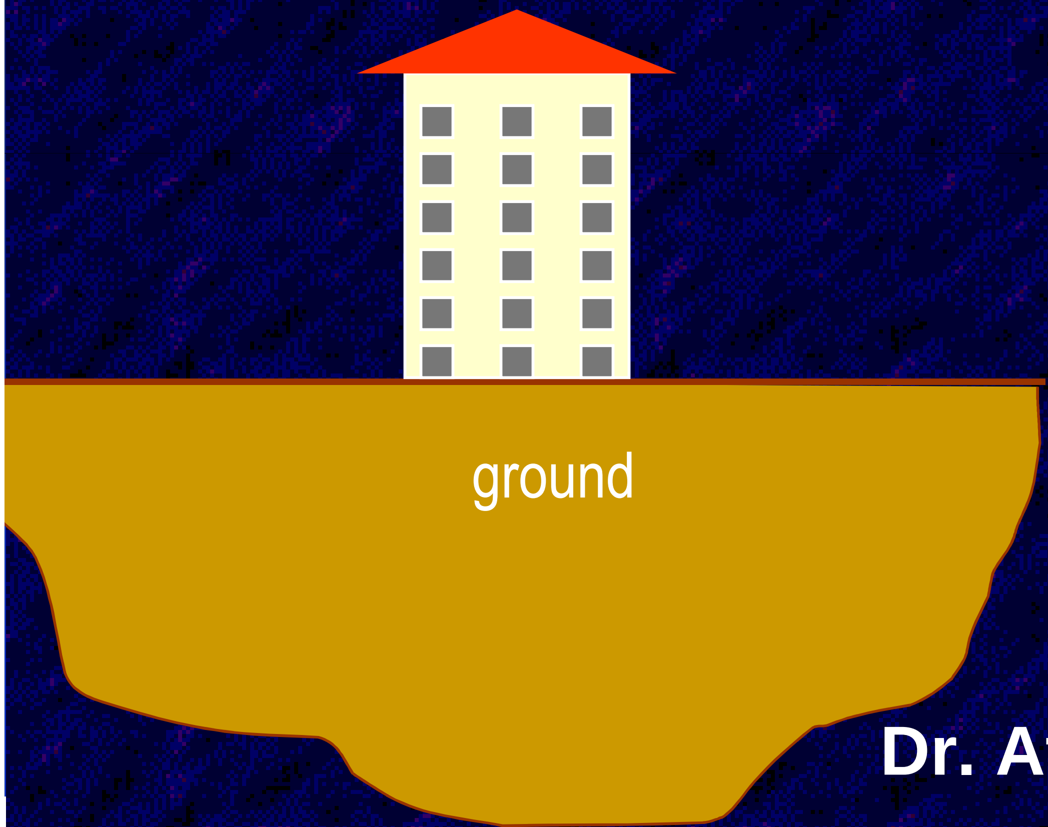
Introduction to
Soil Mechanics
Geotechnical Engineering-II



Dr. Attaullah Shah

Soil Formation

- Soil derives from Latin word " Solum" having same meanings as our modern world.
- From Geologist point of view, " The superficial unconsolidated mantle of disintegrated and decomposed rock material"-The entire mantle or rock decay.
- Soil is a complex of inorganic matters that may or may not contain organic decomposed organic residues and other substances, which blanket the earth's crust, which is formed by the process of weathering (Disintegration and decomposition) of rock and mineral.
- The weathering agents include physical, mechanical or chemical agents.

- The factors of weathering in the process of soil formation may be atmospheric such as pressure, temperature, wind and water erosion and transportation by the water erosion and transportation by water and glaciers, plant and animal life.
- Soil is a mixture of Water, Air and Solids. The solids are mixture of mineral matters with particle sizes differing in sizes, shapes and structure and varying in chemical compositions.
- The top soil which supports vegetation is called “Top soil” and the undisturbed strata lying immediately below the natural top soil is termed as “ sub soil”.

Types of Soils:

- Six main types:
  - Gravels.
  - Sands
  - Silts
  - Clay
  - Fine grained soils and pets.
- They are further classified into two types:
  - Cohesive soils: Clay, shale and silts.
  - Non cohesive or Cohesion-less soils: Sand and Gravels, which possesses no plasticity and tend to lack cohesion specially when in dry state.

Problems to be studied before execution of the projects

- How deep the soil exploration must be made?
- What is the safe and allowed bearing capacity?
- What is the load of structures to be applied at the soil?
- What is the intensity and stress distribution in a soil induced by various kinds of loading?
- How thick should be thickness of layer of good soil over a poor one in order to prevent the foundation from punching.
- Does soil possesses properties (friction and cohesion) which will assure satisfactory stability for foundation.
- How much counter weight must be placed as remedial measures against the lateral motion of soil

- The settlement of soils under applied loads and its rate and nature.
- The depth of ground water and its variation at various depths.
- Depth of frost penetration and subsequent depth of foundation and effect of freeze and thaw on pavement and structures.
- The suitability of soil for the construction of structures like dams, roads and buildings.
- The issues relating to water logging and salinity in soils etc.

Natural Soil Deposits

- Soils are the results of weathering, mechanical disintegration, and chemical decomposition of the parent material, mainly rocks
- The products of weathering may have the same composition as the parent material, or they may be new minerals that have resulted from the action of water, carbon dioxide, and organic acids with minerals comprising the parent material.
- The products of weathering that remain in place are termed residual soils.
- In most cases gravity and erosion by ice, wind, and water move these soils to form new deposits, termed transported soils.
- In humid and tropical climates, weathering may significantly affect the character of the soil to great depths, while in temperate climates it produces a soil profile that primarily affects the character of surface soils.
- The character of natural soil deposits usually is complex.

Identification of Soils

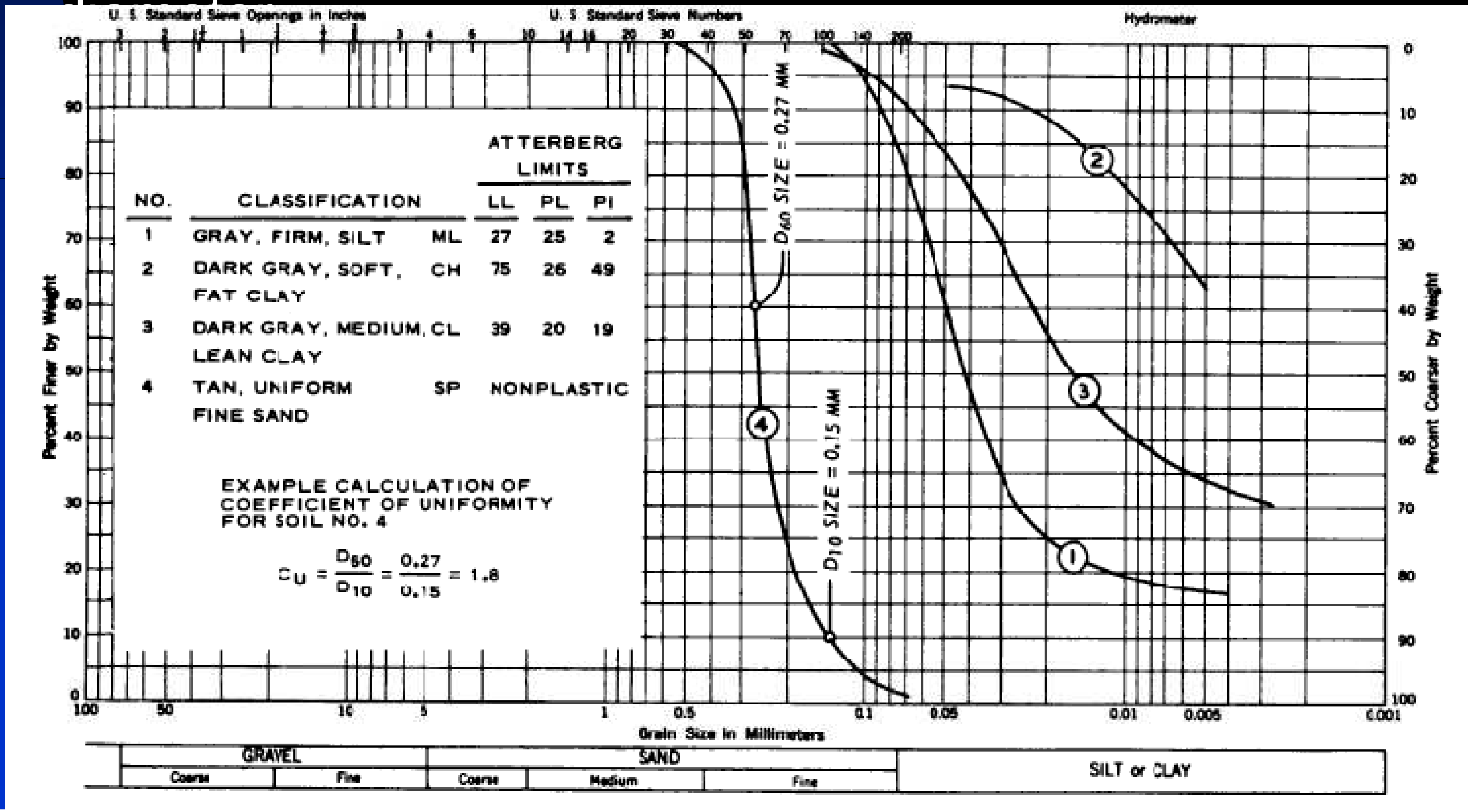
- Soils are identified by visual examination and by means of their index properties (grain-size distribution, Atterberg limits, water content, specific gravity, and void ratio).
- A description based on visual examination should include color, odor when present, size and shape of grains, gradation, and density and consistency characteristics.
  - Coarse grained soils: soils have more than 50 percent by weight retained on the No. 200 sieve and are described primarily on the basis of grain size and density
  - Fine-grained soils have more than 50 percent by weight finer than the No. 200 sieve. Descriptions of these soils should state the color, texture, stratification, and odor, and whether the soils are soft, firm, or stiff, intact or fissured.
  - The visual examination should be accompanied by estimated or laboratory determined index properties.

Physical properties of soils

- Color: Depends on
  - Minerals of soil.
  - Organic contents
  - Amount of oxides
  - Color is natural state is noted.
- Soil Structure: depends on
  - Size and shapes of soil particles.
    - **Terzaghi grouped soil in three groups**
    - **Granular or single grained soil: Silt and Clay**
    - **Flocculent Structure: Clay**
    - **Dispersed Structure: Transportation process: Man**
    - **fills.**
- Particle Shapes:
    - **Angular**
    - **Sub Angualr**
    - **Rounded**
    - **Elongated**
    - **Flaky**

Soil Index Properties:

- Grain-size distribution. The grain-size distribution of soils is determined by means of sieves and/or a hydrometer analysis, and the results are expressed in the form of a cumulative semi-log plot of percentage finer versus grain diameter



- ***Atterberg limits***. The Atterberg limits indicate the range of water content over which a cohesive soil behaves plastically. The upper limit of this range is known as the liquid limit (LL); the lower, as the plastic limit (PL). The LL is the water content at which a soil will just begin to flow when slightly jarred in a prescribed manner. The PL is the water content at which the soil will just begin to crumble when rolled into threads 1/8 inch in diameter.

- ***Density***. The mass density of a soil material is its weight per unit volume. The dry density of a soil is defined as the weight of solids contained in the unit volume of the soil and is usually expressed in pounds per cubic foot.

- ***Specific gravity***. The specific gravity of the solid constituents of a soil is the ratio of the unit weight of the solid constituents to the unit weight of water. For routine analyses, the specific gravity of sands and clayey soils may be taken as 2. 65 and 2. 70, respectively.

- Consistency. The consistency of an undisturbed cohesive soil may be expressed quantitatively by the unconfined compressive strength **qu.**

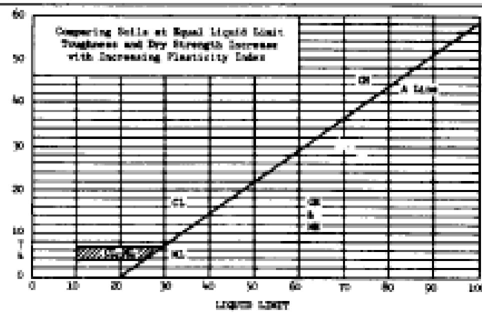
Soil Classification

- **Unified Soil Classification: The Unified Soil Classification System, based on identification of soils according to their grain-size distribution, their plasticity characteristics, and their grouping with respect to behavior, should be used to classify soils in connection with foundation design.**

Major Divisions			Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)			Information Required for Describing Soils	Laboratory Classification Criteria	
1	2		3	4	5			6	7	
Coarse-grained Soils More than half of material is larger than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.			For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics.	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.				Not meeting all gradation requirements for GW	
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixture.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.	Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).				Atterberg limits above "A" line with PI greater than 7	
	Sands More than half of coarse fraction is smaller than No. 4 sieve size.	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.				$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.				Not meeting all gradation requirements for SW	
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			Example: Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).	Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).				Atterberg limits above "A" line with PI greater than 7	
					Identification Procedures on Fraction Smaller than No. 40 Sieve Size					
					Dry Strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)			
Fine-grained Soils More than half of material is smaller than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Silts and Clays Liquid limit is less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium			
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight	Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses.		
	Silts and Clays Liquid limit is greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium			
			CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High			
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium	Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML).		
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.					

Use grain-size curve in identifying the fractions as given under field identification.

Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows: Less than 5% GW, GP, SW, SP. More than 12% GM, GC, SM, SC. 5% to 12% Borderline cases requiring use of dual symbols.



PLASTICITY CHART

For laboratory classification of fine-grained soils

(1) Boundary classifications: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U. S. standard.

Major Divisions		Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)			Information Required for Describing Soils	Laboratory Classification Criteria			
2		3	4	5			6	7			
Gravels: More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.			For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics.	Use grain-size curve in identifying the fractions as given under field identification.	Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows: Less than 5% ... GW, GP, SW, SP. More than 12% ... GM, GC, SM, SC. 5% to 12% ... Borderline cases requiring use of dual symbols.	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.						Not meeting all gradation requirements for GW	
	Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixture.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.			Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
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		SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			Example: Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).			Not meeting all gradation requirements for SW	
	Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).						Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
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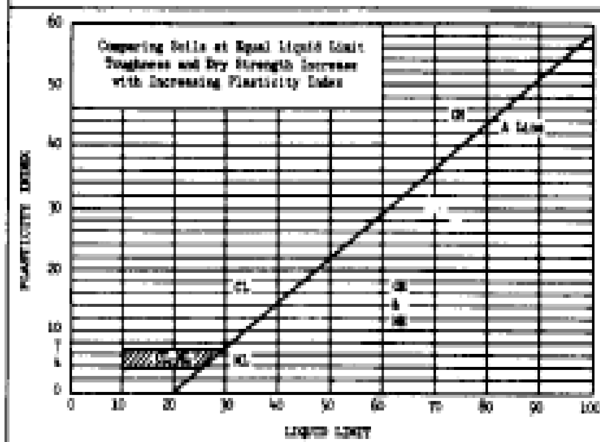

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Weight Volume relationships of soils

WATER CONTENT $w = \dfrac{W_w}{W_s}$

SPECIFIC GRAVITY $G_s = \dfrac{W_s}{V_s \, \gamma_w}$

VOLUME OF SOLIDS $V_s = \dfrac{W_s}{G_s \, \gamma_w}$

VOLUME OF VOIDS $V_v = V - V_s$

VOID RATIO $e = \dfrac{V_v}{V_s} = \dfrac{n}{1 - n}$

POROSITY $n = \dfrac{V_v}{V} = \dfrac{e}{1 + e}$

DEGREE OF SATURATION $S = \dfrac{V_w}{V_v} = \dfrac{w \, G_s}{e}$

UNIT WEIGHT OF WATER (FRESH WATER) $\gamma_w = \dfrac{W_w}{V_w} = 62.4$ PCF

DRY UNIT WEIGHT $\gamma_d = \dfrac{W_s}{V} = \dfrac{\gamma_m}{1 + w}$

WET UNIT WEIGHT $\gamma_m = \dfrac{W}{V}$

SUBMERGED (BOUYANT) UNIT WEIGHT $\gamma' = \gamma_m - \gamma_w = \dfrac{G_s - 1}{1 + e} \gamma_w$