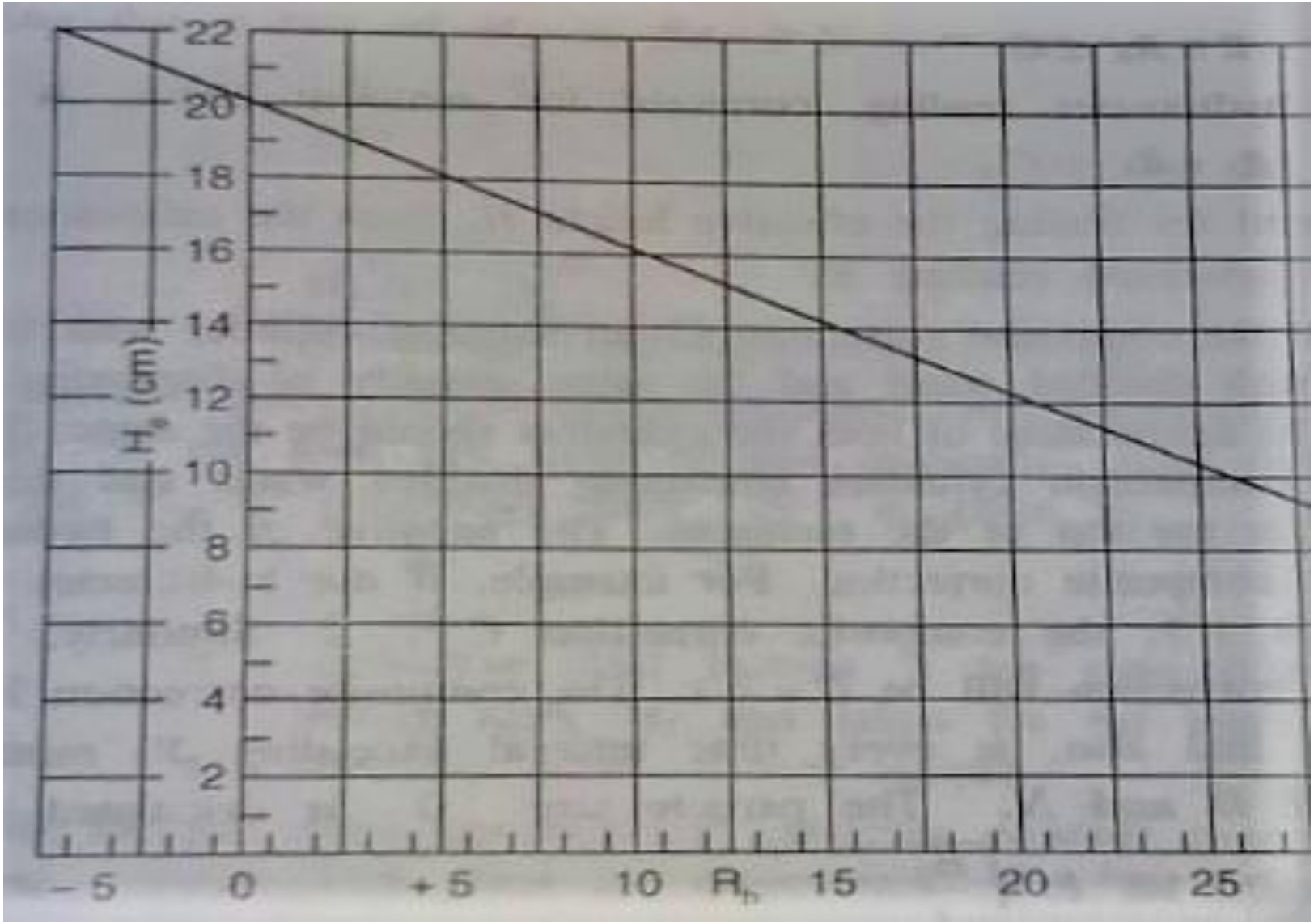

−5
0
5
10
15
20
25
30
0.995
1.000
1.005
1.010
1.015
1.020
1.025
1.030
R_h
H
h
(a) Hydrometer
a
a
b
b
H_e
(b) Sedimentation Jar Before Immersion of Hydrometer
a_1
a_1
R_h
$\frac{V_h}{A}$
H
h/2
b_1
b_1
$\frac{V_h}{2A}$
(c) Effect of Hydrometer Immersion

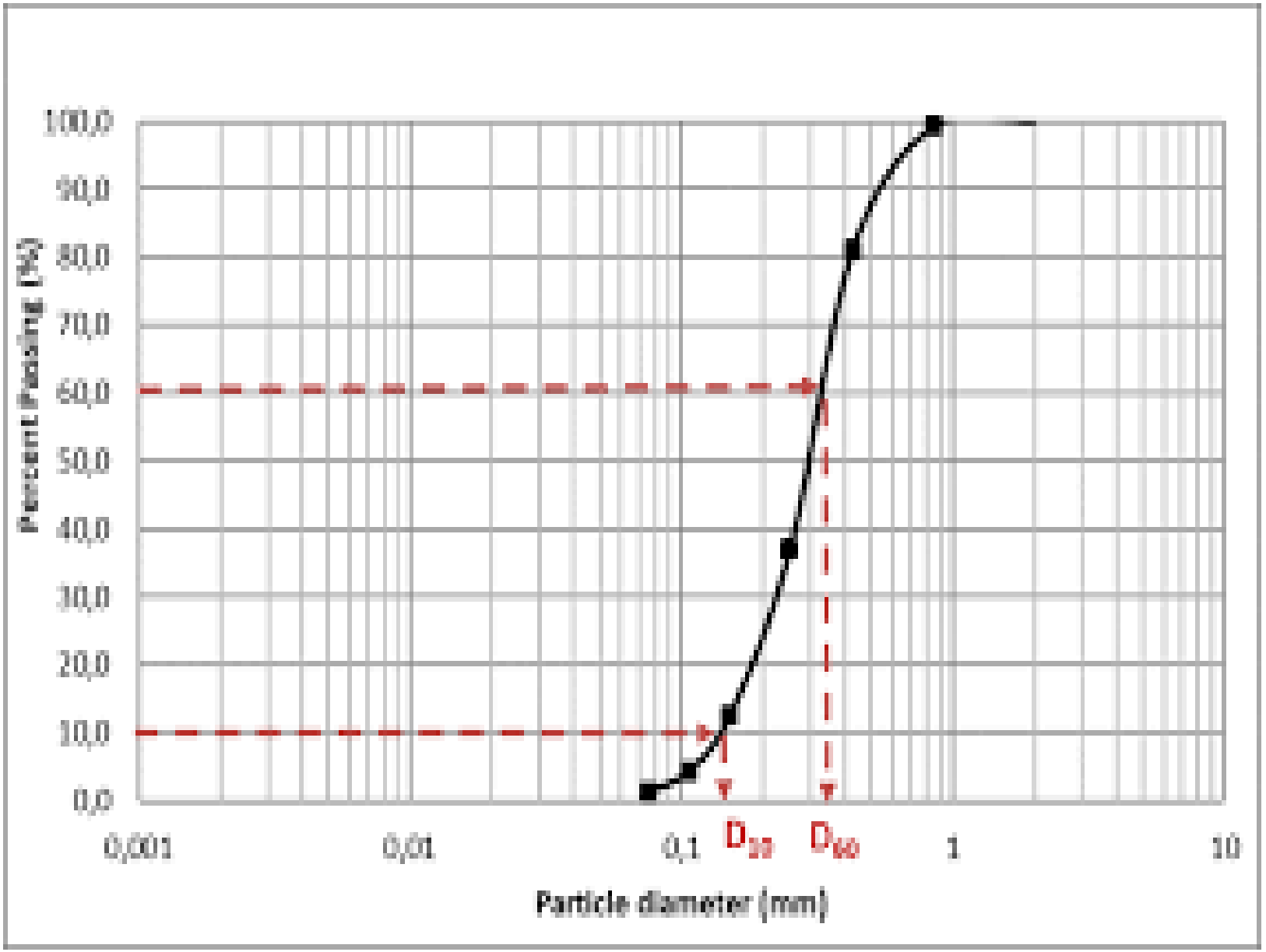
Time min., t	R_h	$R_h = R_h + C_m$	H_e (from calbr. chart	$D = k\sqrt{H_e/t}$	P'	P
0.50						
1.0						
2.0						
4.0						
8						
15						
30						
60						
120						
1440						

$P' = \{G/(G-1)\}\ ((R_h + C_m - C_d \pm C_t - 1)$

$C_m = 0.0005$, $C_d = 0.002$, C_t & k (from tables)

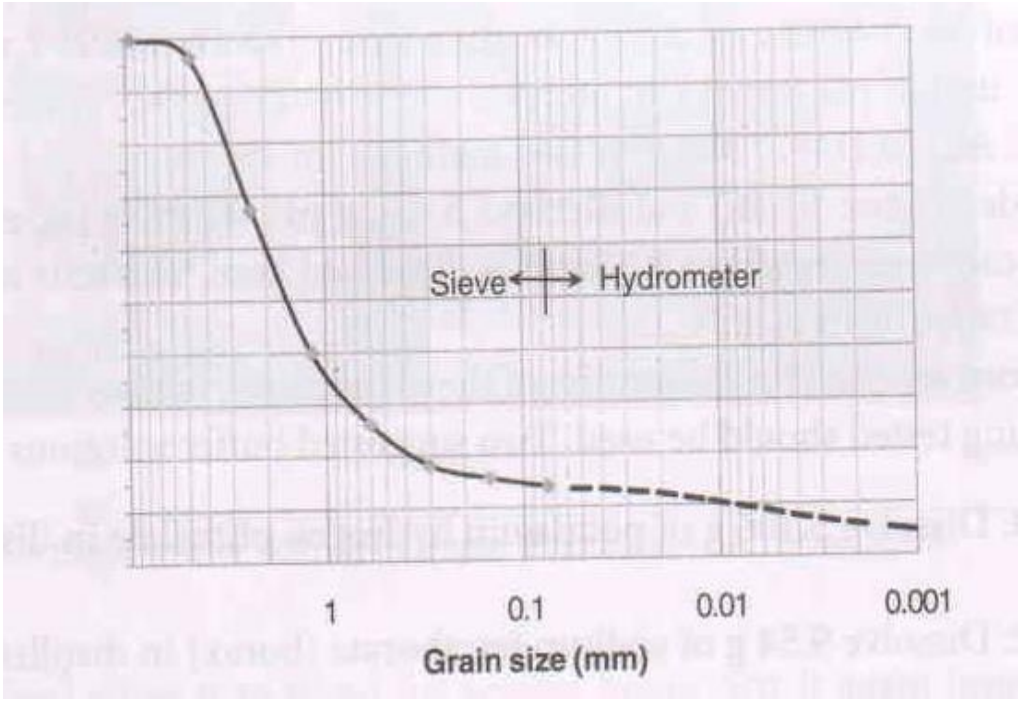
$$P = P'\left(\frac{Fraction\ passing\ through\ 75\ \mu\ sieve\ used\ for\ hydrometer\ test}{Total\ wt.of\ soil\ taken\ for\ analysis}\right)$$


22
20
18
16
14
12
10
8
6
4
2
I_o (cm)
−5
0
+5
10
R_h
15
20
25


100,0
90,0
80,0
70,0
60,0
50,0
40,0
30,0
20,0
10,0
0,0
Percent Passing (%)
0,001
0,01
0,1
1
10
D_{10}
D_{60}
Particle diameter (mm)

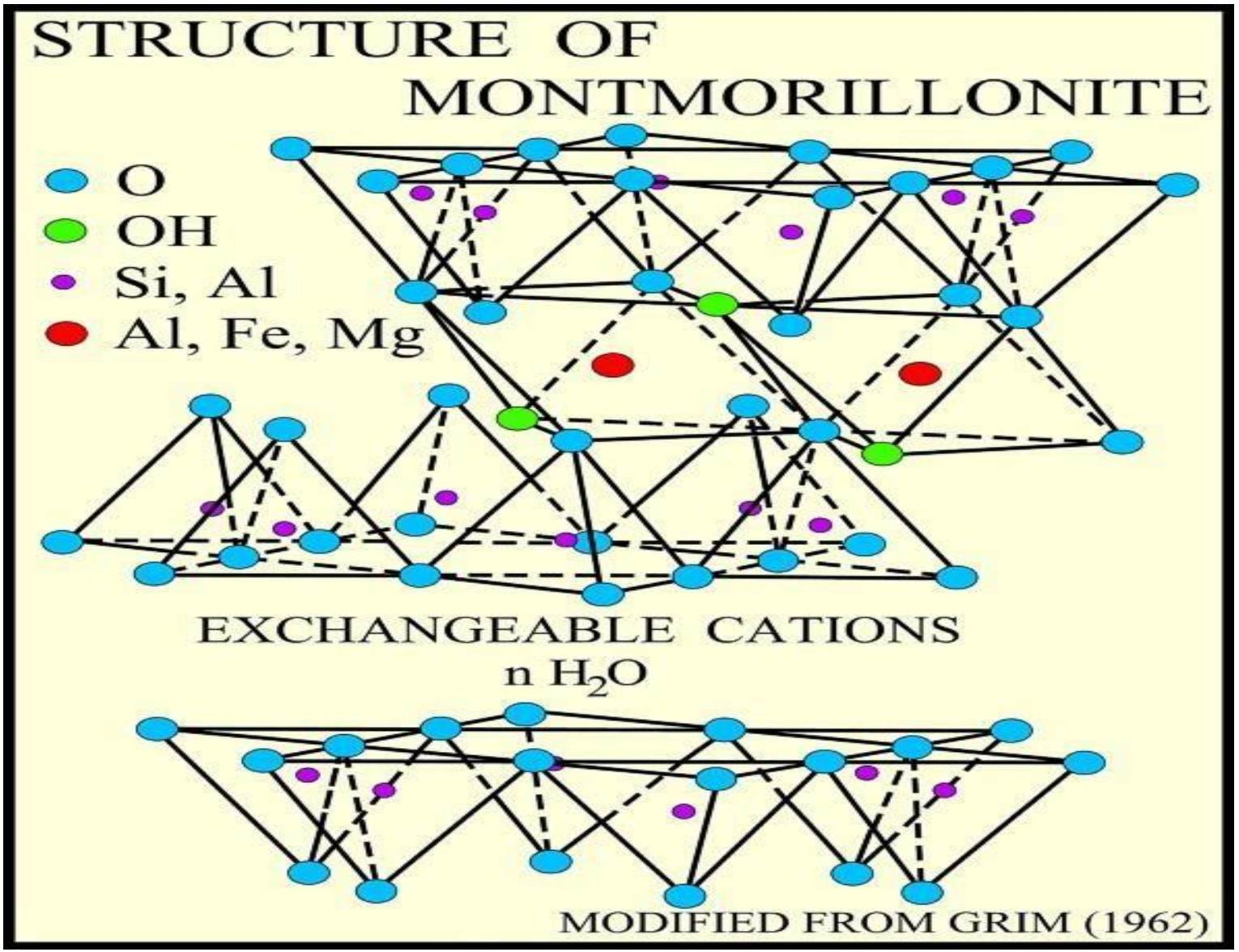
Grain Size Distribution

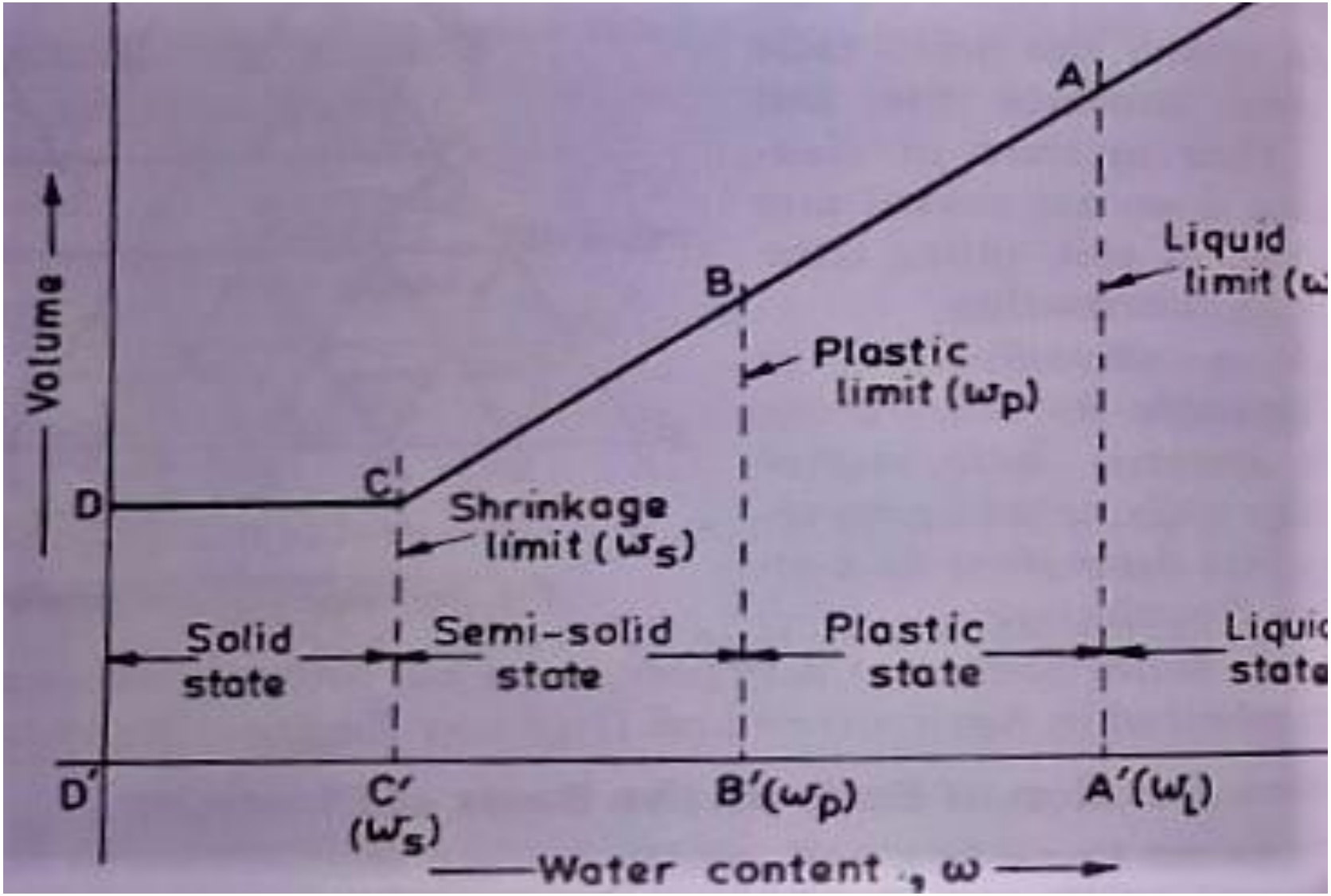
%Finer



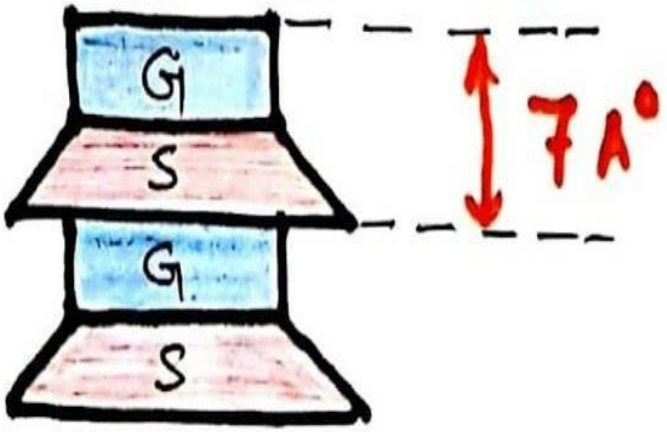
$C_u = D_{60}/D_{10}$, $C_c = D_{30}^{\ 2}/(D_{60} \times D_{10})$

Plasticity

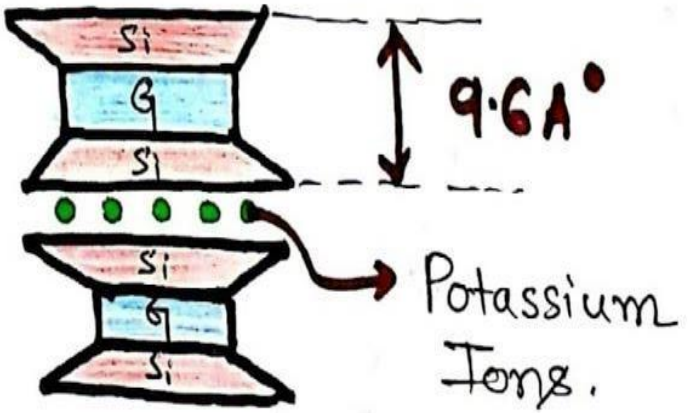

STRUCTURE OF
MONTMORILLONITE
O
OH
Si, Al
Al, Fe, Mg
EXCHANGEABLE CATIONS
n H_2O
MODIFIED FROM GRIM (1962)


A
B
C
D
Volume
Liquid limit (ω
Plastic limit (ωp)
Shrinkage limit (ωs)
Solid state
Semi-solid state
Plastic state
Liquid state
D'
C' (ωs)
B' (ωp)
A' (ωL)
Water content, ω

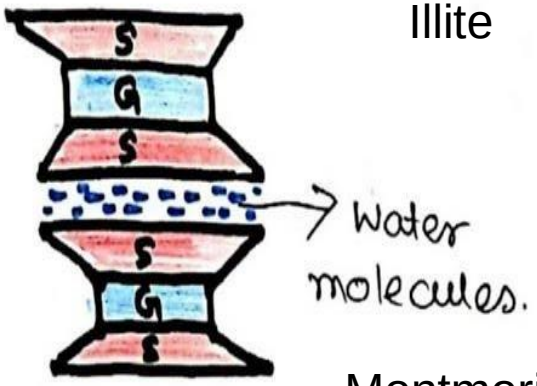
CLAY MINERALS



Kaolinite

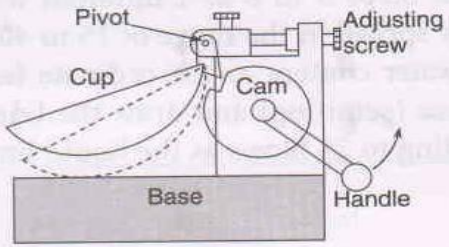


Illite

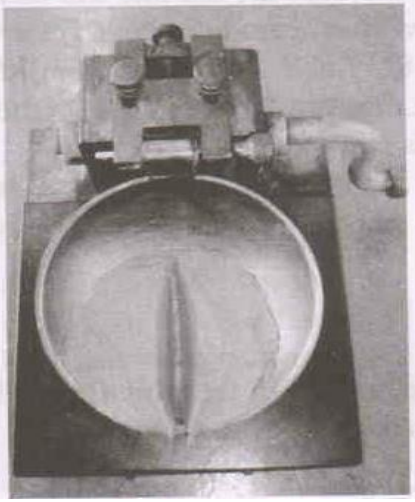


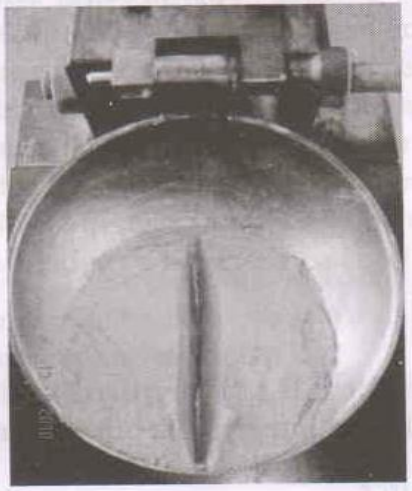
Montmorillonite

Liquid limit test(Casagrande's)



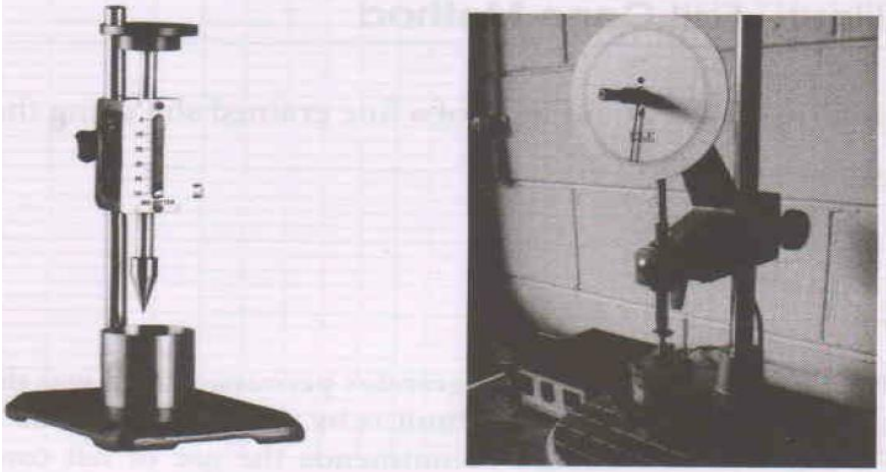
(a)



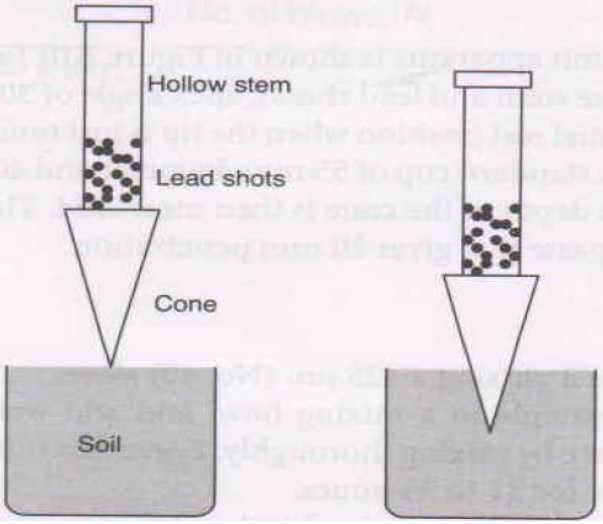


Concept?

LL-Cone penetrometer Method



(a)



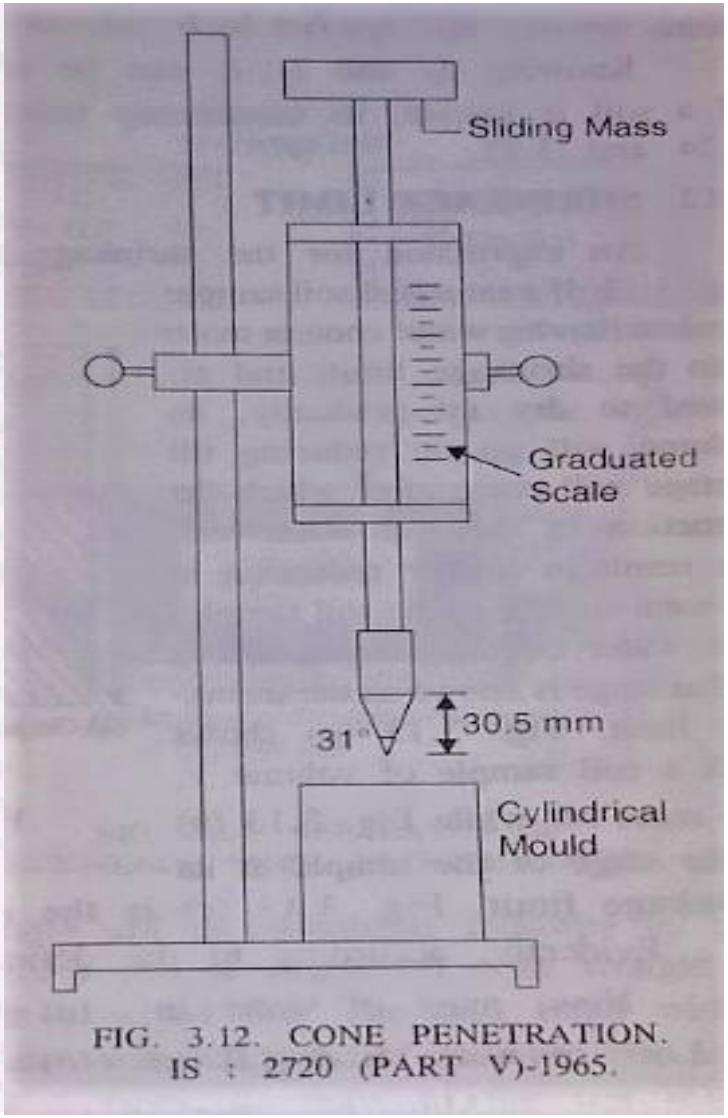
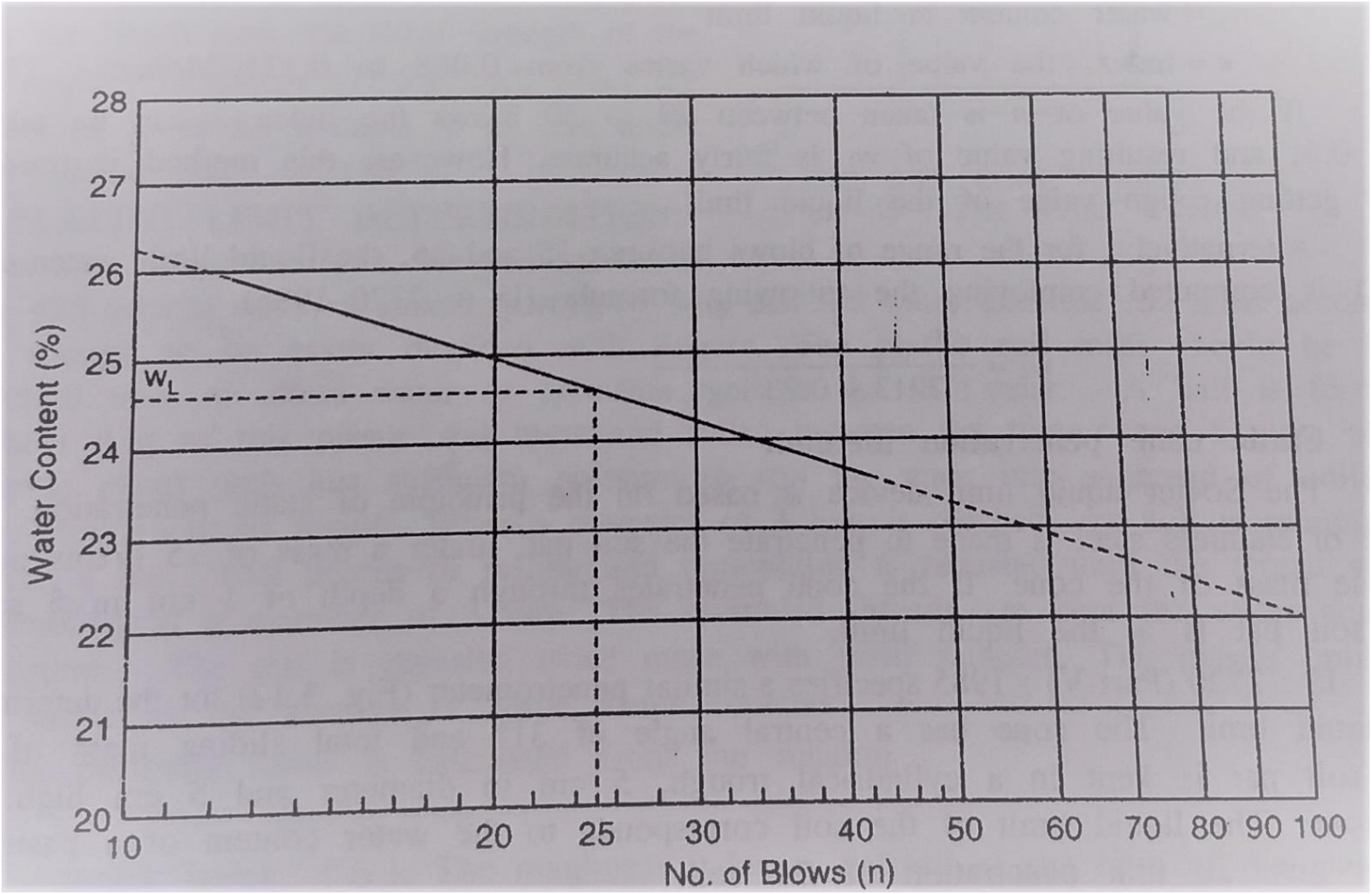
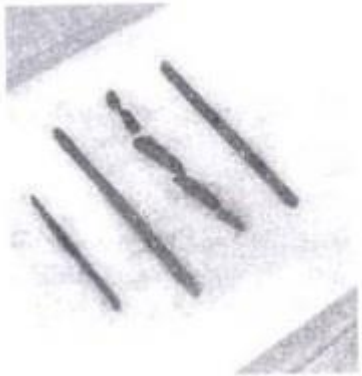


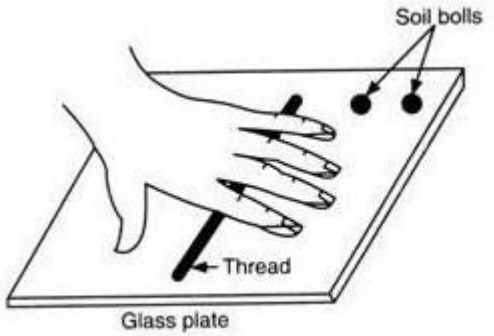
FIG. 3.12. CONE PENETRATION.
IS : 2720 (PART V)-1965.


28
27
26
25
24
23
22
21
20
Water Content (%)
w_L
10
20
25
30
40
50
60
70
80
90
100
No. of Blows (n)

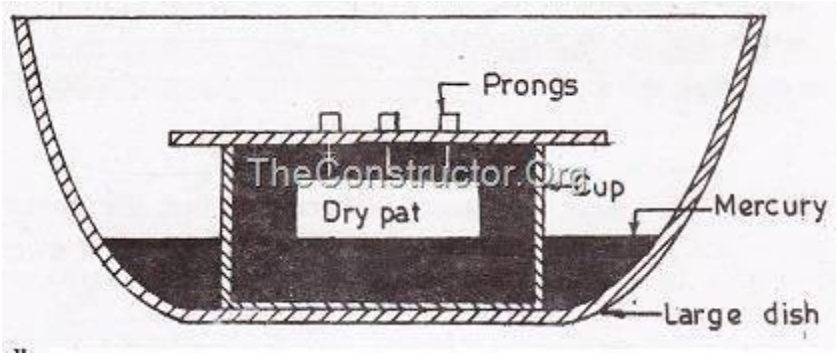
Plastic Limit Test

- Shear strength- 100 times that at LL



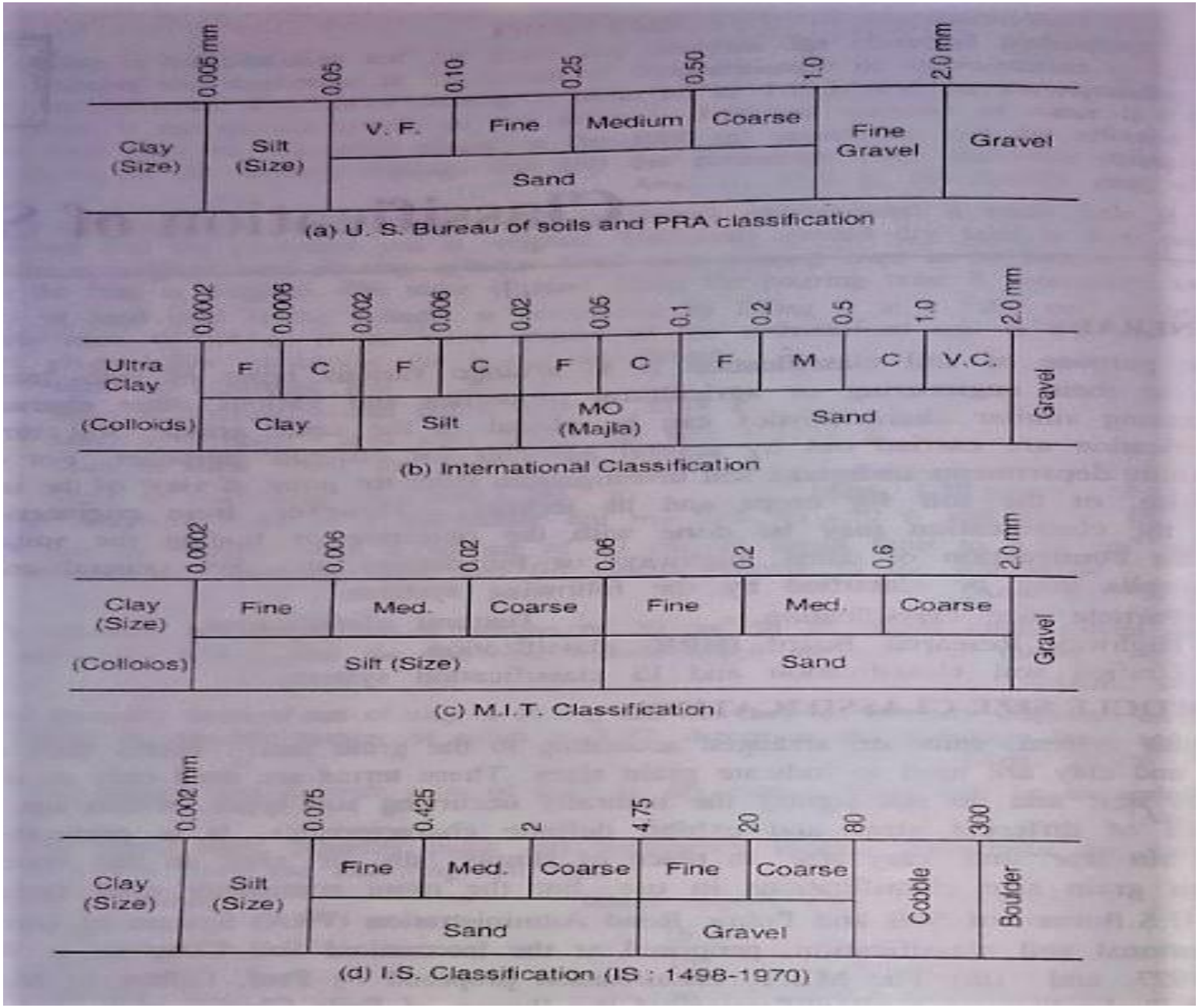


Shrinkage Limit Test

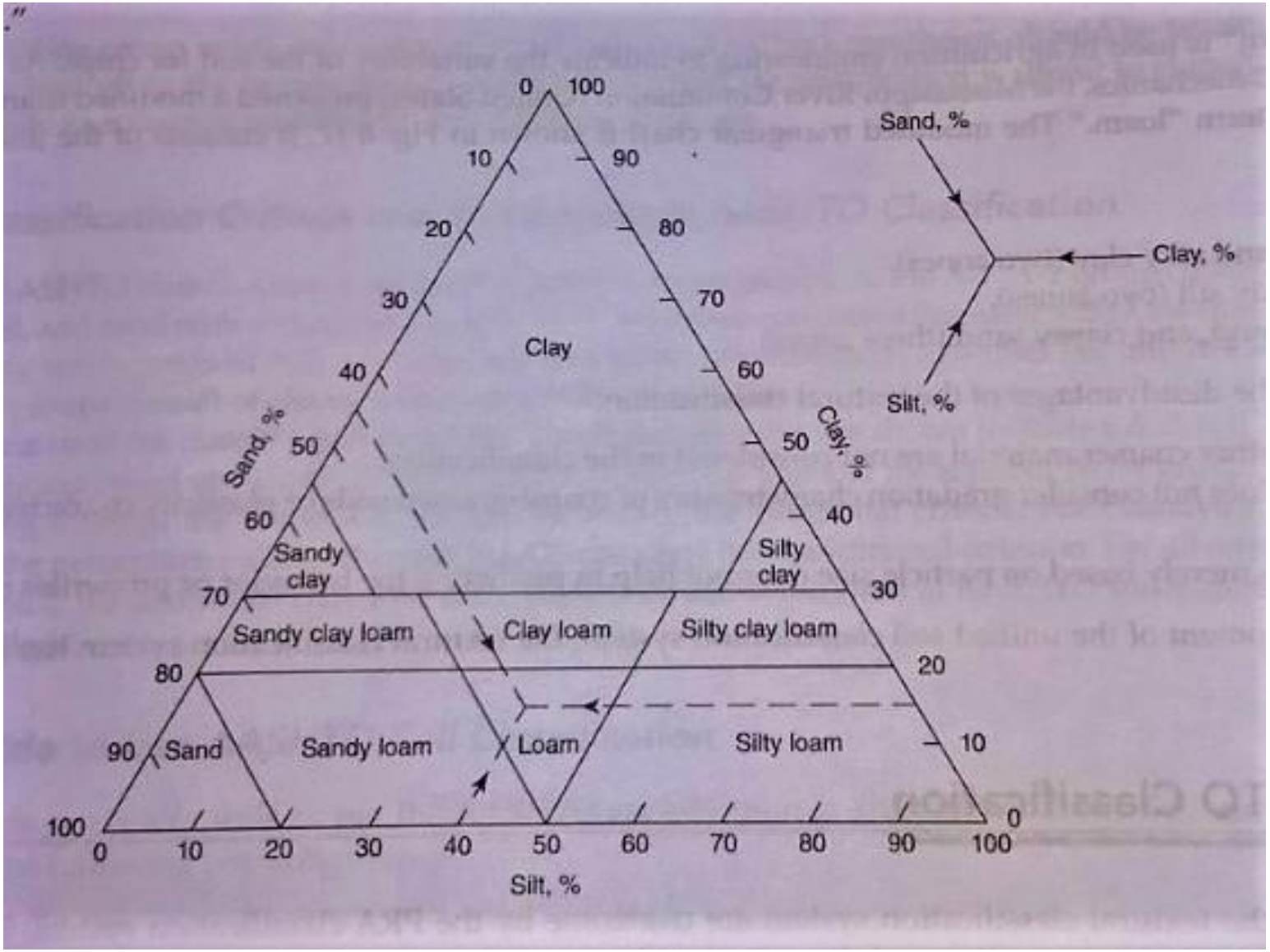


$$w_s = w_1 - \{(V_1 - V_2)\,w / W_s\}$$

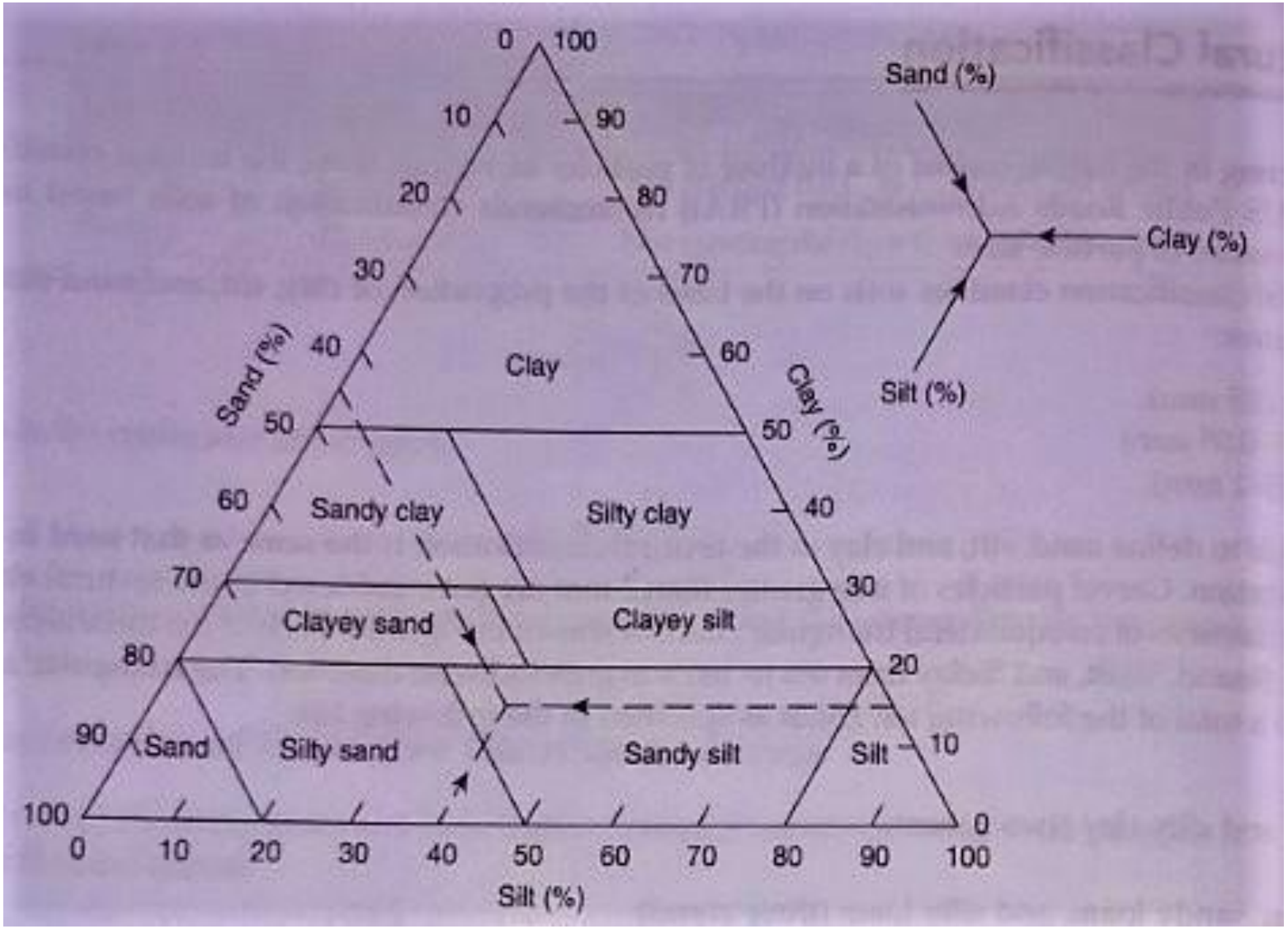
Classification of Soils



Textural Classification



Modified Textural Classification



AASHTO Classification

Table 6.7 HRB or AASHTO soil classification system

General Description	Granular material (35% or less passing 75-μm Sieve)							Silt and Clay materials (more than 35% passing 75-μm Sieve)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve analysis: % Passing											
2.0 mm Sieve	50 max										
425-μm Sieve	30 max	50 max	51 min								
75-μm Sieve	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of soil passing 425-μm sieve:											
Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max	6 max	NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Group index			Zero			4 max		8 max	12 max	16 max	20 max
Usual type of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soil		Clayey soil	
General rating as subgrade	Excellent to good							Fair to poor			

Group Index (GI)

$$GI = 0.2\,a + 0.005\,ac + 0.01\,bd$$

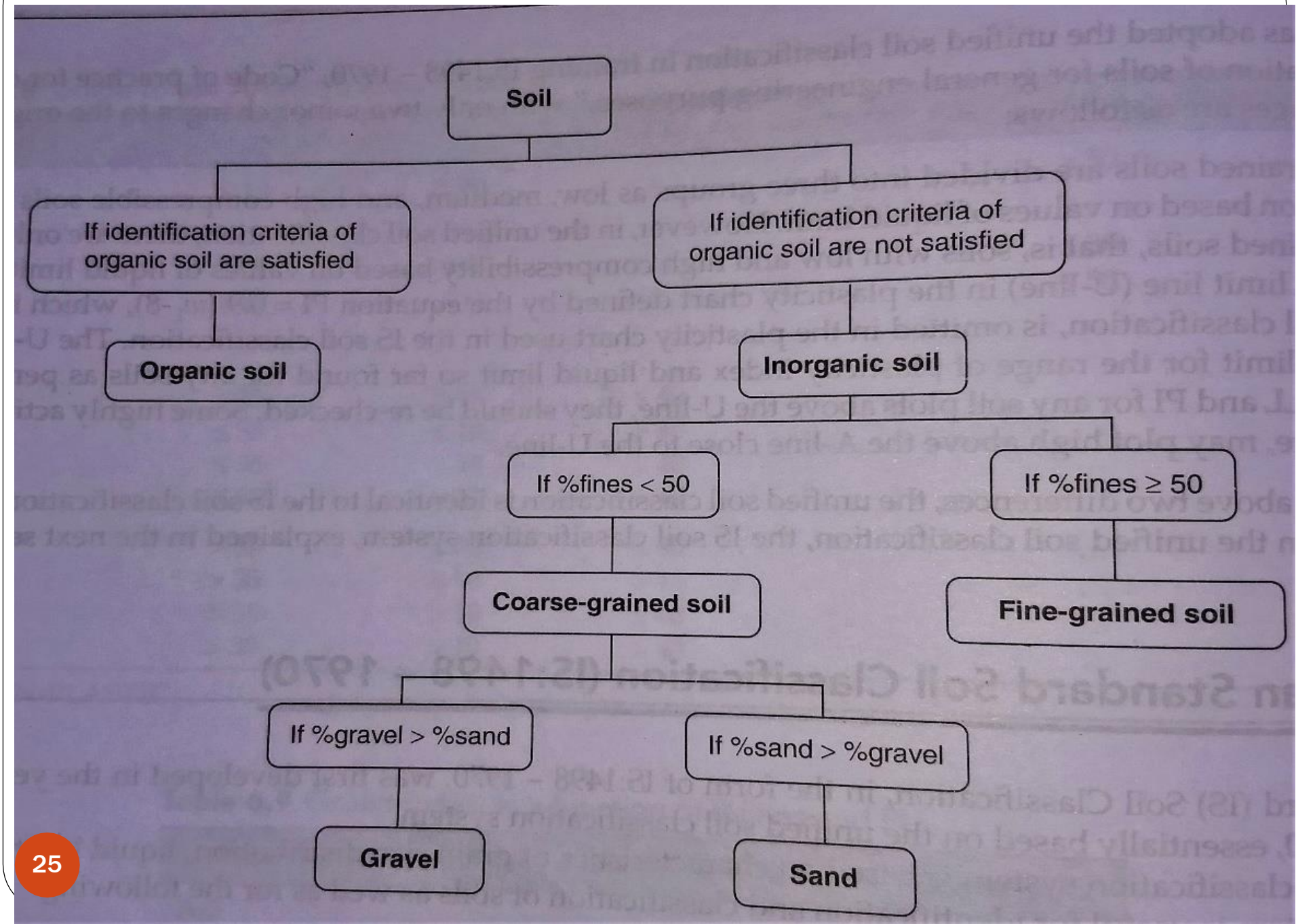
Where, a = Percent passing -75 μ sieve, >35 <75 expressed as (0-40)

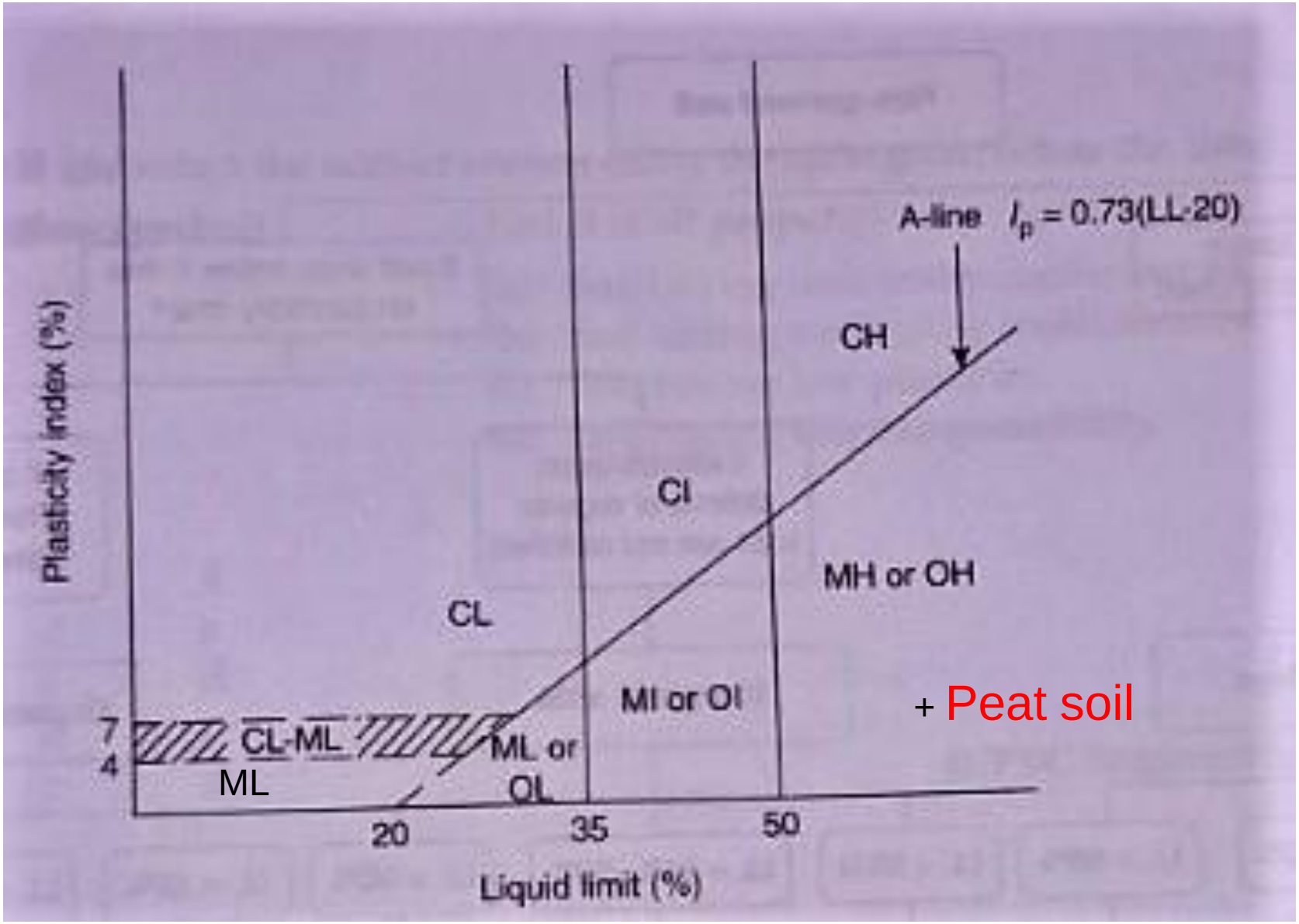
b = Percent passing -75 μ sieve, >15 < 55 expressed as (0-40)

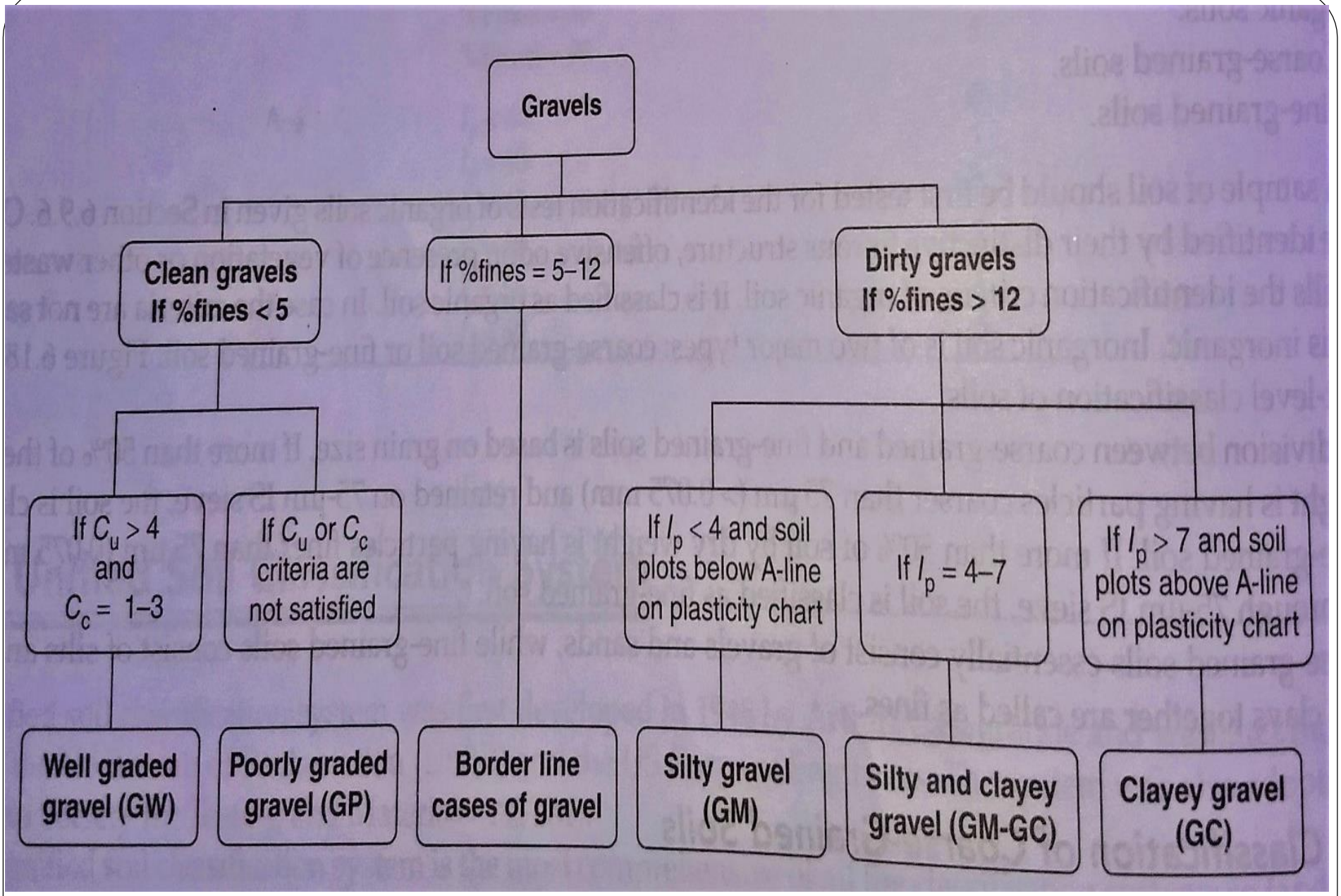
c = Liquid limit >40 < 60 expressed as (0-20)

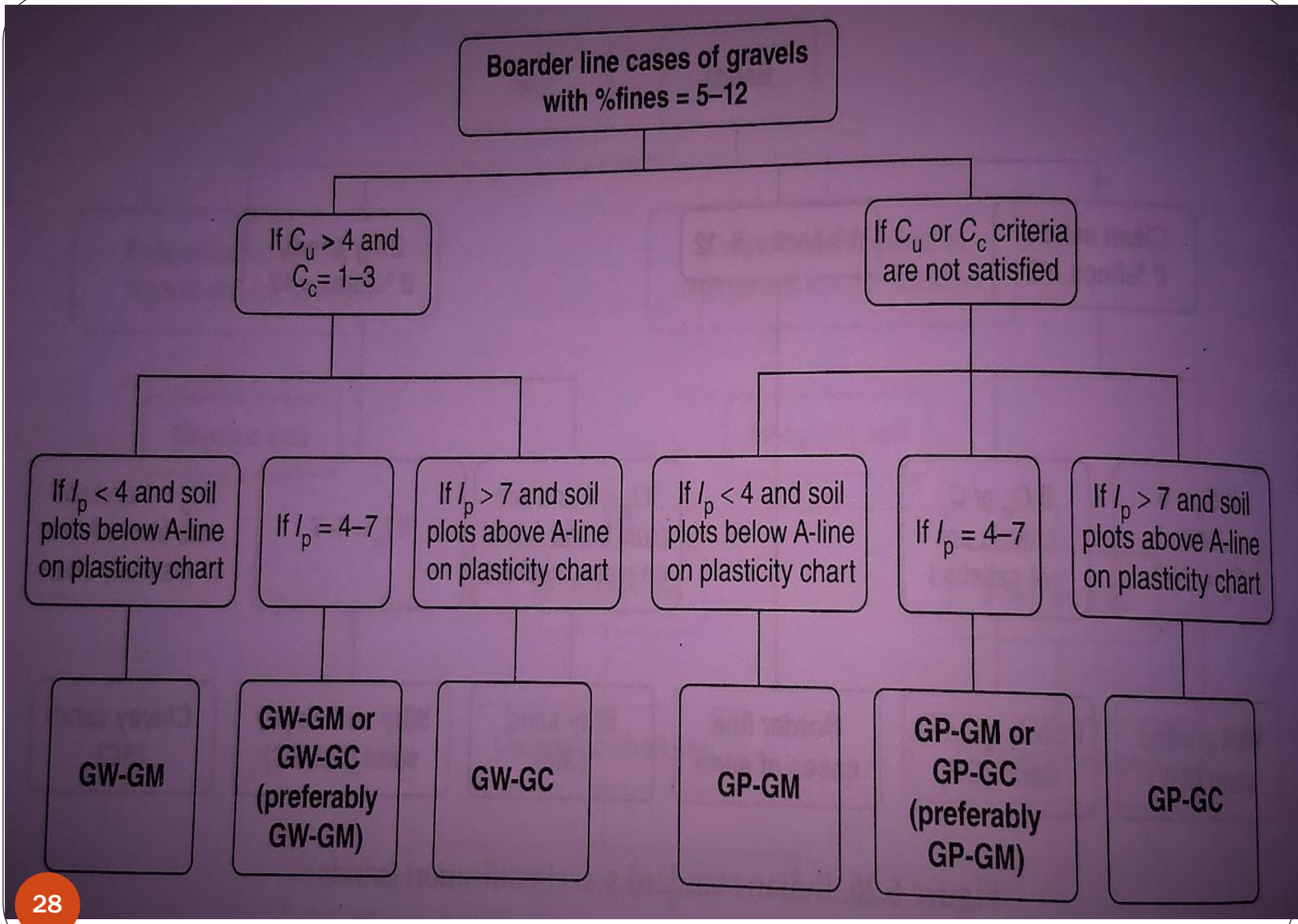
d = Plasticity index >10 < 30 expressed as (0-20)

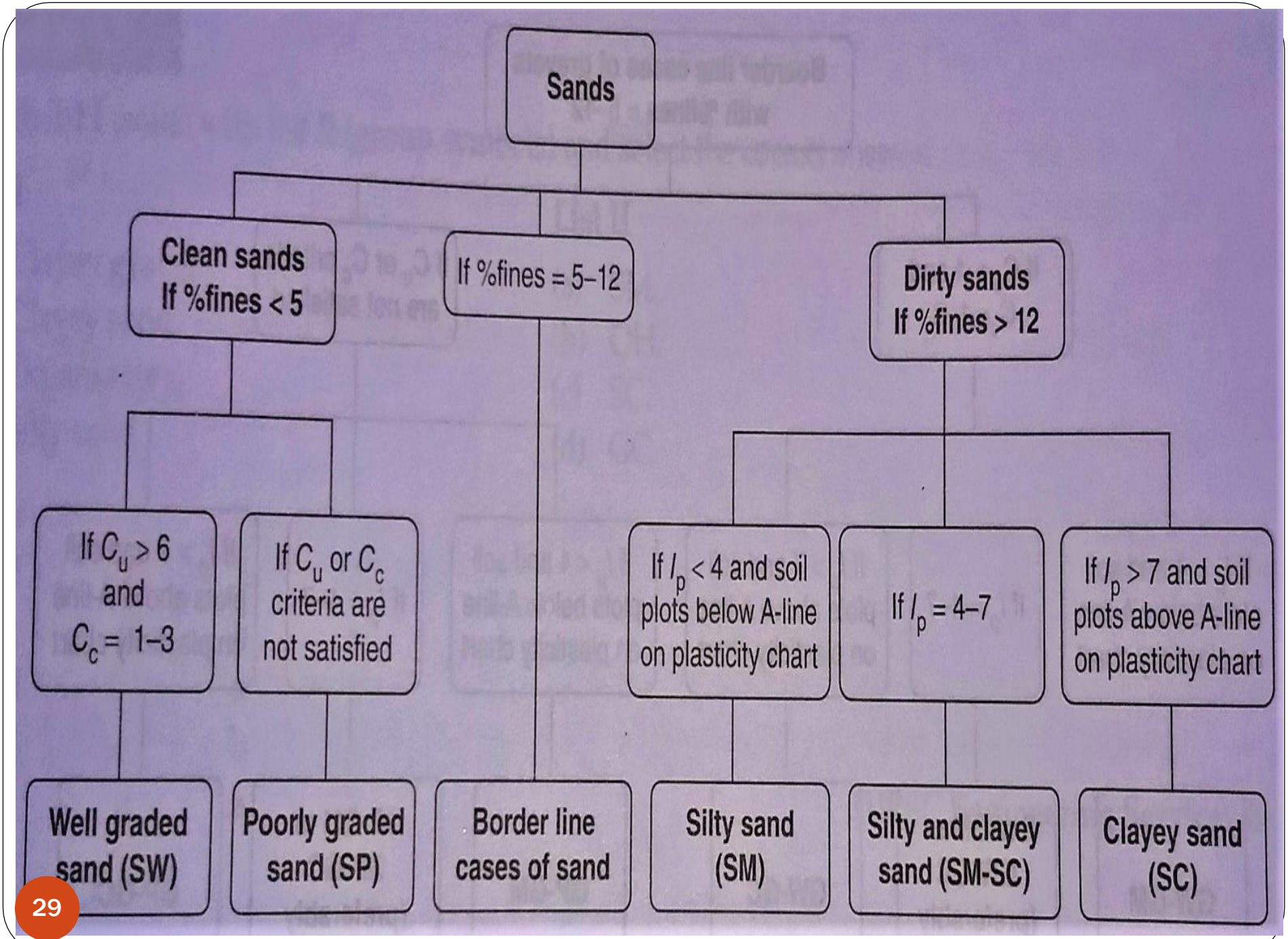
IS SOIL CLASSIFICATION

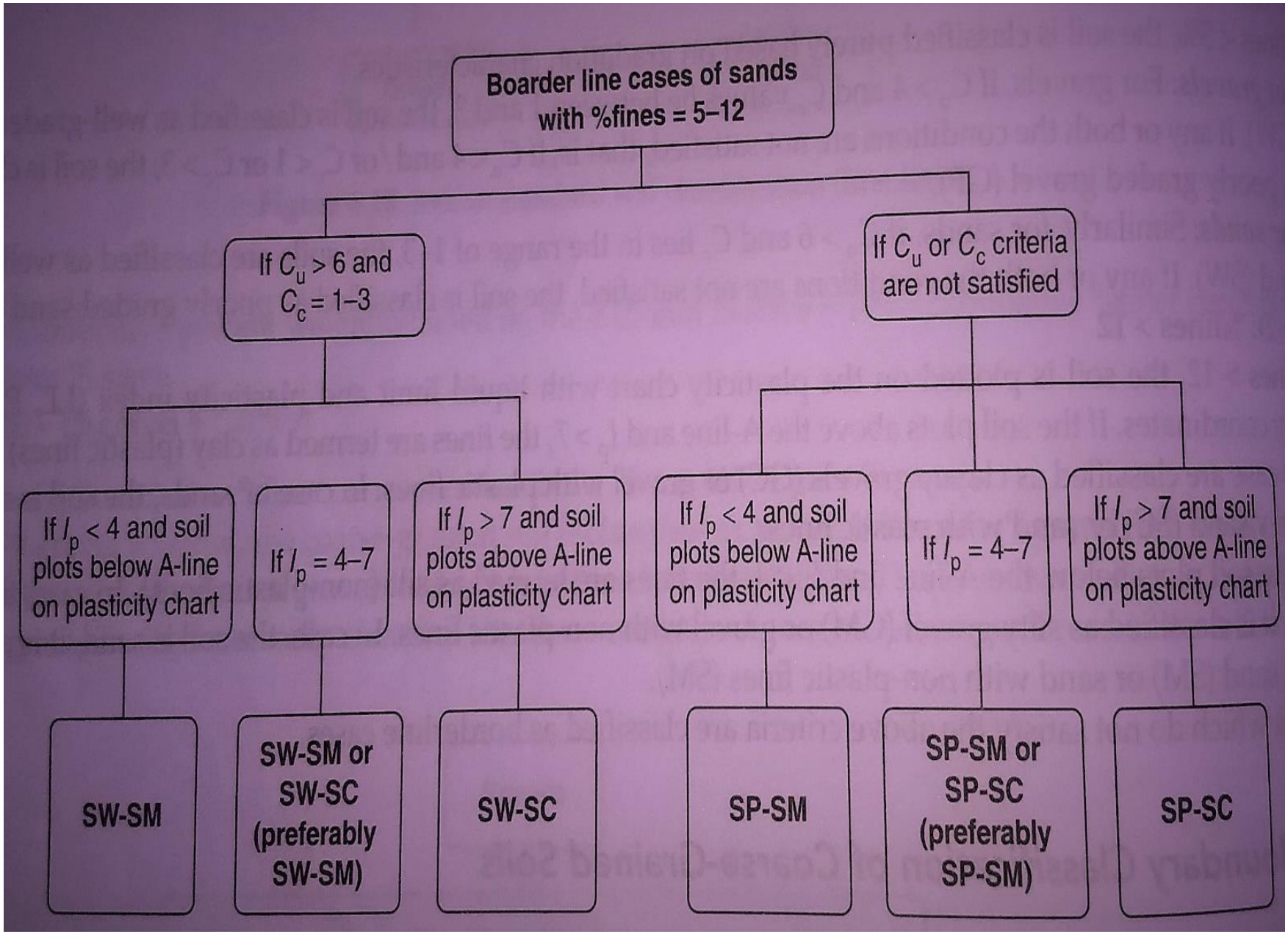



A-line $I_p = 0.73(LL-20)$
CH
CI
MH or OH
CL
MI or OI
+ Peat soil
7
4
CL-ML
ML
ML or
OL
20
35
50
Plasticity index (%)
Liquid limit (%)


Gravels
Clean gravels
If %fines < 5
If %fines = 5–12
Dirty gravels
If %fines > 12
If $C_u > 4$ and $C_c = 1–3$
If C_u or C_c criteria are not satisfied
If $I_p < 4$ and soil plots below A-line on plasticity chart
If $I_p = 4–7$
If $I_p > 7$ and soil plots above A-line on plasticity chart
Well graded gravel (GW)
Poorly graded gravel (GP)
Border line cases of gravel
Silty gravel (GM)
Silty and clayey gravel (GM-GC)
Clayey gravel (GC)


Boarder line cases of gravels with %fines = 5–12
If C_u > 4 and C_c = 1–3
If C_u or C_c criteria are not satisfied
If I_p < 4 and soil plots below A-line on plasticity chart
If I_p = 4–7
If I_p > 7 and soil plots above A-line on plasticity chart
If I_p < 4 and soil plots below A-line on plasticity chart
If I_p = 4–7
If I_p > 7 and soil plots above A-line on plasticity chart
GW-GM
GW-GM or GW-GC (preferably GW-GM)
GW-GC
GP-GM
GP-GM or GP-GC (preferably GP-GM)
GP-GC

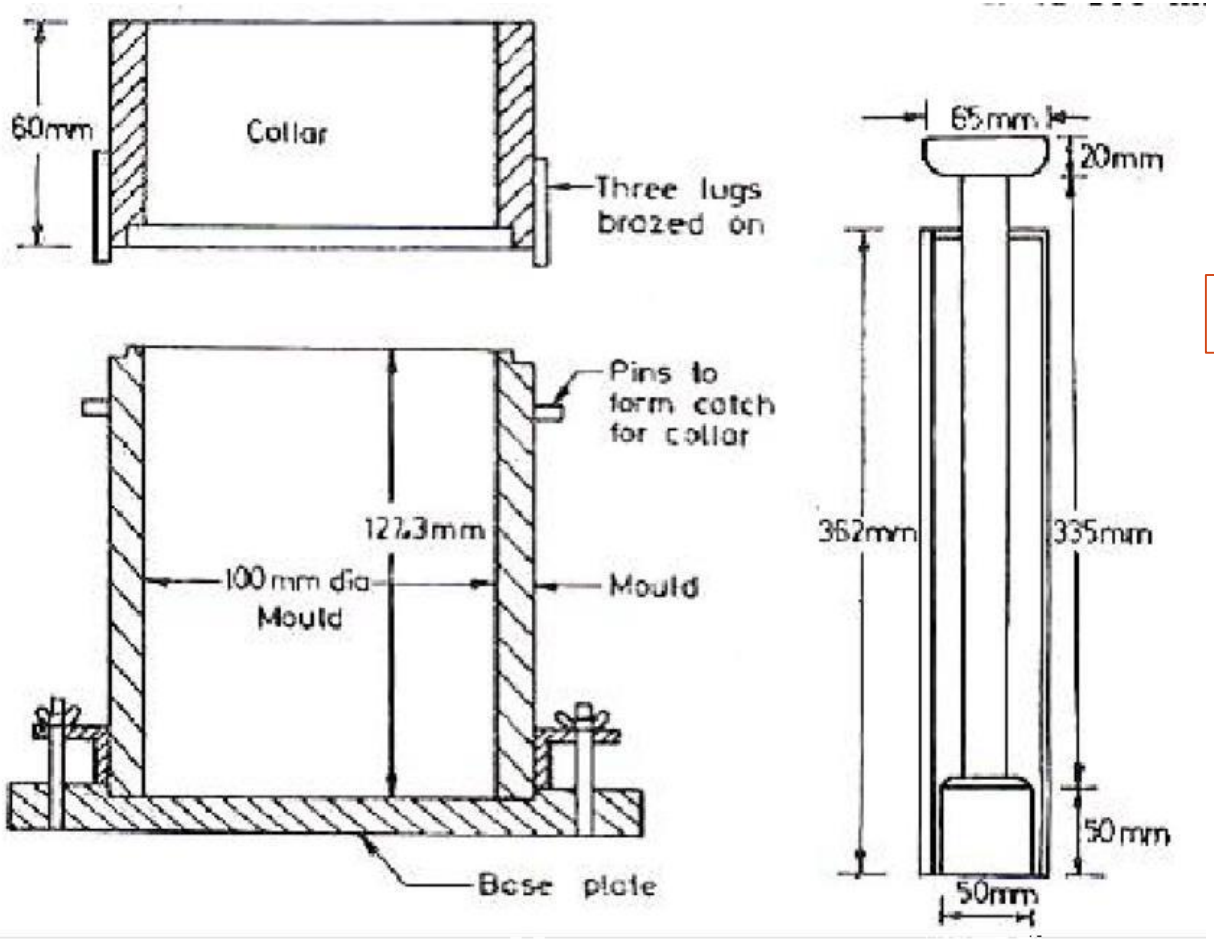

Sands
Clean sands
If %fines < 5
If %fines = 5–12
Dirty sands
If %fines > 12
If $C_u > 6$ and $C_c = 1–3$
If C_u or C_c criteria are not satisfied
If $I_p < 4$ and soil plots below A-line on plasticity chart
If $I_p = 4–7$
If $I_p > 7$ and soil plots above A-line on plasticity chart
Well graded sand (SW)
Poorly graded sand (SP)
Border line cases of sand
Silty sand (SM)
Silty and clayey sand (SM-SC)
Clayey sand (SC)


Boarder line cases of sands with %fines = 5–12
If C_u > 6 and C_c = 1–3
If C_u or C_c criteria are not satisfied
If I_p < 4 and soil plots below A-line on plasticity chart
If I_p = 4–7
If I_p > 7 and soil plots above A-line on plasticity chart
If I_p < 4 and soil plots below A-line on plasticity chart
If I_p = 4–7
If I_p > 7 and soil plots above A-line on plasticity chart
SW-SM
SW-SM or SW-SC (preferably SW-SM)
SW-SC
SP-SM
SP-SM or SP-SC (preferably SP-SM)
SP-SC

Comparison Between AASHTO & Unified Classification Systems

S.N0	AASHTO System	Unified System
1.	Limiting fines content to demarcate fine & coarse grained soils is 35%. >35% fines- Fine grained soil. This limiting value is somewhat better as soils with 35% fines behave as fine grained soils.	Limiting fines content to demarcate fine & coarse grained soils is 50%. >50% fines- Fine grained soil, 50% fines as limiting value is somewhat higher.
2.	2 mm size is taken for gravel size.	4.75 mm is taken for gravel size.
3.	Gravels & sands are not clearly demarcated. A2 group contains variety of soils	Gravels &sand are clearly demarcated.
4.	Symbols are little difficult to remember.	Symbols can be more easily remembered.
5.	There is no place for organic soils.	Organic soils are classifies under OI, OH &peat
6.	Process of elimination is time consuming.	More convenient to use.

Standard Proctor Test



Concept?

Compaction sample: Passing 19 mm size. In case + 19 mm size > 5%, Large size mould 2250 cc is to be used with – 40 mm size sample.

IS Light Compaction: Mould =1000 cc

No. of layers: 3

No. of blows/layer = 25

Wt. of hammer = 2.6 kg

Ht. of fall = 31 cm

IS Heavy Compaction: Mould = 1000cc

No. of layers = 5

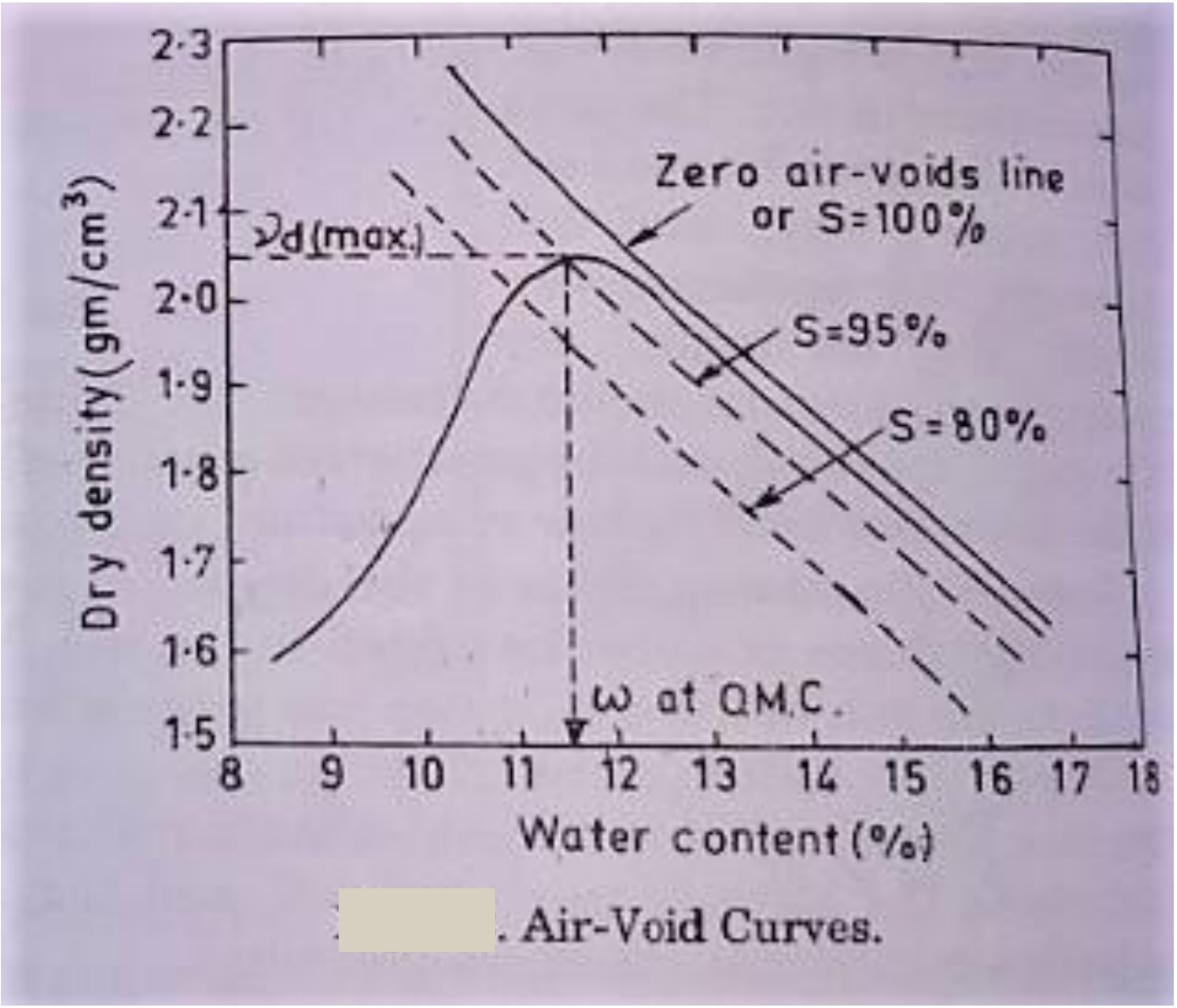
No. of blows/layer = 25

Wt. of hammer = 4.89 kg

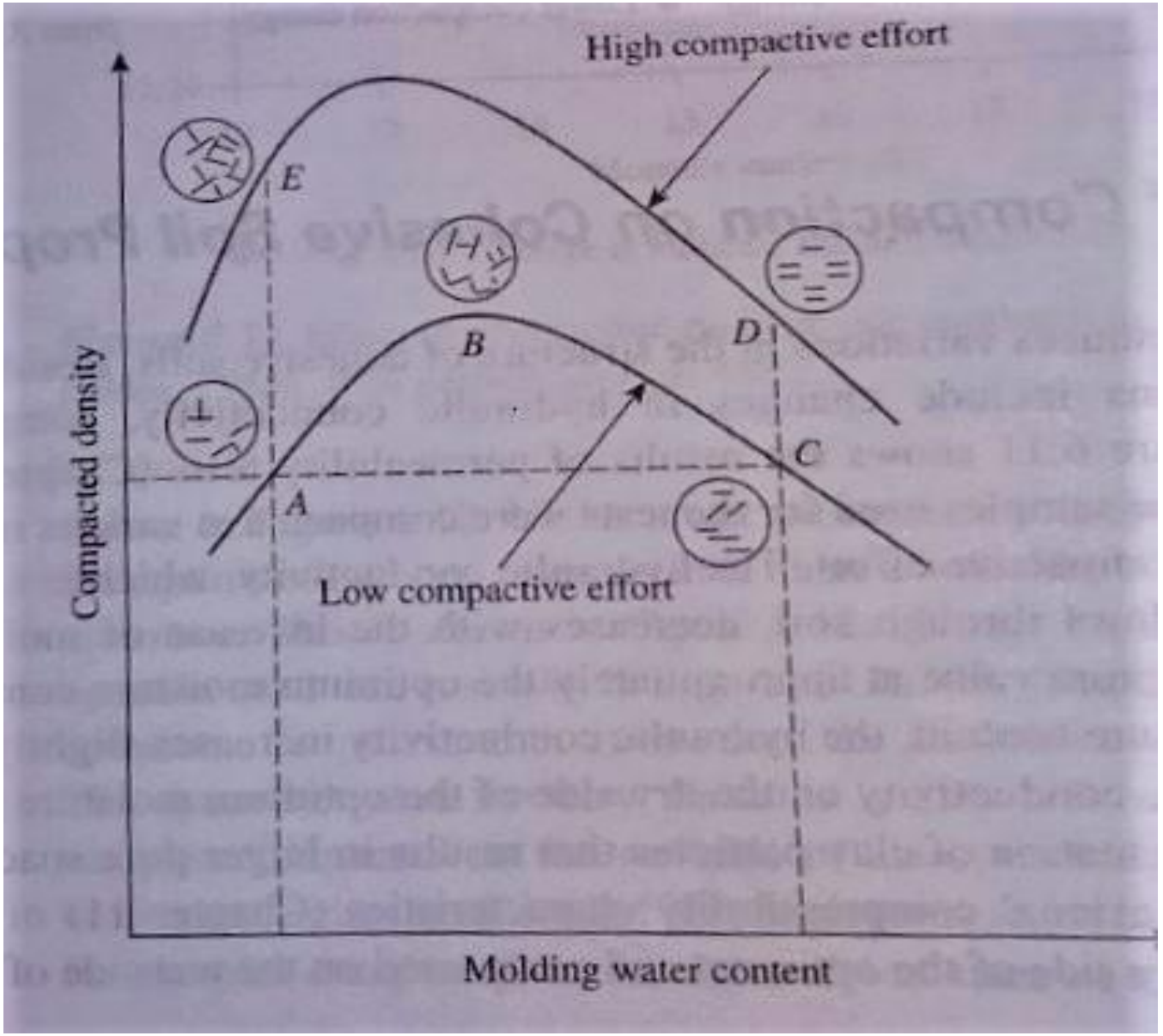
Ht. of fall = 45 cm

Compaction test- Calculations

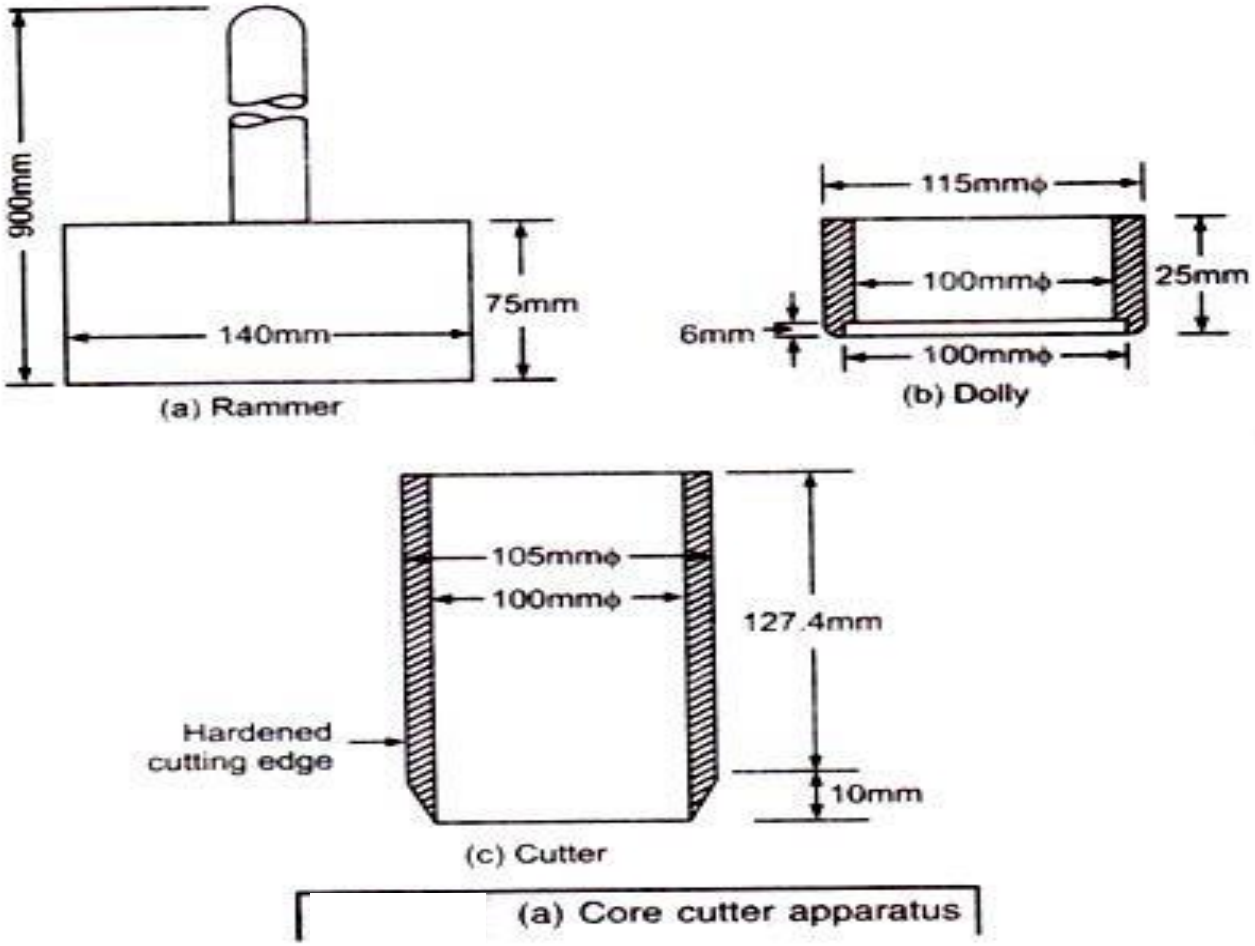
Details	1	2	3	4	5
Wet Wt. of soil (W), g					
Bulk density, γ, g/cc					
Dry density, γ_d, g.cc					
Water Content					
Cup + wet soil ($w_{1)}$ g					
Cup + Dry soil ($w_{2)}$ g					
Wt. of cup (w_3) g					
W.C. (%)					
$(w_1 - w_2) / (w_2 - w_3)$					



. Air-Void Curves.

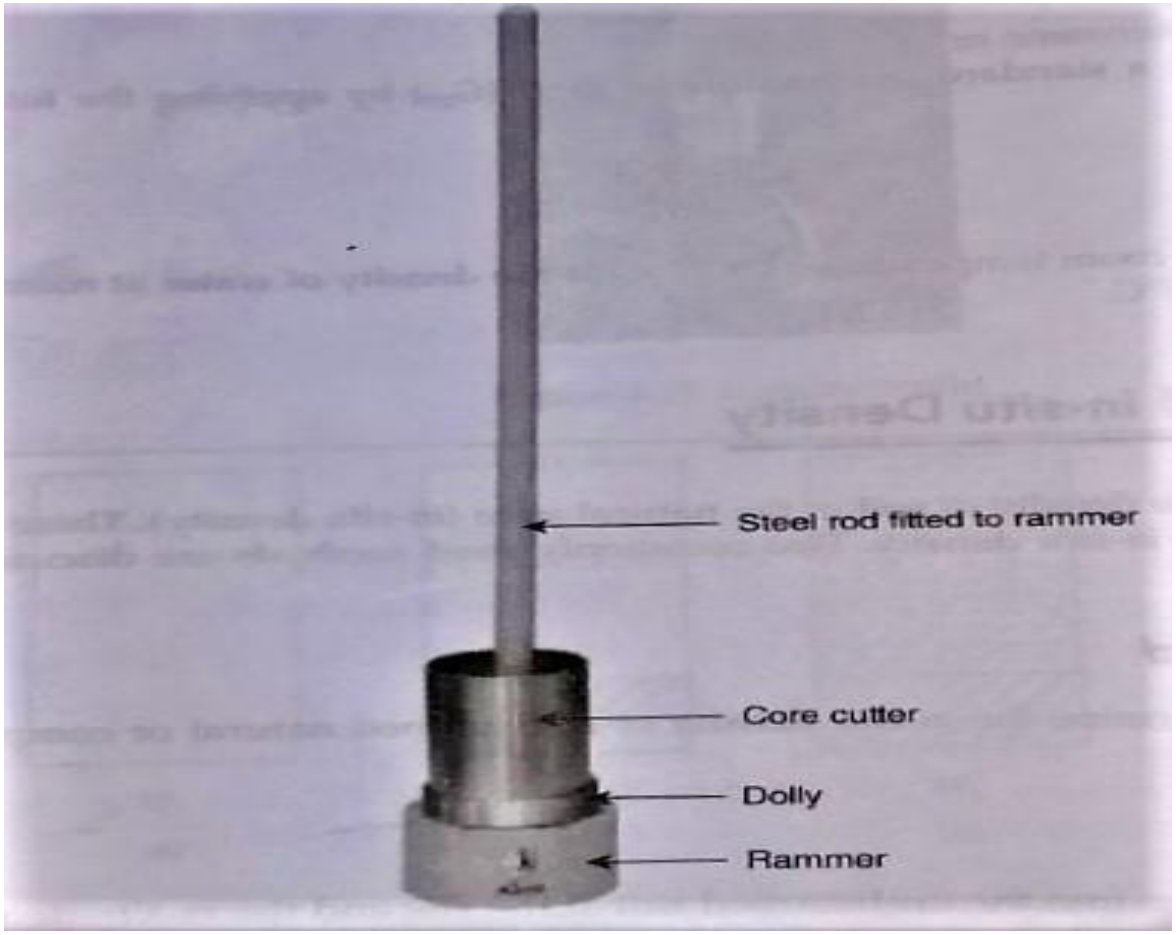

High compactive effort
E
B
D
C
A
Low compactive effort
Compacted density
Molding water content

Field Density Tests → Relative Compaction



(a) Core cutter apparatus

Core Cutter Method

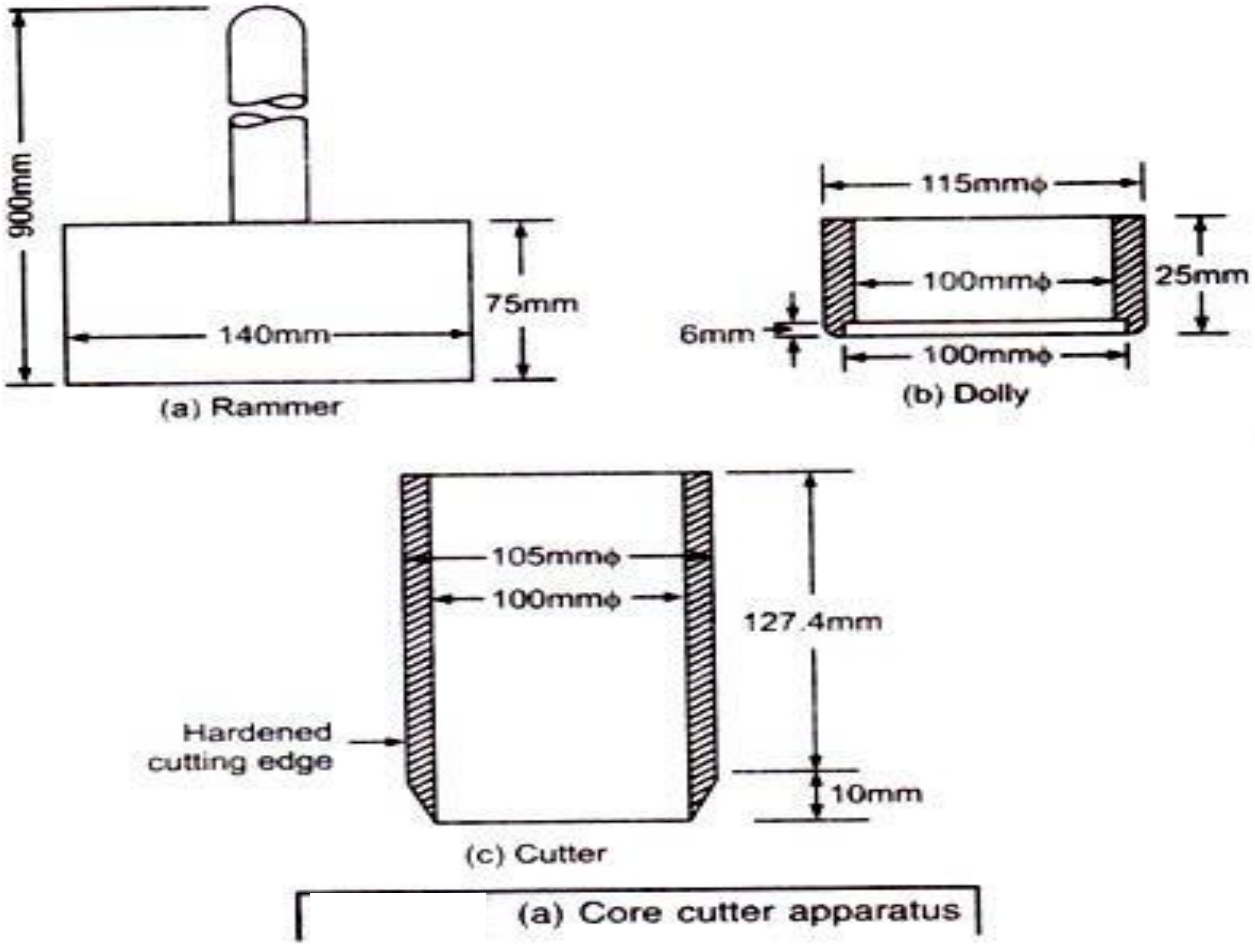


Field density – Relative Compaction

Sand Replacement Method

Field Density Tests → Relative Compaction

Field Density Tests → Relative Compaction



(a) Core cutter apparatus

CBR TEST APPARATUS (AIMIL)

- Test details

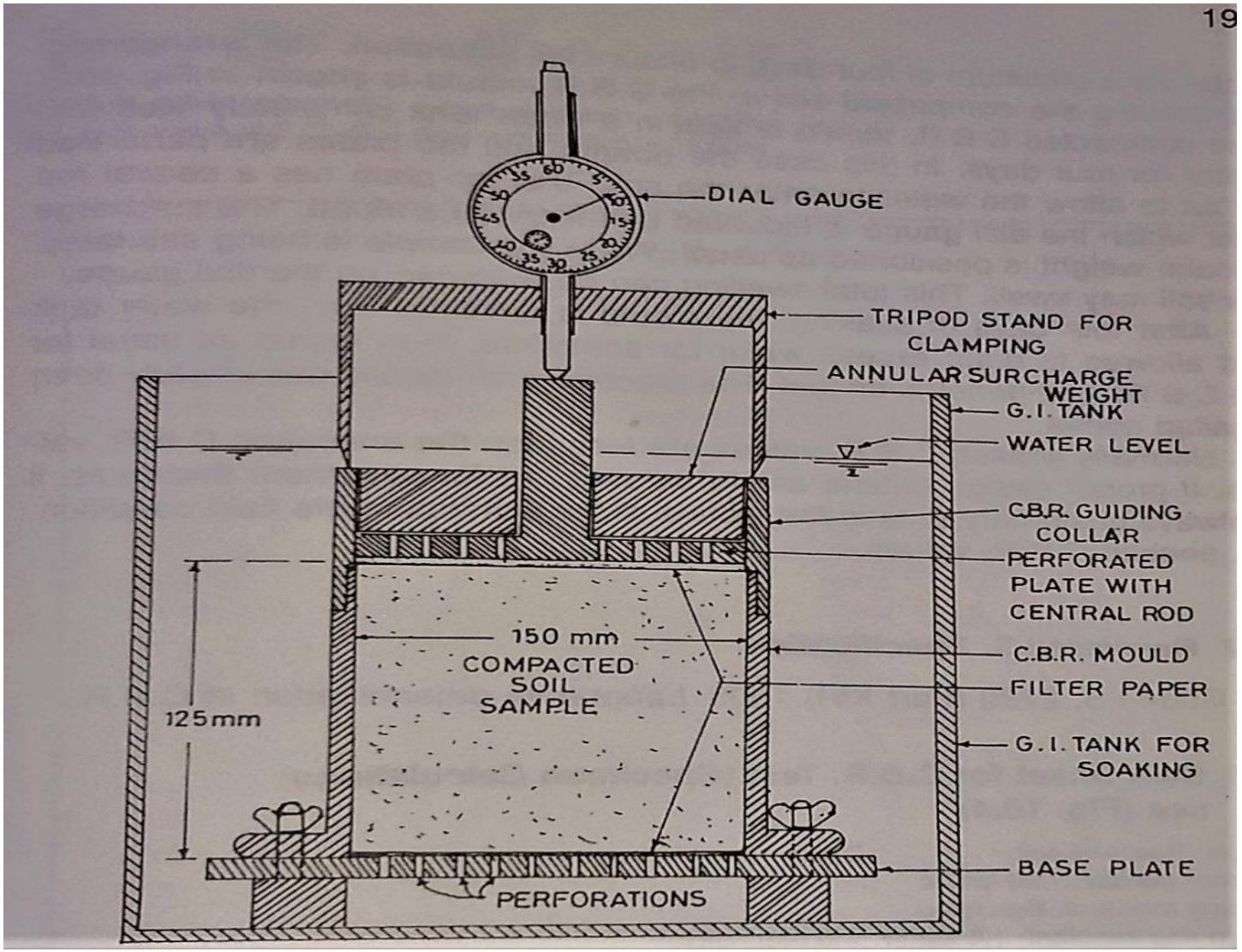
CBR Sample: Passing through 19 mm. In case of fraction > 19 mm is present, it is to be accounted.

Soil fraction + 4.75 mm & - 19 mm is added in equal amount to compensate the omitted + 19 mm fraction.

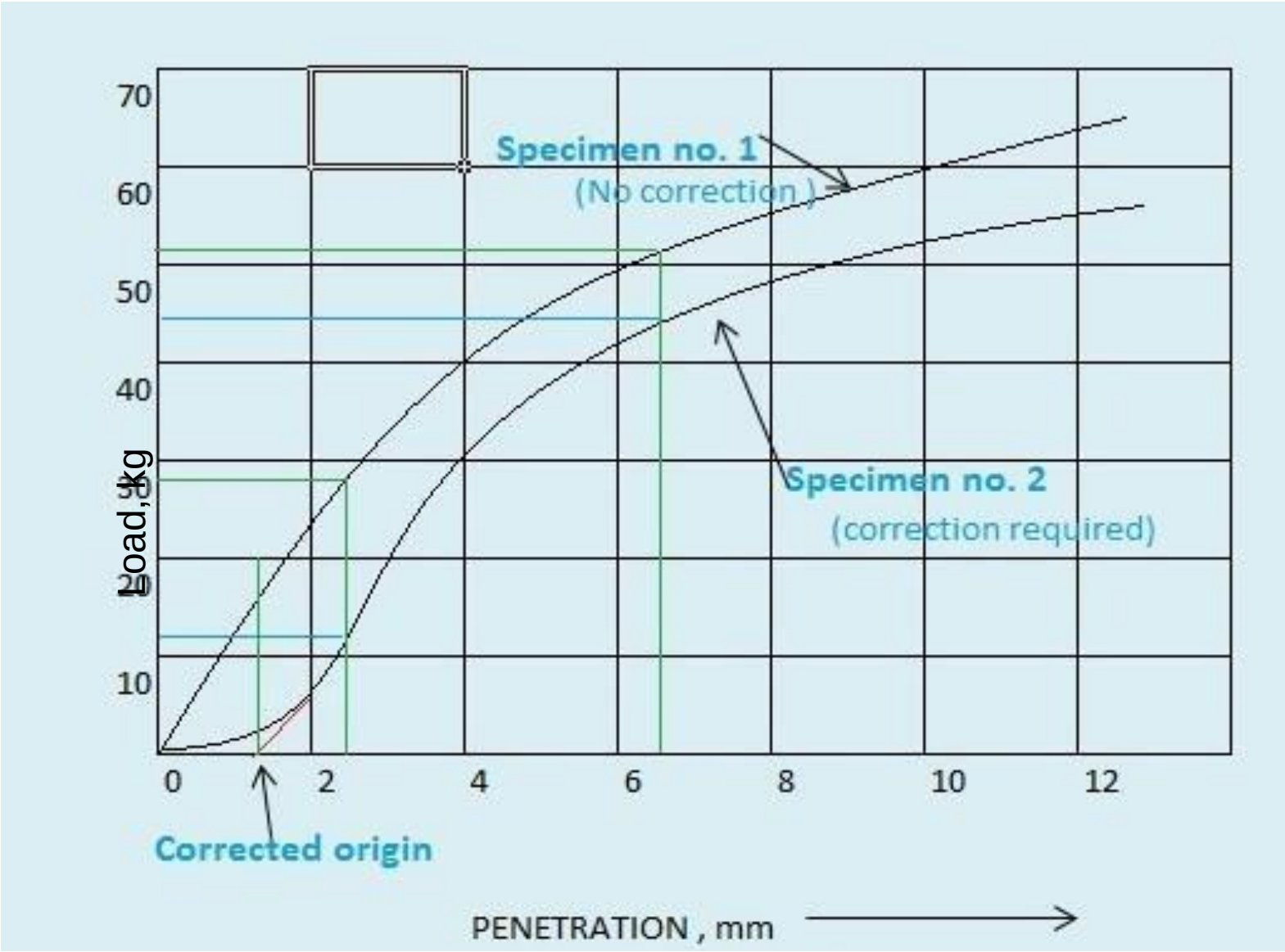
Compaction: 1. *Light compaction*: 3 layers, 56 blows/layer, Wt. hammer = 2.6 kg falling from 31 cm ht.

2. *Heavy compaction*: 5 layers, 56 blows/layer, Wt. of hammer = 4.89 kg falling from 45 cm ht

Soaking of CBR Sample



Penetration(mm)	Applied Load (kg)
0.50	
1.00	
1.50	
2.00	
2.50	
4.00	
5.00	
7.50	
10.00	
12.50	


70
60
50
40
30
20
10
Load,kg
Specimen no. 1
(No correction)
Specimen no. 2
(correction required)
0
2
4
6
8
10
12
Corrected origin
PENETRATION , mm

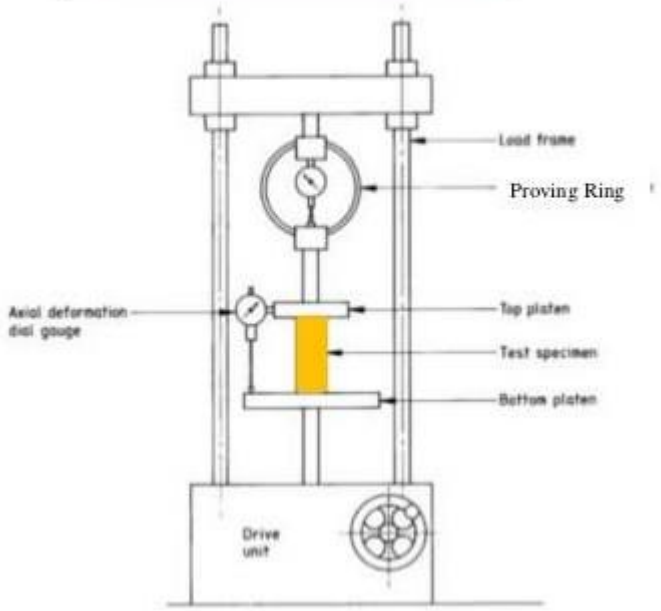
Typical CBR Values Table

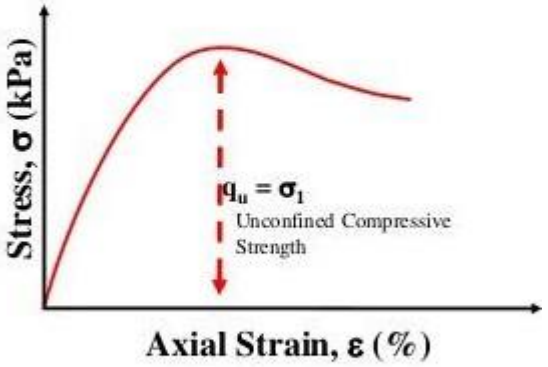
USCS Soil Class	Soil Type	Laboratory CBR Range	Field CBR Range
GW	Well graded sandy gravel	20 – 60	60 – 80
SW	Well graded sand	15 – 40	20 – 40
SC	Sandy clay	4 – 7	10 – 20
CL	Clay	1 – 3	5 – 15

Note: *The CBR value of the standard sample is assumed to be 100*

UNCONFINED COMPRESSION TEST

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





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