بسم الله الرحمن الرحيم

Faculty of Science

Geology Department

Soil Mechanics

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Second year students

Main Topics

1- Introduction, Definition

2- Three phases soil system

3- Soil evaluation

4- Sampling

5- Laboratory geotechnical testes

6- *In Situ* geotechnical testes

7- Ground water related soil foundation (Porosity, Permeability, Flow, Hydraulic Gradient, …).

8- Engineering Classifications of soils

9- Problematic soils

- **Difinations**:

Mechanics of materials is a branch of engineering that deal with stresses and properties of materials.

Steel & Concrete: homogeneous (same composition throughout), isotropic (same directional properties throughout), Lab. Testing.

Rocks & Soil: inhomomgeneous & anisotropic, both Lab. and field Testing.

Definitions:

- Soil is composed of individual particles with differing sizes, shapes, and mineral composition.
- The engineering properties of soil depend on how these individual particles behave as a mass.
- For Engineering purposes, it is useful to anticipate the behavior of a soil mass based on ist soil classification.

Three phases soil system:

1- Solid phase 2- Liquid phase 3- Gas phase

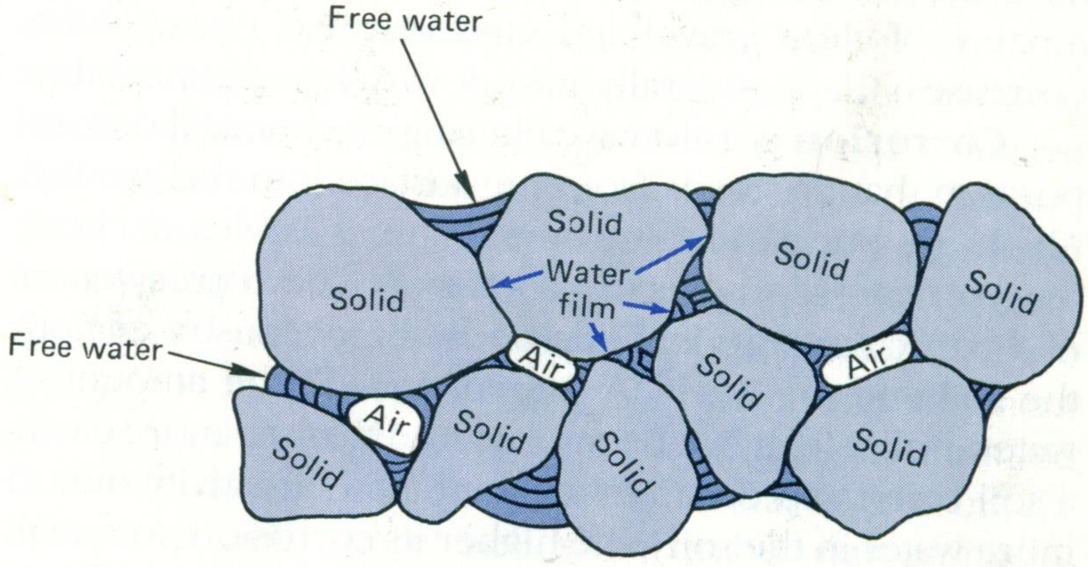


Figure 4.5

Partly saturated soil showing particle-water-air relationships. Particle size is greatly magnified. Attraction (apparent cohesion) between the water and soil particles (surface tension) develops a stress that holds the grains together. The cohesion is destroyed if the soil dries out or becomes completely saturated. (After R. Pestrong, *Slope Stability,* American Geological Institute, 1974.)

Soil evaluation:

1- Residual soils (Weathered)
2- Transformed soils (Detrital, mechanical, organic,..)

Sampling

i- undisturbed samples.

ii- disturbed samples

i- undisturbed samples:

Undisturbed samples retain the in situ soil structure and the in situ water content, they are suitable to determine water content, density, stress history, compressibility, stress-strain and strength characteristics and flow properties.

Undisturbed samples obtained from block samples, that have been cut by hand at the bottom or from the sides of trial pits or by special devised samplers.

Disturbed samples are representative of the particle size distribution, but the structure has been destroyed and significant changes of the water content have occurred. They are suitable for classification tests and compaction tests.

Samples obtained from trial pits, augers, etc.

- Samples are classified into five classes depending on their quality, according to the information that can obtained from them.

1- class 1: classification tests, water content, density, stress-strain and strength, compressibility, stress history, flow properties. (must be undisturbed sample)

2- class 2: limited to classification tests, water content, and density. (must be undisturbed sample)

3- class 3: classification and water content tests.

4- class 4: classification tests.

5- class 5: limited to soil identification.

- Engineering classification of soil are based on texture and plasticity.
- Gradation of soil is a common means for describing the particle size distribution present in soil.

1- Grain size analysis:

  a- Sive analysis

  b- Sedimentation analysis

2- Consistency (Atterberg limits) test

  (Plasticity)

1- Grain size analysis:

Coefficient of uniformity (Cu)

$C_u = D_{60}/D_{10}$ (must be greater than 4 for gravel, and greater than 6 for sand)

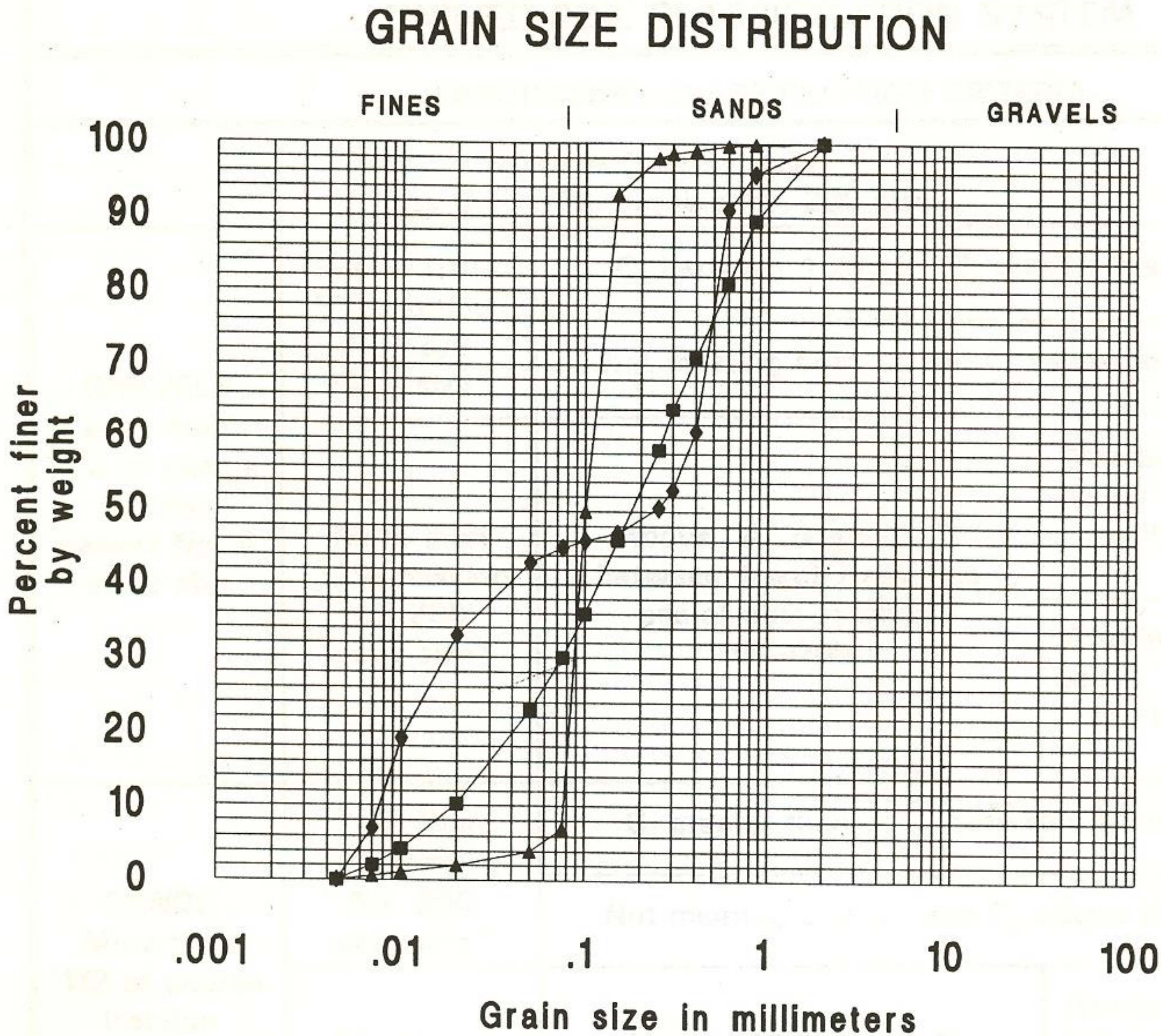
D_{60}: the particle size diameter for which 60 percent of the sample was finer.

D_{10}: the particle size diameter for which 10 percent of the sample was finer.

Coefficient of curvature (C_c)

$C_c = D_{30}^2/D_{10} * D_{60}$ (must be between 1 and 3)

D_{30}: the particle size diameter for which 30 percent of the sample was finer.



A: well-graded (poorly sorted)

B: poorly graded (well sorted)

C: skip or gap-graded

Figure 11.1

2- Consistency (Atterberg limits) test (Plasticity):

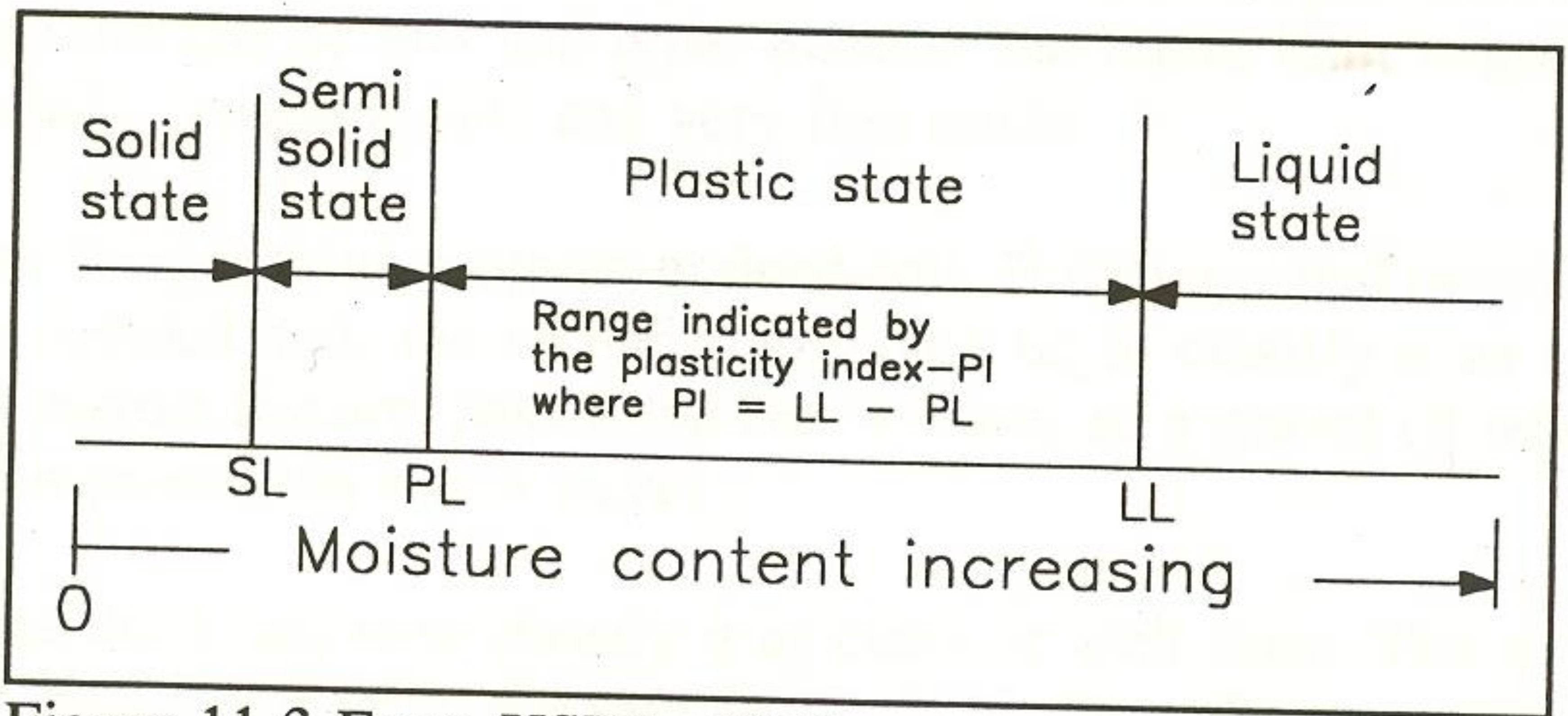


Figure 11.3-From USBR, 1974

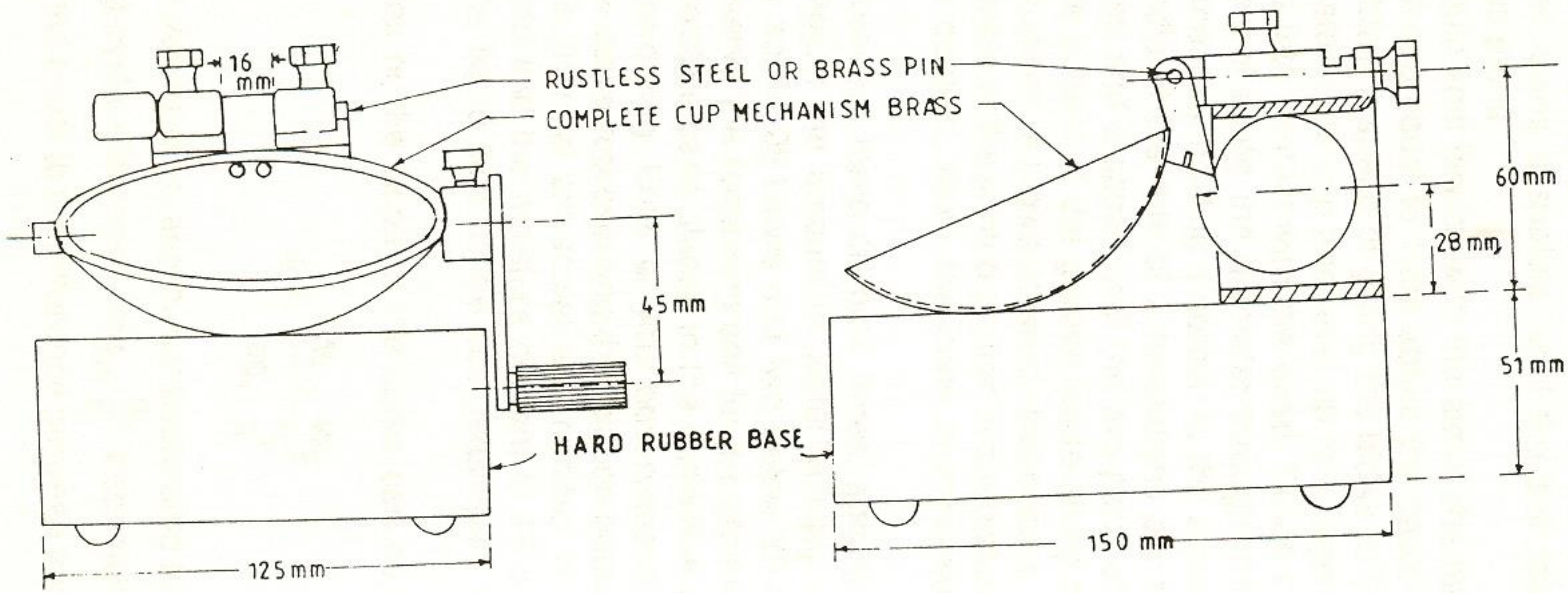


Fig. 5.2. Laboratory liquid limit apparatus

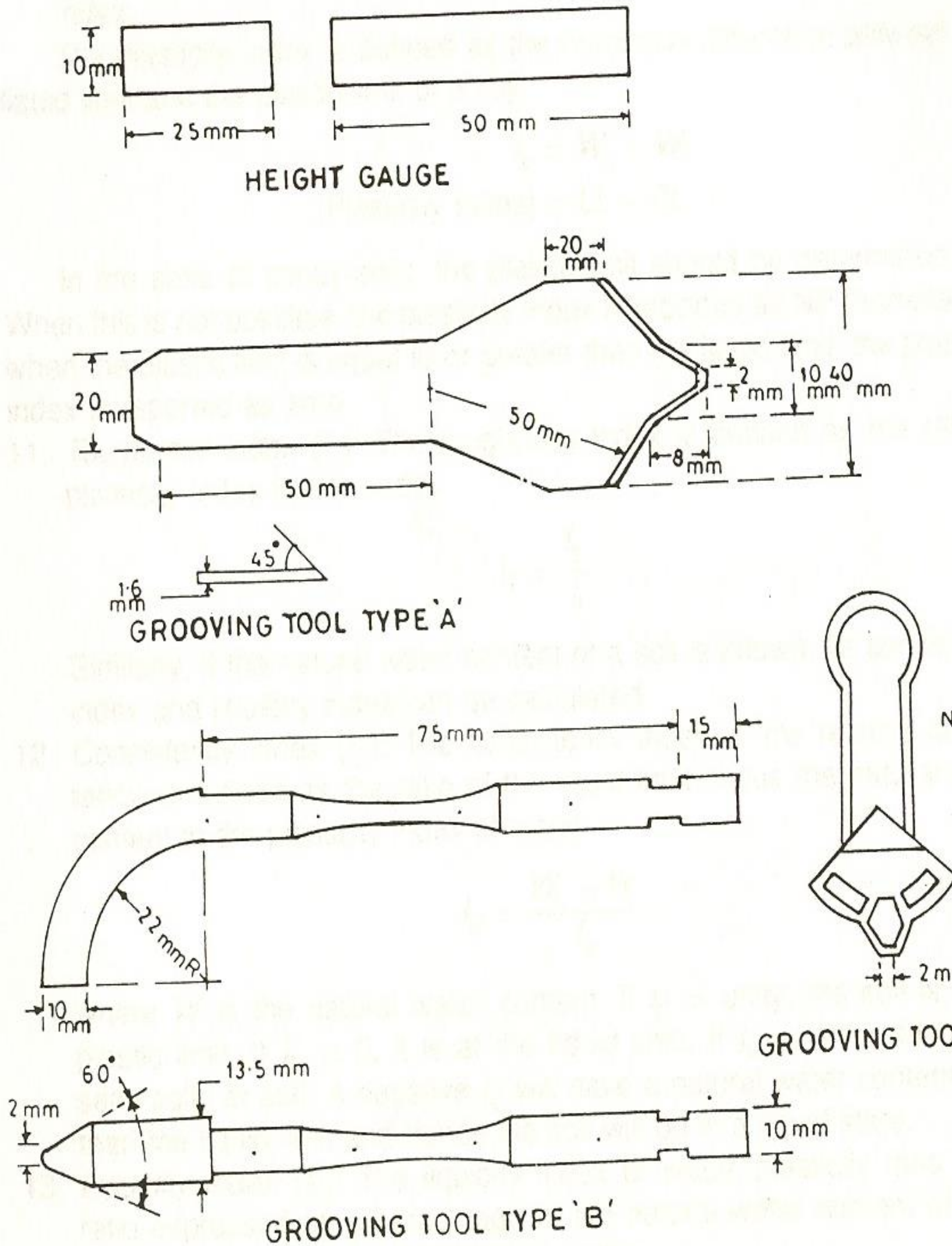


Fig. 5.3. Grooving tools and height gauge

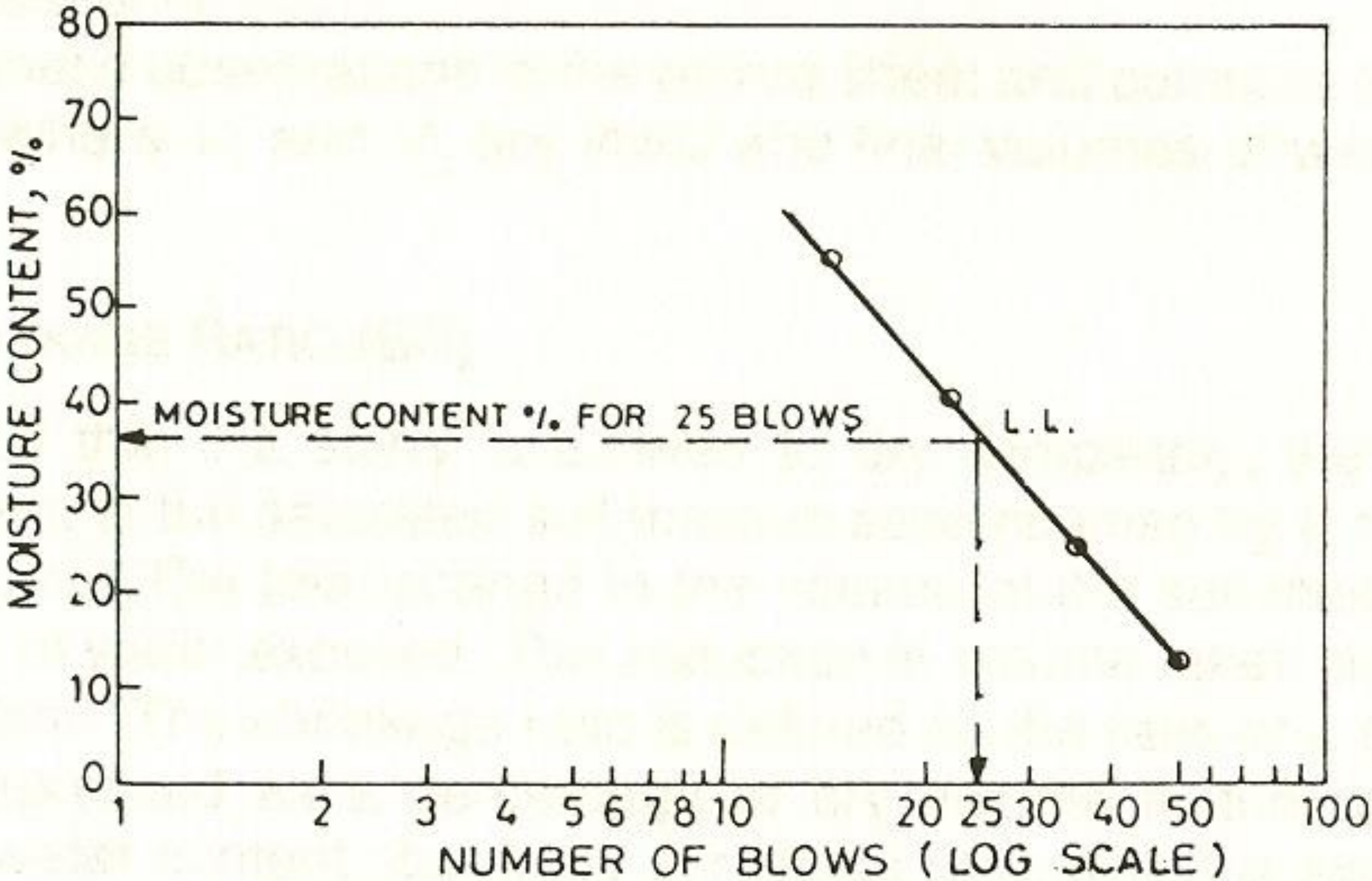


Fig. 5.4. Liquid limit plot

Plasticity Index (PI) = Liquid limit (LL) – Plastic limit (PL)

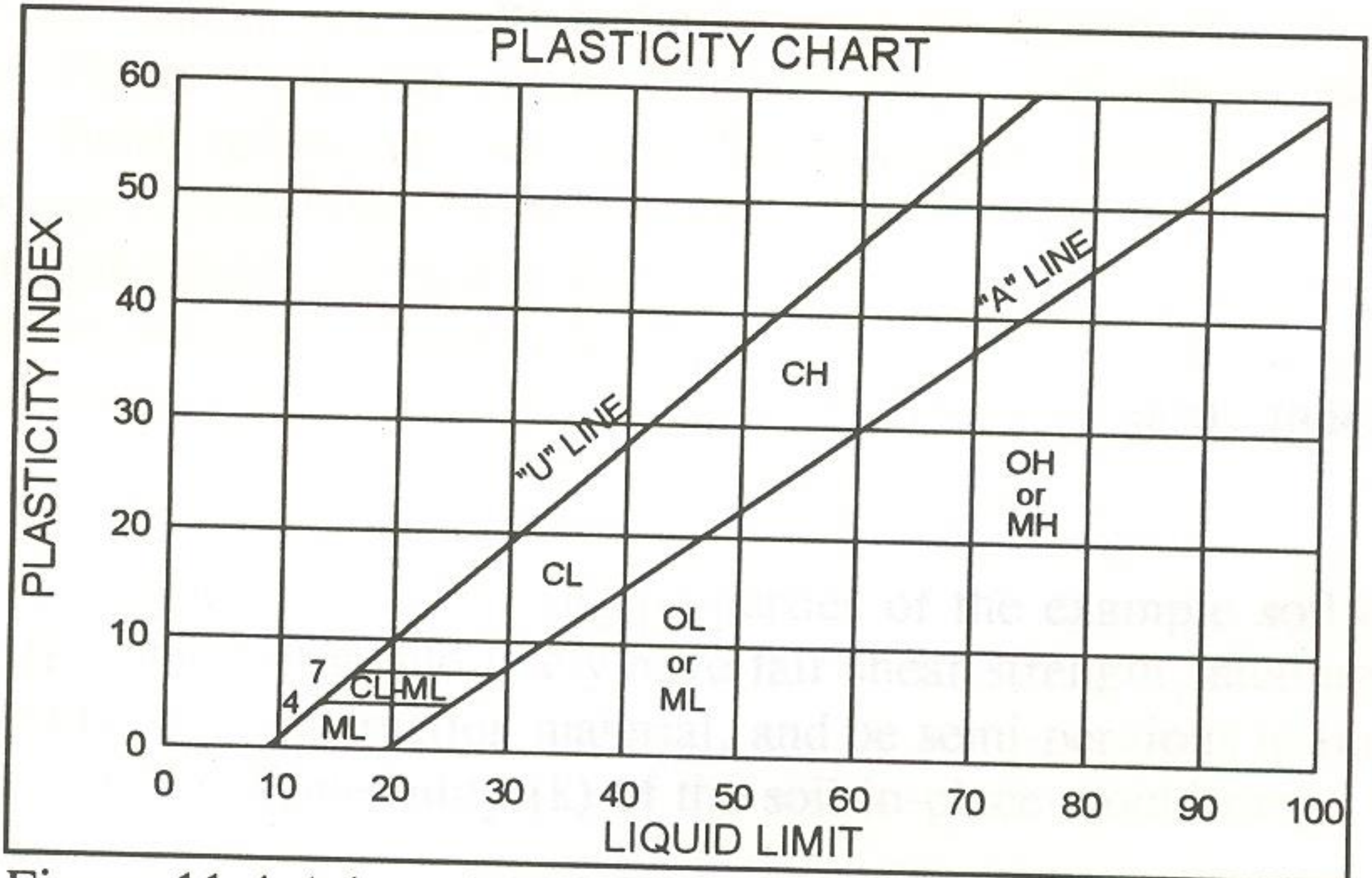


Figure 11.4-Adapted from NAVFAC, 1982

Soil compaction

Types of soil compaction:

1- Dynamic compaction

2- Kneeding compaction

3- Static compaction

4- Vibratory compaction

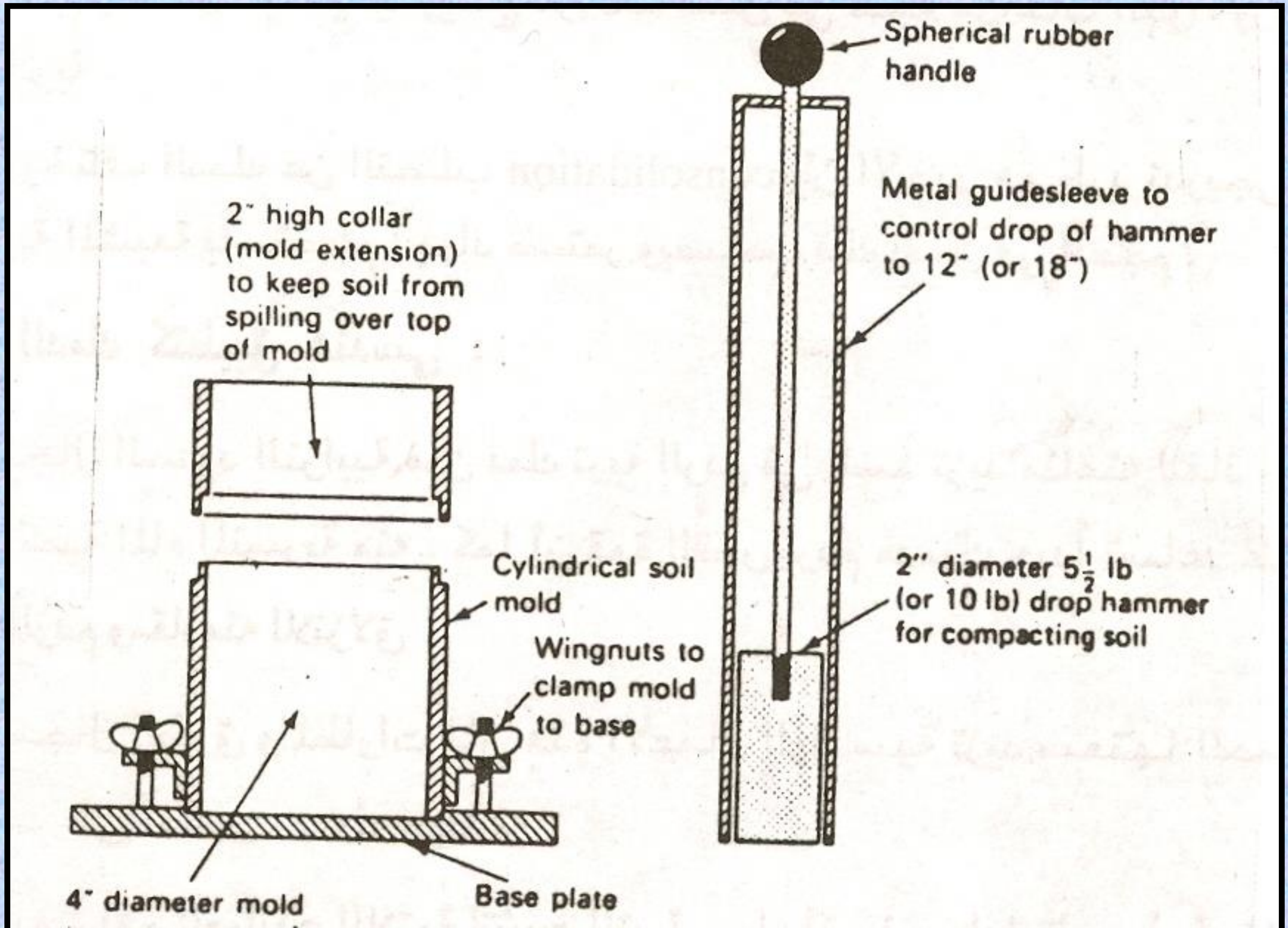
Dynamic compaction

Proctor tests:

1- Standard Proctor test

2- Modified Proctor test.

Standard Proctor test

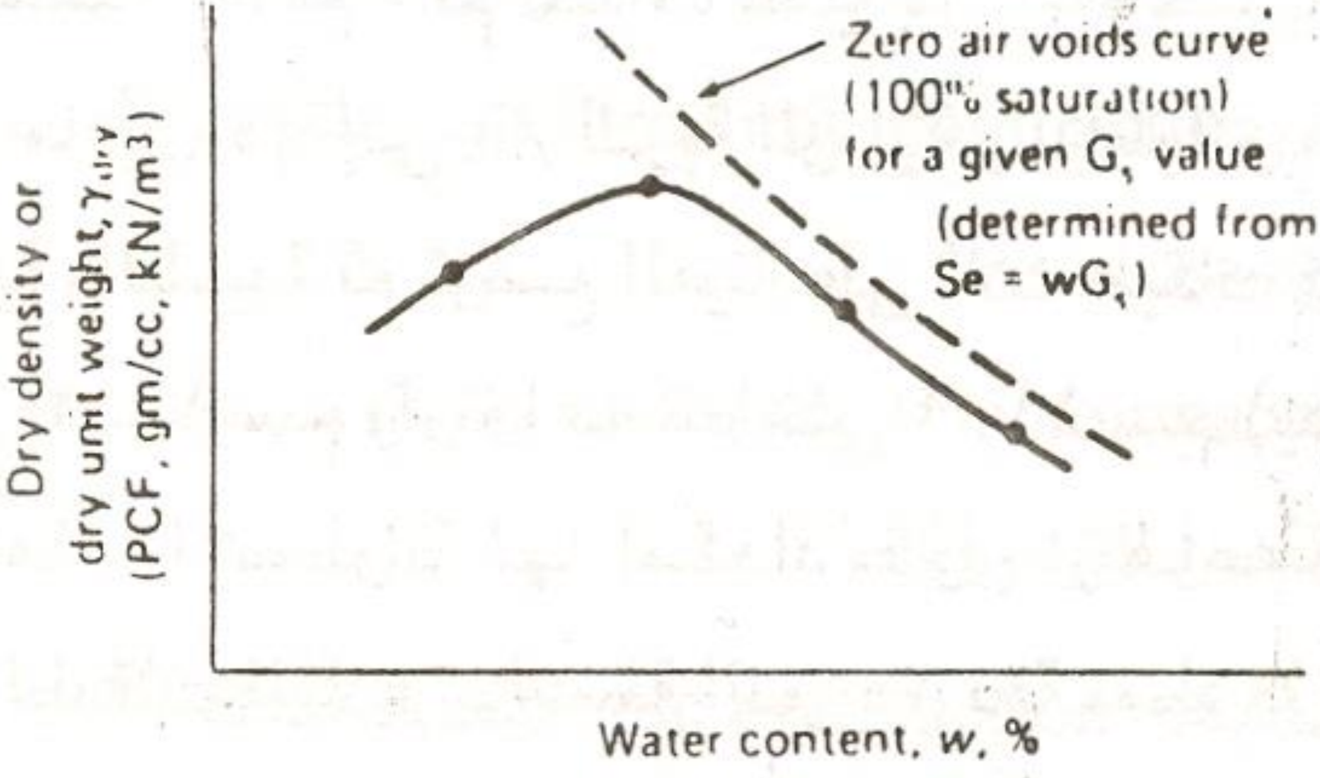


جدول (٨-١) بيـــانات اختبـــارات الدمك

Elements of the standard compaction tests

	Standard (ASTM D698)	Modified (ASTM D1557)
Hammer	24.5 N (5.5 lb)	44.5 N (10 lb)
Height of hammer fall	305 mm (12 in)	457 mm (18 in)
Number of layers	3	5
No. of blows/layer	25	25
Mold volume	0.000 942 2 m (1/30' ft^3)*	
Soil	(–) No. 4 sieve	
Compaction energy (CE)	595 kJ/m^3 (12400)	2698 kJ/m^3 (56 250 lb. ft/ft^3)

* Using the 102-mm (4-in) diameter mold.



شكل (٨–٣) منحنى الفراغ الهوائى الصفرى وعلاقته بمنحنى الرطوبة – الدما

Index of compaction: (I_{comp})

= Dry Density (in situ) / Maximum Dry Density (in proctor test)

Soil classifications

1- Particle size classification

2- Textural classification

3- Highway research board (H.R.B) classification

4- Unified soil classification

1- Particle size classification

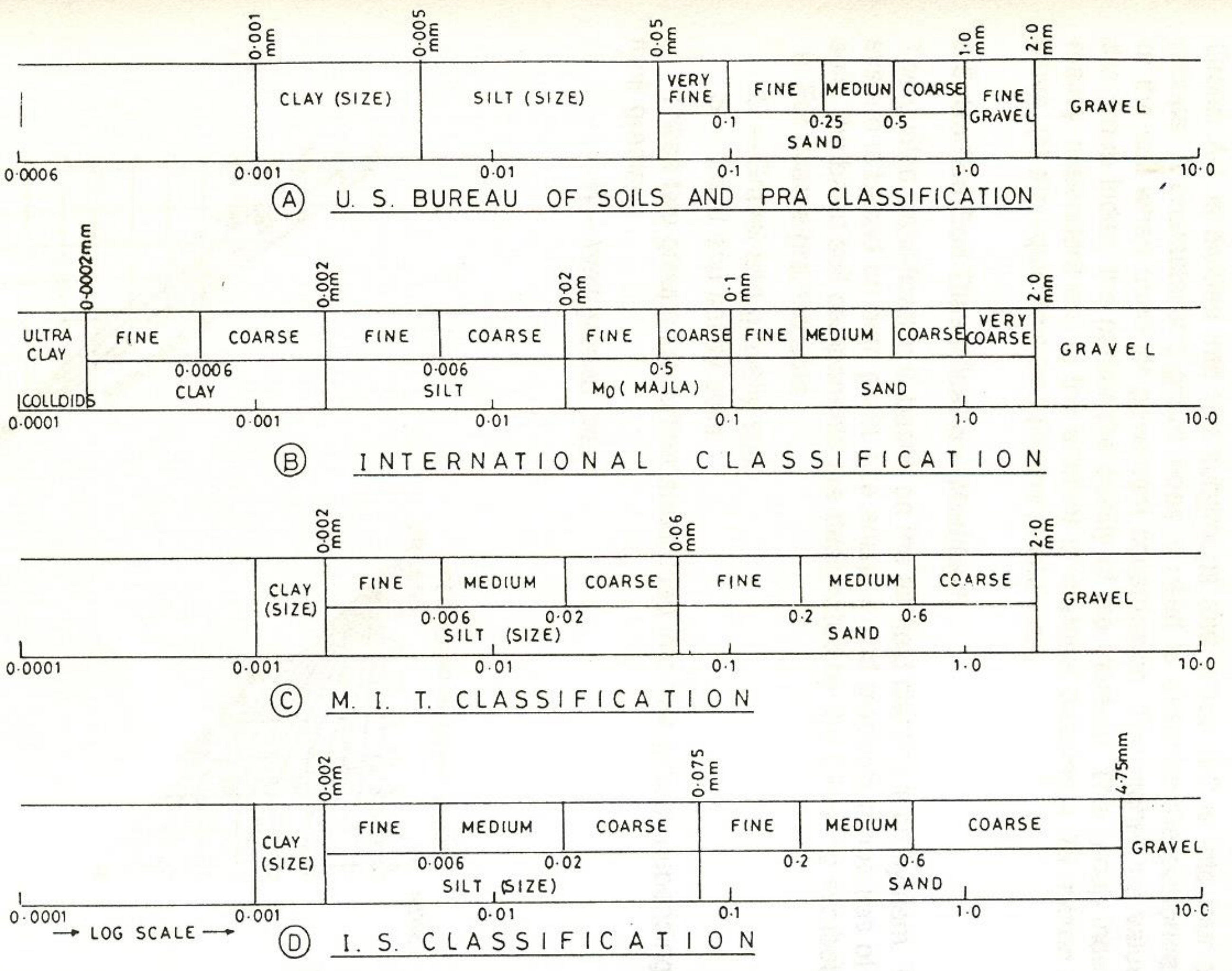


Fig. 6.1. Different grain size classification systems

2- Textural classification

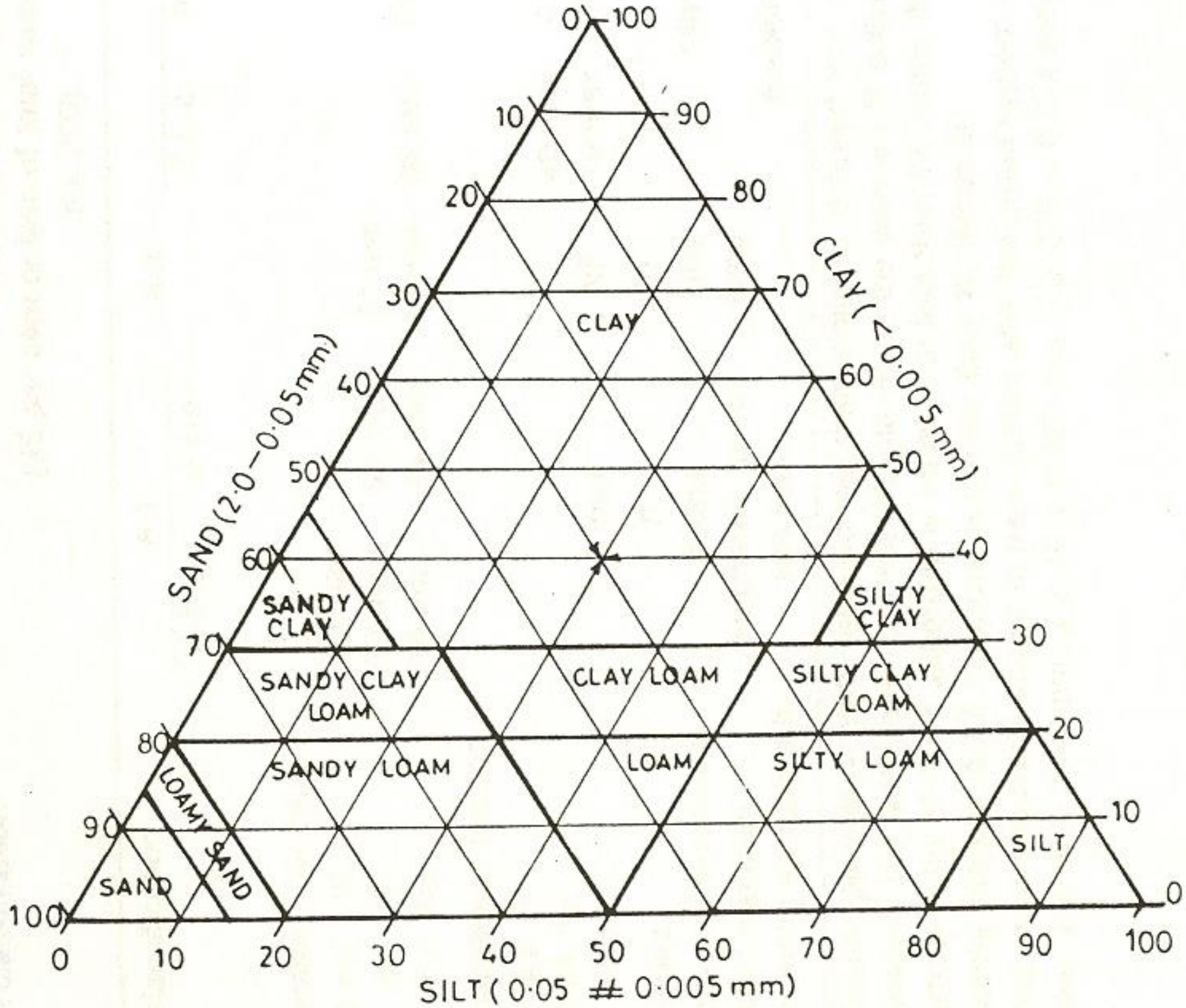


Fig. 6.2. Textural classification chart

3- Highway research board (H.R.B) classification

Table 6.1 H.R.B. Aasho soil classification system (with suggested subgroups)

General classification	Granular materials (35 per cent or less of total sample passing no. 200)							Silty-clay materials (more than 35 per cent of total sample passing no. 200)			
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 and A-7-6
Sieve analysis per cent passing $\neq\neq$ 10	50 max										
$\neq\neq$ 40	30 max	50 max	51 min								
$\neq\neq$ 200	15 max	25 max	10 min	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing $\neq\neq$ 40											
Liquid limit, W_L				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plastic Index, I_P	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Group Index	0		0	0		4 max		6 max	12 max	16 max	20 max
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

Classification procedure: With required test data available, proceed from left to right (Table 6.1) and the correct group will be found by the process of elimination. The first group from the left into which the data will fit is the correct classification.

a—Plasticity index of A-7-5 subgroup is equal to or less than W_L minus 30.

b—Plasticity index of A-7-6 subgroup is greater than W_L minus 30.

c—Group index should be shown in parentheses after the group symbol, As A-2-6(3), A-4(5), A-6(12), A-7-5(17).

Sieves $\neq\neq$ 10 = 2.00 mm, $\neq\neq$ 40 = 0.420 mm, $\neq\neq$ 200 = 0.074 mm.

4- Unified soil classification

UNIFIED SOIL CLASSIFICATION SYSTEM				
LABORATORY CLASSIFICATION CRITERIA				
Coarse Grained Soils Less than 50% passing No. 200 sieve				GROUP SYMBOLS
GRAVELS Less than 1/2 of coarse fraction passes No. 4 sieve size	Less than 5% passing No. 200 sieve size*	C_c between 1 and 3; C_u greater than 4		GW
		Not meeting both C_c and C_u values above		GP
	More than 12% passing No. 200 sieve size*	Above "A" line with PI between 4 and 7 requires use of dual symbols (GC-GM)	Atterberg lim. below"A" line or PI <4	GM
			Atterberg lim. above "A"line or PI >7	GC
SANDS More than 1/2 of coarse fraction passes No. 4 sieve size	Less than 5% passing No. 200 sieve size*	C_c greater than 6; C_u between 1 and 3		SW
		Not meeting both C_c and C_u values above		SP
	More than 12% passing No. 200 sieve size*	Above "A" line with PI between 4 and 7 requires use of dual symbols (SC-SM)	Atterberg lim. below "A"line and PI <4	SM
			Atterberg lim. above "A"line and PI >7	SC

* Borderline cases between 5% and 12% require use of dual symbols such as SW-SC

Unified soil classification

Fine Grained Soils More than 50% passing No. 200 sieve		GROUP SYMBOLS
SILTS AND CLAYS	See adjoining plasticity chart ("A" line)	ML
		CL
		MH
		CH
	Below "A" line and LL (oven dry soil) / LL (air dry soil) < 0.75	OL
		OH
	Visual identification	Pt

Figure 11.2-Adapted from NAVFAC, 1982

UNIFIED SOIL CLASSIFICATION SYSTEM

Group symbol	Typical names	Shear strength	Compress-ibility	Work-ability	Permeability		
					When compacted	K cm./sec	K ft/day
GW	Well graded gravels, gravel-sand mixtures, little or no fines	Excellent	Negligible	Excellent	Pervious	$> 10^{-2}$	> 30
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	Good	Negligible	Good	Very pervious	$> 10^{-2}$	> 30
GM	Silty gravels, gravel-sand-silt mixtures	Good to fair	Negligible	Good	Semi-perv. to imperv.	10^{-3} to 10^{-6}	3 to 3×10^{-3}
GC	Clayey gravels, gravel-sand-clay mixtures	Good	Very low	Good	Impervious	10^{-6} to 10^{-8}	3×10^{-3} to 3×10^{-5}
SW	Well graded sands, gravelly sands, little or no fines	Excellent	Negligible	Excellent	Pervious	$> 10^{-3}$	> 3
SP	Poorly graded sands, gravelly sands, little or no fines	Good	Very low	Fair	Pervious	$> 10^{-3}$	> 3
SM	Silty sands, sand-silt mixtures	Good to fair	Low	Fair	Semi-perv. to imperv.	10^{-3} to 10^{-6}	3 to 3×10^{-3}
SC	Clayey sands, sand-clay mixtures	Good to fair	Low	Good	Impervious	10^{-6} to 10^{-6}	3×10^{-3} to 3×10^{-5}
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Fair	Medium to high	Fair	Semi-perv. to imperv.	10^{-3} to 10^{-6}	3 to 3×10^{-3}
CL	Inorganic clays of low to med. plasticity, gravelly clays, sandy, silty and lean clays	Fair	Medium	Good to fair	Impervious	10^{-6} to 10^{-6}	3×10^{-3} to 3×10^{-5}
MH	Inorganic silts, micaceous or diatomaceous, fine sandy or silty soils, elastic silts	Fair to poor	High	Poor	Semi-perv. to imperv.	10^{-4} to 10^{-6}	3×10^{-1} to 3×10^{-3}
CH	Inorganic clays of high plasticity, fat clays	Poor	High to very high	Poor	Impervious	10^{-6} to 10^{-8}	3×10^{-3} to 3×10^{-5}
OL	Organic silts and organic silt-clays of low plasticity LL < 50	Poor	Medium	Fair	Semi-perv. to imperv.	10^{-4} to 10^{-6}	3×10^{-1} to 3×10^{-3}
OH	Organic clays of med. to high plasticity LL >50	Poor	High	Poor	Impervious	10^{-6} to 10^{-8}	10^{-3} to 10^{-5}
Pt	Peat and other highly organic soils	Not suitable for construction					

Figure 11.5

Problematic soils

<u>Definition of Problematic soils (Difficult soils):</u>

<u>Types of problematic soils:</u>

1- Soft clay soil (normally consolidated Clay, Organic soil, Peat, Muck, Sabkha)

2- Expansive or swelling soil (shale, Mudstone, Claystone, Marl)

3- Collapsing soil (Loss, cohesive sands, sand dunes, loss granular soil)

4- Fills

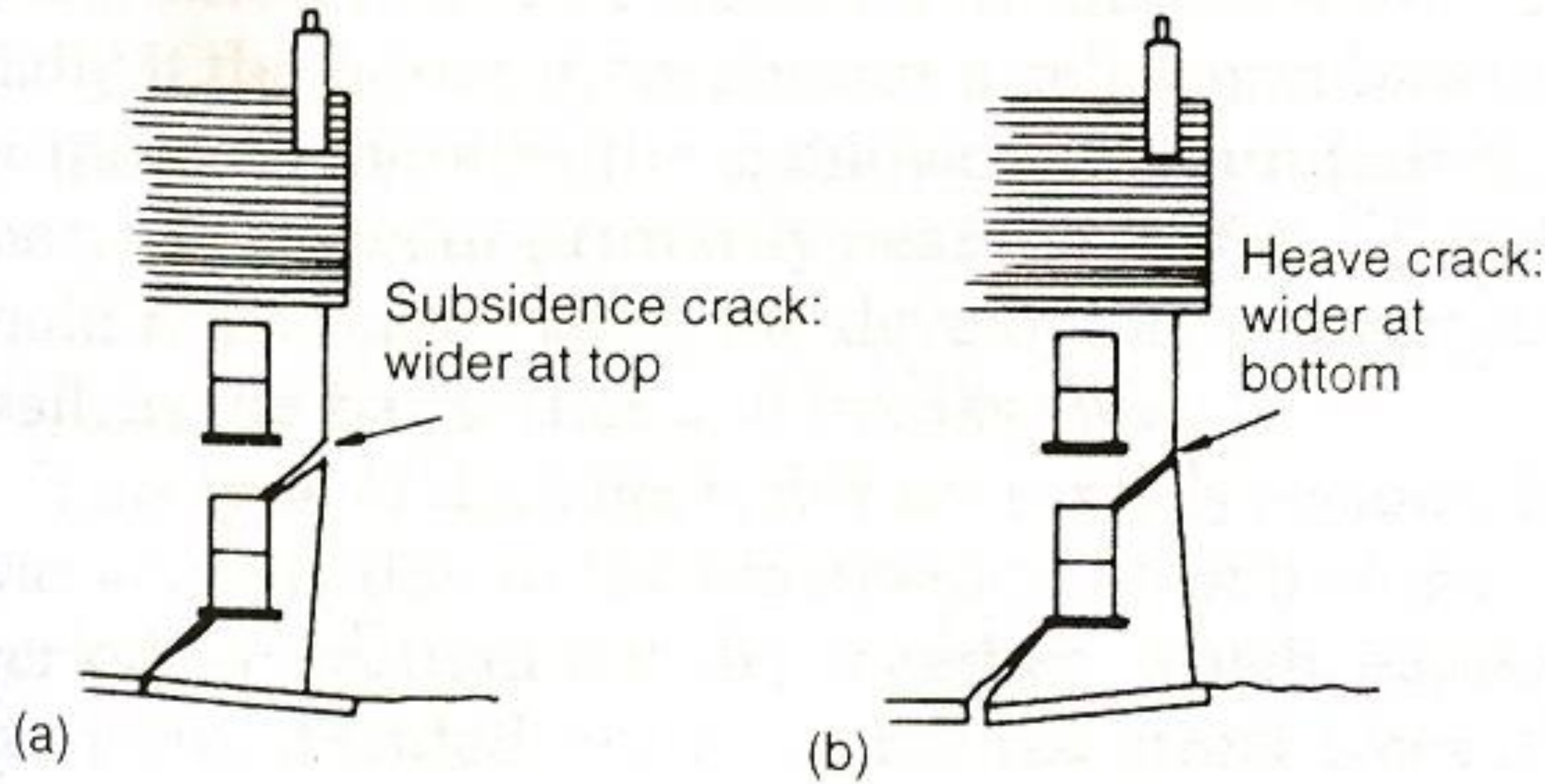


Figure 1.20 *Diagonal cracks in walls due to (a) foundation subsidence; (b) foundation heave.*