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SOIL MECHANICS/GEOTECHNICAL ENGINEERINGI

ORIGIN OF SOIL, INDEX PROPERTIES AND CLASSIFICATION

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Agricultural and Engineering soil

Top Soil: A layer of organic soil not more than 500 mm thick is often found.

Organic Soil: humus (highly organic partly decomposed vegetable mater

Sub soil: Portion of Earth crust affected by current weathering and lying between the top soil and unweathered soil below

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Agricultural and Engineering soil

Hardpan: In humid climates humic acid can be formed by rain water causing decomposition of humus. This acid leaches out iron and alumina oxides down into the lower layer where they act as cementing agents to form a hard rock like material. It is difficult to excavate and does soften when wet

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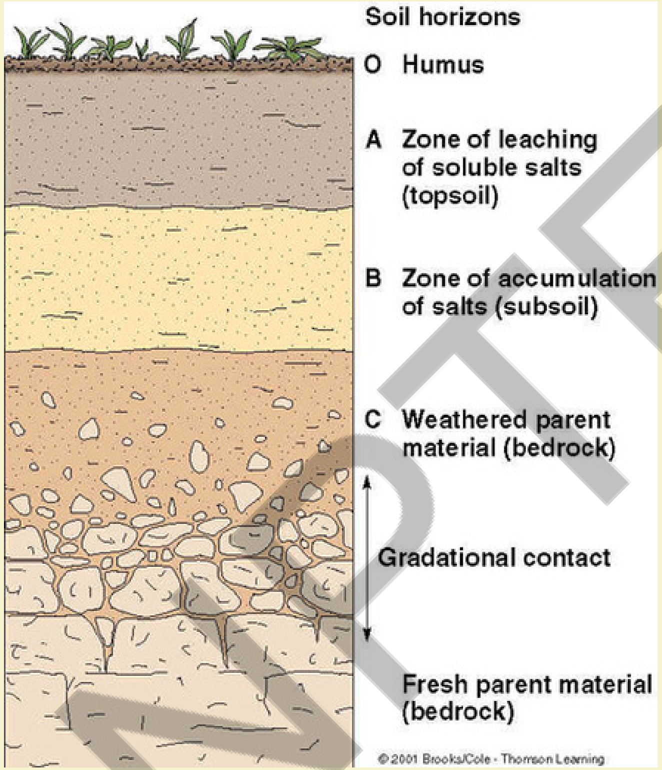

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Agricultural and Engineering Soil

Soil: The soft geological deposits from the subsoil to the bedrock. In some soils there is a certain amount of cementation between the grains which affect the physical properties of the soil. If this cementation is such that a rock hard material has been produced then the material must be described as rock. **A rough rule is that if the material can be excavated by hand or hand tools it is a soil**

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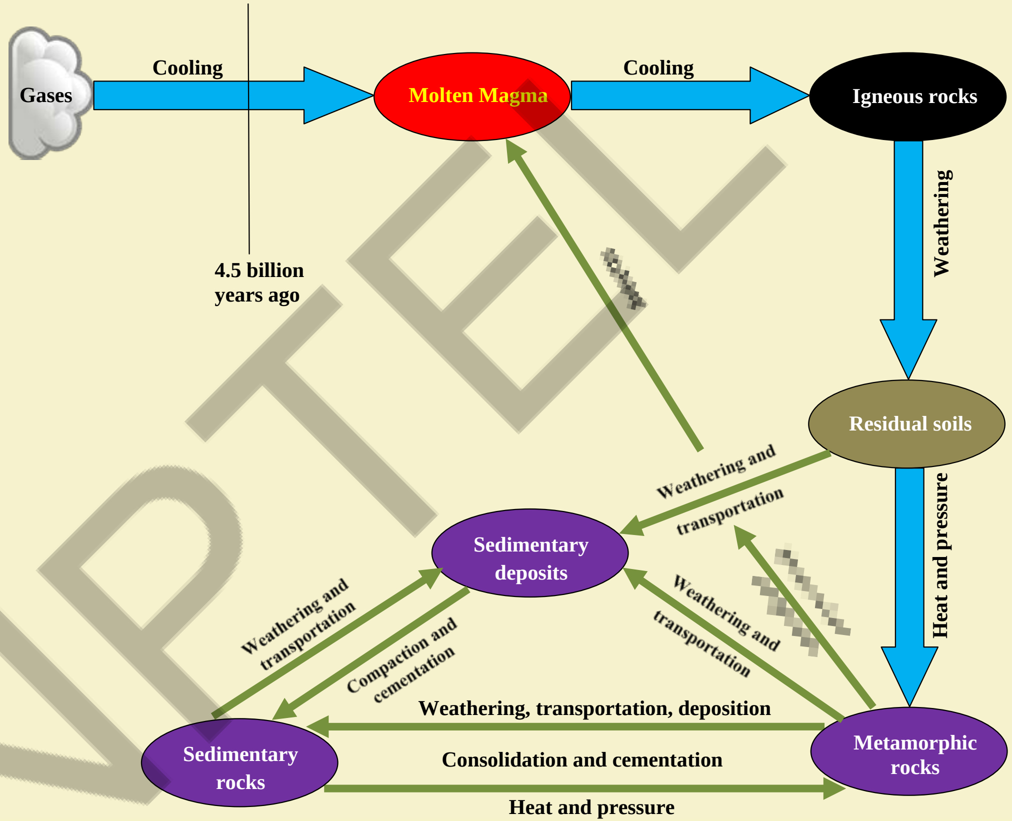
Engineering definition

Geologists class all items of the Earth's crust as rock, whether hard or soft deposits. Civil engineers consider rock and soil separately

Rock Cycle



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Rock

Rocks are made from various types of minerals. Minerals are substances of crystalline form made up from a particular chemical combination. The main minerals in rocks include quartz, feldspar, calcite, and mica. Geologists classify all rocks into three basic groups: Igneous, sedimentary and metamorphic.

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Rock

- **Igneous Rock**: **These rocks have become solid from a melted liquid state. *Extrusive igneous rocks* are those that arrived on the surface of the earth as molten lava and cooled. *Intrusive igneous rocks* are formed from magma (molten rock) that forced itself through cracks into rock beds below the surface and solidified there.**
- **Example**: **granite, Basalt, gabbro**

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Igneous Rock: example and characteristics

Name	Grain Texture	Color	Composition
Granite	Coarse	Light Gray	Mainly quartz and orthoclase mixed with biotite, muscovite, hornblende, magnetite
Gabbro	Coarse	Dark	Mainly plagioclase and pyroxenes mixed with biotite and magnetite
Basalt	Fine	Dark	Mainly plagioclase and pyroxenes mixed with biotite and magnetite

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Rock

- **Sedimentary Rock:** Weathering reduces the rock mass to fragmented particles, which can be more easily transported by wind, water and ice. When dropped by the agents of weathering, they are termed sediments. These sediments are typically deposited in layers or beds called strata and when compacted and cemented together (lithification) they form sedimentary rocks.
- **Example:** shale, sandstone, chalk

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Sedimentary Rock: example and characteristics

Name	Group Type	Grain Texture	Brief description
Lime stone	Chemical	Usually Fine	Mainly calcium carbonate in the form of calcite or arogonite. Usually relatively soft and easily soluble in acidic solutions
Sand stone	Clastic	Intermediate	Mainly pressure cemented particles of sand, feldspar, hornblende, volcanic matter,. Porous and sandrock mass is relatively easily crushed into smaller particles
Shale	Clastic	Fine	Mainly clay minerals and fine particles of silica. Two types : cementation shale and Compaction shale

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Rock

- **Metamorphic Rock: Metamorphism through high temperatures and pressures acting on sedimentary or igneous rocks, produces metamorphic rocks. The original rock undergoes both chemical and physical alterations**

- **Example: slate, quartzite and marble**

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Metamorphic rock: Example and characteristics

Name	Texture	Mineral arrangement	Brief Description
Slate	Fine	Foliated	Metamorphized shale composed mostly of quartz and secondary mica, is a dense rock characterised by well developed tabular cleavage
Gneiss	Medium to Coarse	Poor	Characterised by alternating bands of different colours and highly contorted shapes. Common minerals are mica, feldspar, hornblende and quartz
Marble	Medium to Coarse	Non-foliated	Formed by recrystallisation of limestone and dolomite. Used as building material for decorative purposes and as source for lime.

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Soil Formation from Rock

Soil: **The actions of frost, temperature, gravity, wind, rain and chemical weathering are continually forming rock particles that eventually become soils. There are three types of soil when considering modes of formation**

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Soil Formation from Rock

Transported soil: (Gravel, Sand, Silts and Clays) Most soils transported by water. As a stream or river loses its velocity it tends to deposit some of the particles that it is carrying, dropping the larger, heavier particles first. Hence on the higher reaches of a river gravel and sand are found whilst on the lower or older parts silts and clays predominate, especially where the river enters the sea or lake and loses its velocity.

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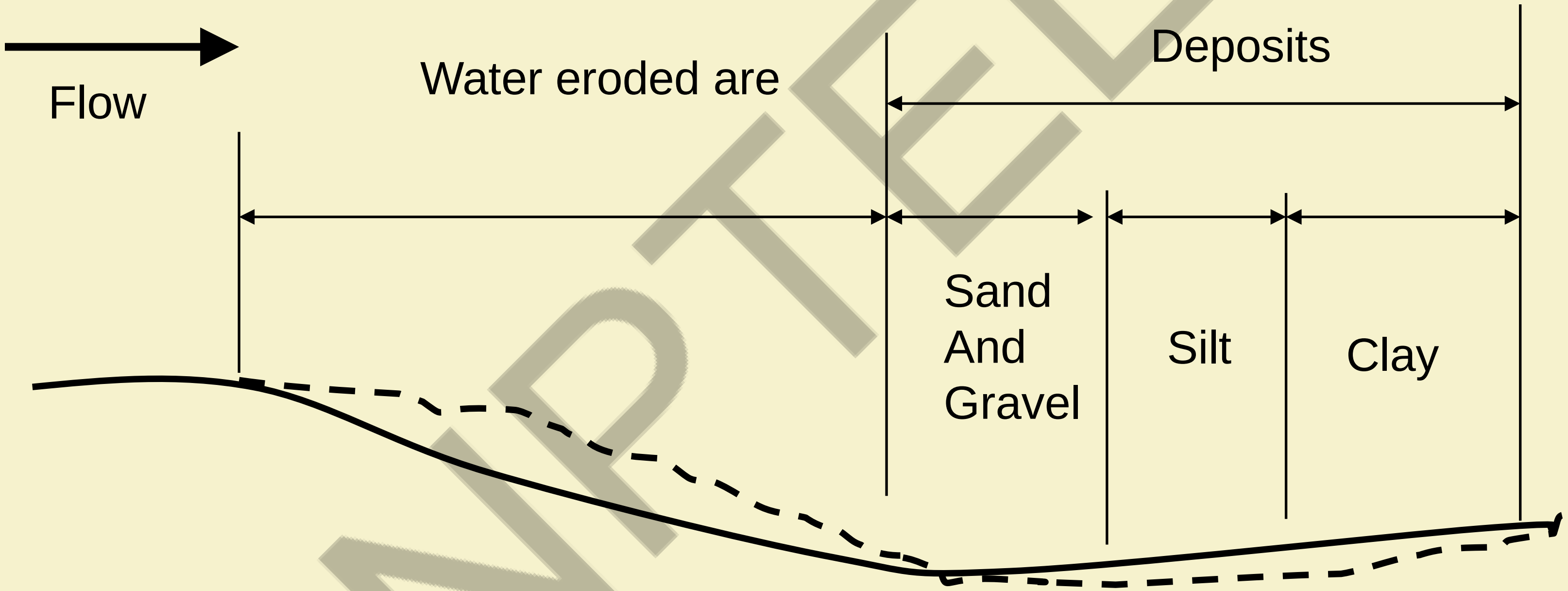
Soil Formation from Rock



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Transported soil: contd..

Loess: **In arid parts of the world wind is continually forming sand deposits in the form of ridges. The sand particles in these ridges have been more or less rolled along and invariable\y rounded and fairly uniform in size. Light brown wind blown deposits of silt size particles, known as loess, are often encountered in thin layers, the particles having sometimes traveled considerable distances.**

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Soil Formation from Rock

Residual soil: **These soils are formed insitu by chemical weathering and may be found on level rock surfaces where the action of the elements has produced a soil with little tendency to move. Residual soil can also occur whenever the rate of break up of the rock exceeds the rate of removal. If the parent rock is igneous or metamorphic the resulting soil sizes range from silt to gravel.**

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Residual soil: contd..

Laterites are formed by chemical weathering under warm, humid, tropical conditions when the rain water leaches out the soluble rock material leaving behind the insoluble hydroxides of iron and aluminium, giving them their characteristics red brown color.

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Organic Soil

- **Organic soil**: These soils contain large amounts of decomposed animal and vegetable matter. They are usually dark in colour and give off a distinctive odour.
- Deposits of organic silts and clays have usually been created from river or lake sediments. Peat is a special form of organic soil and is a dark brown spongy material which almost entirely consists of lightly to fully decomposed vegetable matter. It exists in one of the three forms:

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Organic soil: contd..

Fibrous: **Non plastic with a firm structure only slightly altered by decay.**

Pseudo-plastic: **Peat in this form still has a fibrous appearance but is much softer and more plastic than fibrous peat. The change is due more to prolonged submergence in airless water than to decompositions.**

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Organic soil: contd..

***Amorphous*: with this type of peat decomposition has destroyed the original fibrous vegetable structure so that it has virtually become an organic clay**

Peat deposits occur extensively throughout the world and can be extremely troublesome when encountered in Civil Engineering work

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Engineering soil

Granular and Cohesive soils: Geotechnical engineers classify soils as either granular or cohesive. Granular soils (sometimes referred to as cohesionless soils) are formed from loose particles without strong inter-particle forces. Cohesive soils are made from particle bound together with clay minerals. The particles are flaky and sheet like and retain a significant amount of adsorbed water on their surfaces. The ability of the sheet like particles to slide relative to one another give a cohesive soil the property known as plasticity.

Clay mineral: Kaolinite, Illite and Montmorillonite

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Engineering soil

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Clay mineral: Kaolinite, Illite and Montmorillonite

Soil Versus other Engineering Material

- **Steel and concrete:** Manufactured, can be produced with desired strength and stiffness, quality can be monitored
- **Soil:** Formed Naturally, properties mostly not known or depends on many factors, no control over its quality.

Soil Characterization

- Permeability
- Compressibility
- Shear Strength

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Field identification of soil

Sand	Silt	Clay
Individual particles are visible	Some particles are visible	No particle is visible
Exhibits dilatancy	Exhibits dilatancy	No dilatancy
Easy to crumble and falls off hand when dry	Easy to crumble and can be dusted off hands when dry	Hard to crumble and sticks to hand when dry
Feels gritty	Feels rough	Feels smooth
No plasticity	Some plasticity	Plasticity

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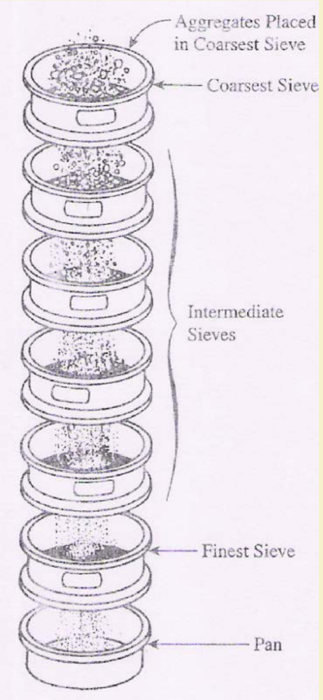
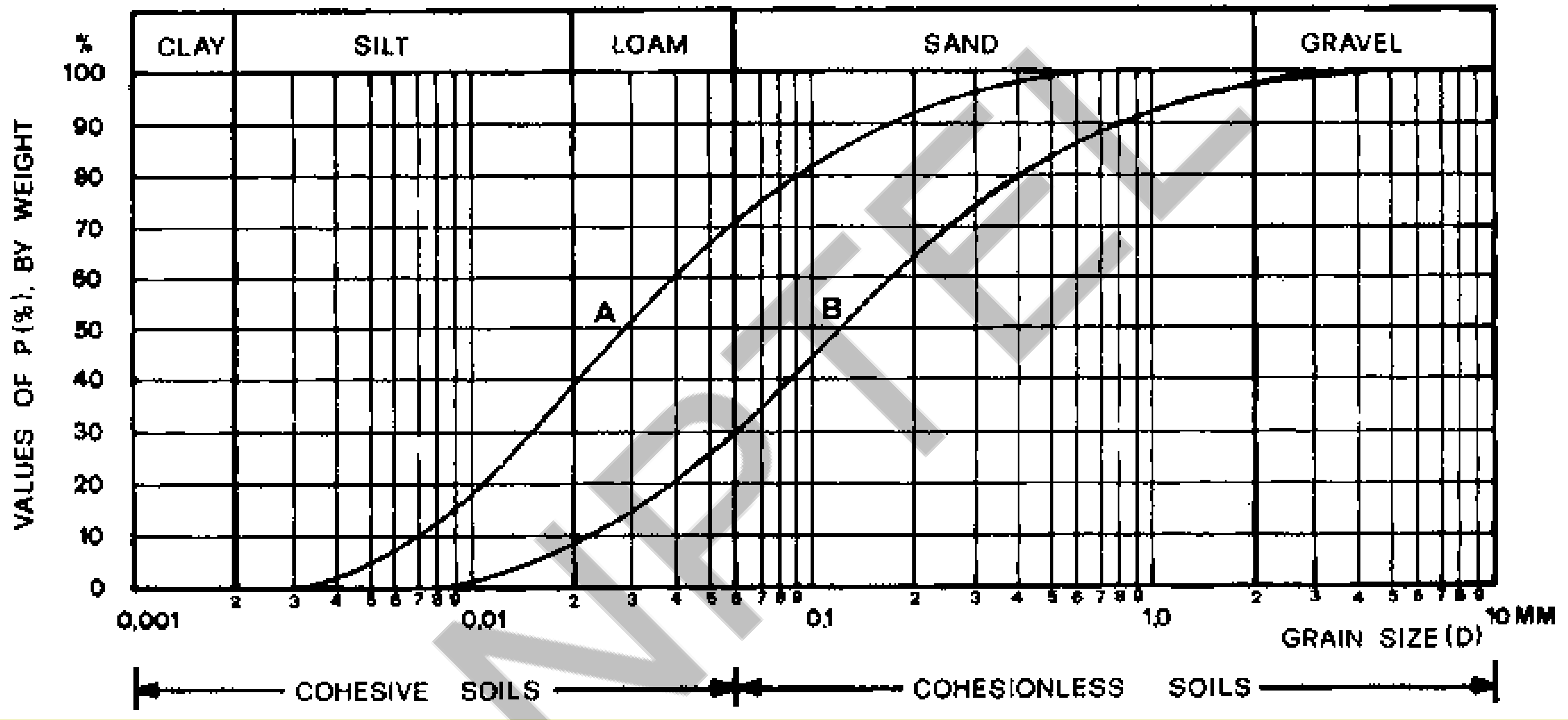
Mechanical analysis/Sieve analysis



Indian Sieves: 4.75 mm, 2.00 mm, 1.18 mm, 600 micron, 425 micron, 300 micron, 150 micron, 75 micron and pan

Sieve size	Weight retained	Cumulative weight retained	Cumulative % retained	% finer
4.75 mm	11.02	11.02	3.67	96.33
2.40 mm	30.45	41.47	13.82	86.18
1.20 mm	46.26	87.73	29.24	70.76
600 µ	48.73	136.46	45.49	54.51
425 µ	50.27	186.73	62.24	37.76
300 µ	45.49	232.22	77.41	22.59
150 µ	40.21	272.43	90.81	9.19
75 µ	20.33	292.76	97.59	2.41
Pan	7.24	300.00	100.00	----


CLAY
SILT
LOAM
SAND
GRAVEL
%
100
90
80
70
60
50
40
30
20
10
0
VALUES OF P(%), BY WEIGHT
A
B
0,001
0.01
0.1
1.0
10 MM
GRAIN SIZE (D)
COHESIVE SOILS
COHESIONLESS SOILS

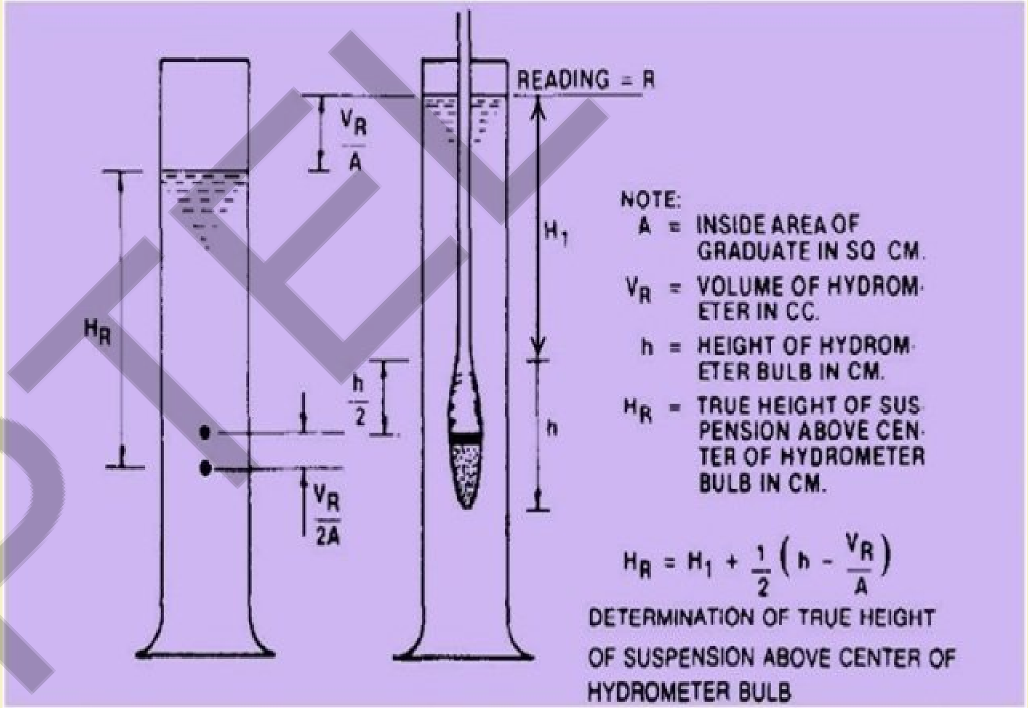
Terminal velocity $v_t = \sqrt{\dfrac{H_R}{t}}$

From Stoke's law

$$D = \sqrt{\frac{1800 \times \mu}{\gamma_s - \gamma_w}} \times \sqrt{\frac{H_R}{t}}$$

Percent finer than D

$$N\% = \frac{G_s}{(G_s - 1)} \frac{1}{W_s} (r + c_m - c_w \pm c_t)$$



Shape parameters

Coefficient of uniformity, $$C_u = \frac{D_{60}}{D_{10}}$$

Coefficient of curvature $$C_c = \frac{D_{30}{}^2}{D_{10} D_{60}}$$

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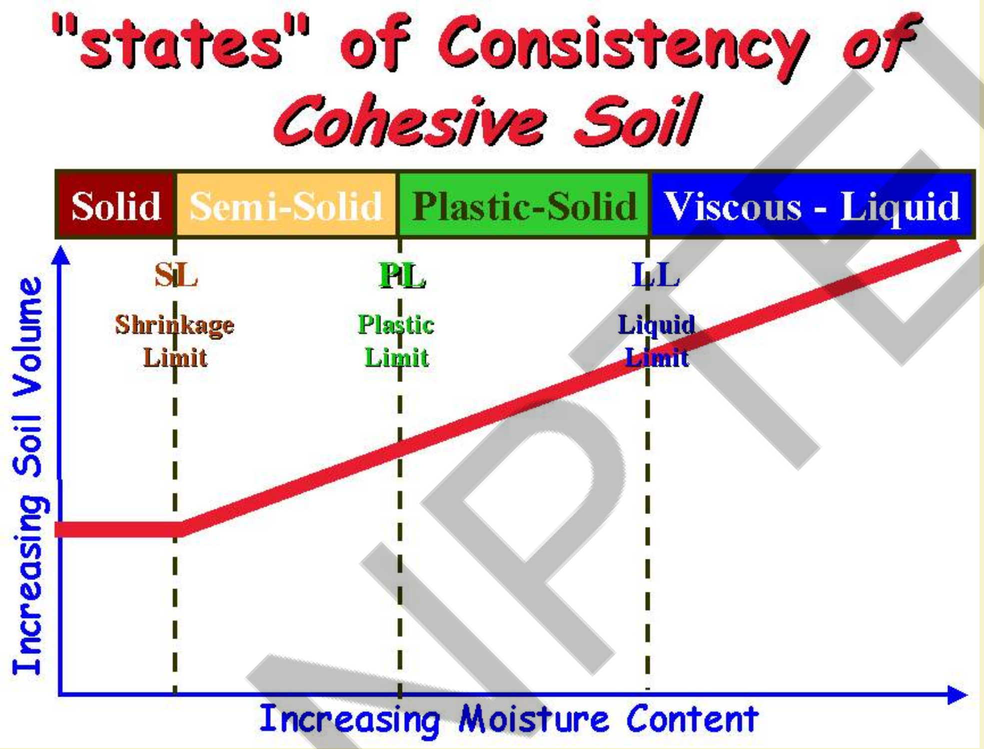
Consistency limits

- **Liquid limit, the boundary water content between the liquid state and the plastic state is called the liquid limit**
- **Plastic limit, the boundary water content between the plastic state to semisolid is called plastic limit**
- **Shrinkage limit, Water content at which the soil reaches its minimum volume keeping it fully saturated**



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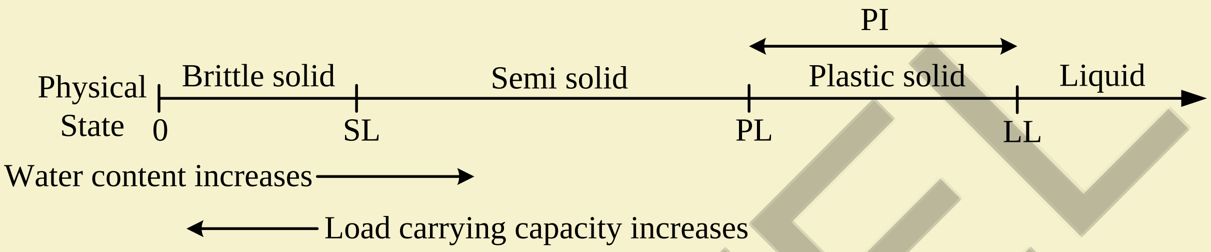

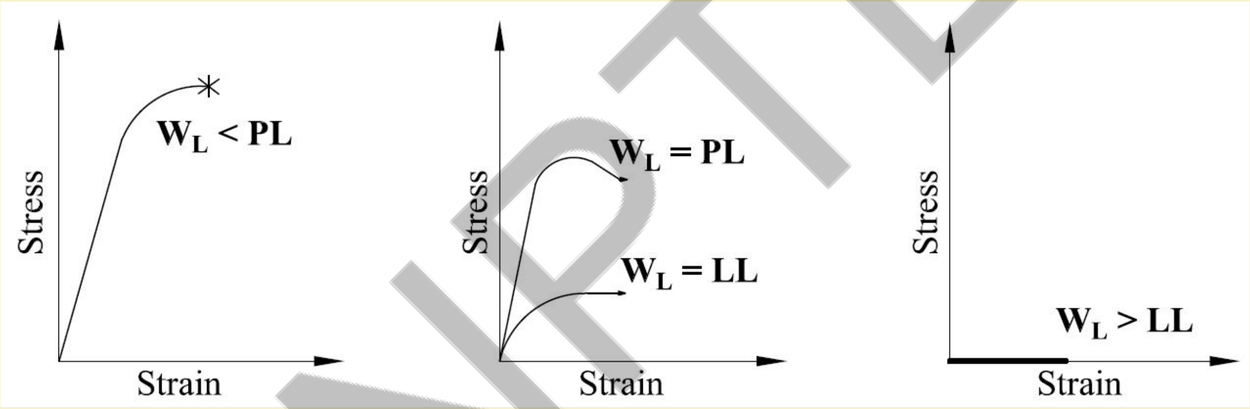

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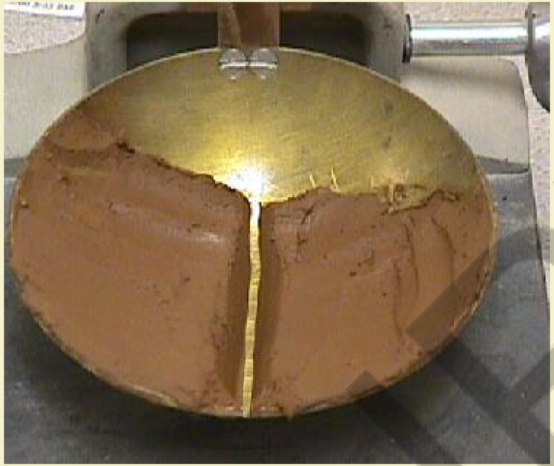
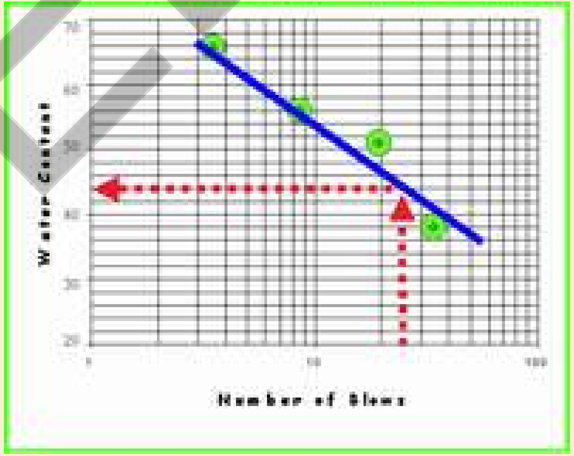
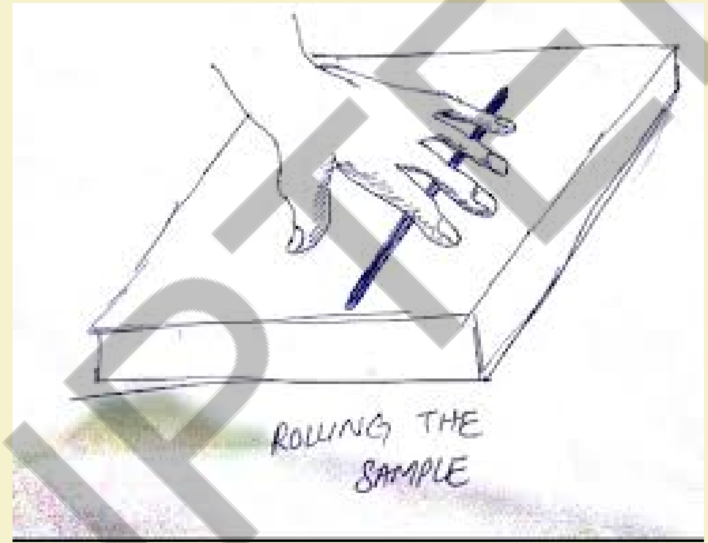
Liquid Limit





Plastic Limit



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Shrinkage limit test apparatus

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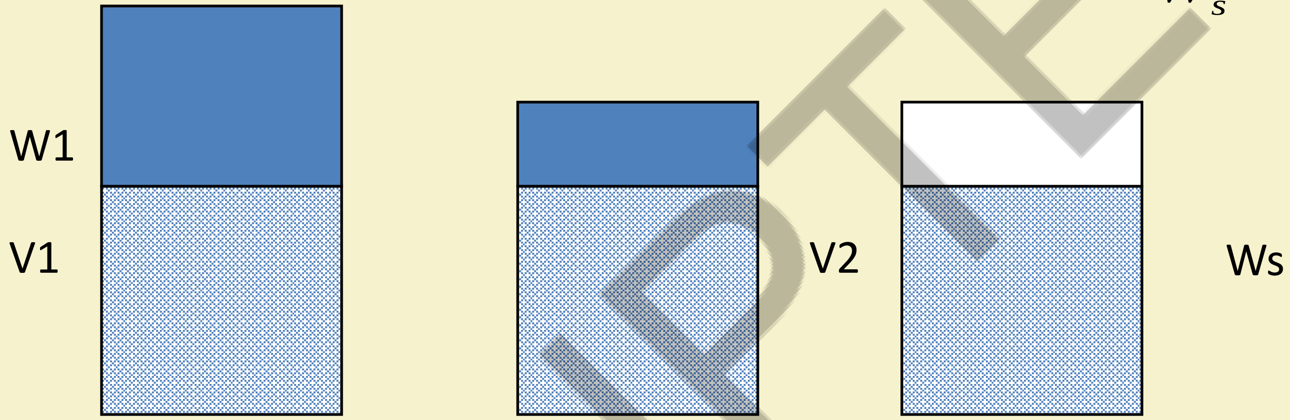
Shrinkage Limit

$$w_s = \frac{W_w}{W_s}$$

$$w_s = \frac{(W_1 - W_s) - (V_1 - V_2)\gamma_w}{W_s}$$



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Plasticity index, $I_p = w_l - w_p$

Liquidity index, $I_l = \frac{w_n - w_p}{I_p}$

Relative consistency, $I_c = \frac{w_l - w_n}{I_p}$

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Soil classification based on Plasticity Index

Plasticity Index	Soil Description
0	Non Plastic
Less than 7	Low Plastic
7-17	Medium Plastic
Greater than 17	Highly Plastic

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Consistency of cohesive soil

Consistency	Description	Ic	I
liquid	liquid	Less than 1	Greater than 1
plastic	Very soft	0-0.25	0.75-1.0
	Soft	0.25-0.5	0.5-0.75
	Medium stiff	0.5-0.75	0.25-0.5
	Stiff	0.75-1.0	0-0.25
Semi solid	V stiff or hard	Greater than 1	Less than 1
solid	Hard/V hard	do	

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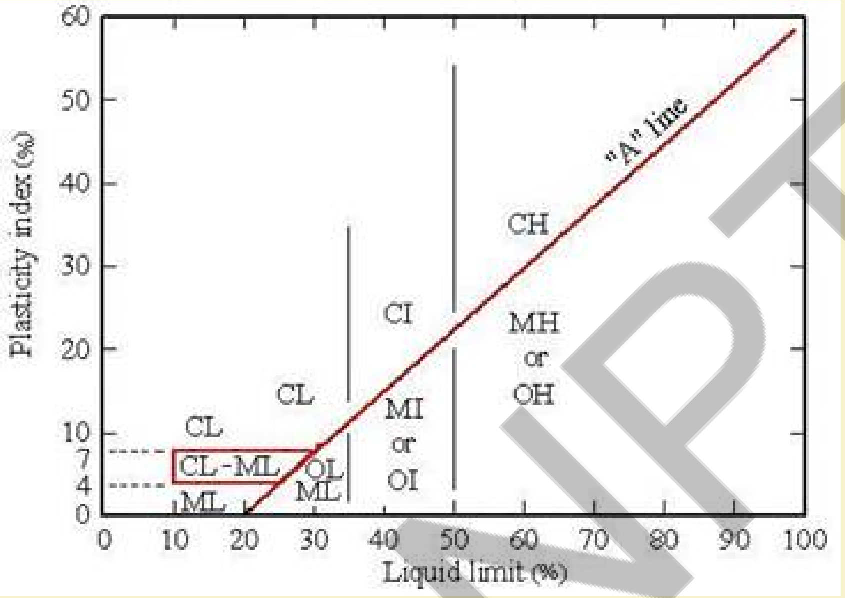
Plasticity Chart



$$PI = 0.73(LL - 20)$$

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Indian Standard soil classification system: Grain size analysis (sieve and hydrometer) and plasticity chart are used for this purpose

Two letters system: 1st one to define soil type and 2nd one for defining subgroup. Example: SP – Poorly graded sand, SM – silty sand

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Prefix and suffix of ISSCS

Soil Type	Prefix	Sub group	Suffix
Gravel	G	Well graded	W
Sand	S	Poorly gradded	P
Silt	M	Silty	M
Clay	C	Clayey	C
Organic	O	wl > 35 per cent 35<wl<50	L I
Peat	Pt	Wl < 50 per cent	H

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Steps in soil Classification

- Determine whether the given soil is of organic origin or coarse grain or fine grained. An organic soil is identified visually by its colour (brownish black or dark) and characteristic odour.
- If 50% or more of the soil by weight is retained on the 75 micron sieve, it is course grained ; if not, it is fine grained

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Steps: Continued

If the soil is course grained

- **Obtain the GSD curve from sieve analysis. If 50% of the coarse fraction (75 micron) is retained on the 4.75 mm sieve, classify the soil as gravel; if not classify as sand.**
- **If the soil fraction passing through the 75 micron sieve is less than 5% determine the gradation of soil by calculating Cu and Cc from the GSD curve. GW, SW or GP, SP**

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Coarse grained soil: contd..

- If more than 12% passes through the 75 micron sieve , perform the liquid limit and plastic limit tests on the soil fraction passing through the 0.425 mm mm sieve. Use the IS Plasticity chart to determine the classification (GM, SM, GC, SC)
- If between 5% and 12% pass through the 75 micron sieve, the soil is assigned a dual symbol appropriate to its gradation and plasticity characteristics (SP-SM, SP-SC, GP-GM)

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If the soil is fine grained

- Determine liquid limit and plastic limit on the soil fraction passing 425 micron sieve and determine the plasticity index
- If the limits plot the A-line, classify as silt (M). Further if liquid limit is less than 35, classify as ML; if liquid limit between 35 and 50, classify as MI; if liquid limit is greater than 50 classify as MH

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Fine grained soil: contd..

- If the limits plot above A-line, classify as clay (c). Assign the group symbol CL or CI or CH depending on the value of liquid limit.
- If the limits plot in the hatched zone, classify as CL-ML. If the limits plot close to the A-line or close to liquid limit = 35% or 50% lines, assign dual symbol

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If the soil has 50% each of fines and coarse grained fraction

- Determine whether the coarse grained fraction is gravel or sand
- **Determine liquid limit and plastic limit on the soil passing 425 micron sieve**
- Determine whether the limits plot above the A-line or below the A-line, Classify as C or M
- **Based on liquid limit classify as L, I or H**
- Assign the dual symbol from the information obtained in above steps. GM-ML, GM-MI etc

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Classification of Sand based on Relative density

Relative Density, $D_r = \dfrac{e_{max} - e}{e_{max} - e_{min}}$

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Classification

Relative density	Soil type
<15%	Very loose
15%-35%	Loose
35% -65%	Medium
65%-85%	Dense
>85%	Very Dense

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