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Soil Mechanics: Stress Distribution

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Module 1: Identification and Classification of Soil and Rock

Learning Objectives

By the end of this section, you will be able to:

- **Identify** soil and rock deposits based on their geologic origin and mode of occurrence.
- **Classify** soil specimens using the Unified Soil Classification System (USCS) and AASHTO methods.
- **Evaluate** the engineering properties and risks associated with special materials such as expansive soils, collapsible soils, and karst formations.

Executive Summary: Accurate soil and rock identification is the foundation of geotechnical design. Engineers must look beyond simple physical descriptions to understand the geologic origin and mode of occurrence, as these factors dictate the uniformity and predictability of engineering properties across a site.

Introduction

This section presents criteria for soil and rock identification and classification based on internationally accepted standards. Common soils and rocks are discussed as well as special materials, such as expansive and collapsing soils, permafrost, limestone, coral formations, and quick clays.

Soil Deposits

Soils are masses of solid particles with voids containing gas or liquid. From a geologic standpoint, soils are classified by origin (e.g., transported, residual) and mode of occurrence (e.g., aeolian, alluvial, glacial).

Geologic Origin and Mode of Occurrence

Soils with similar origin and mode of occurrence are expected to have comparable engineering properties. A study of local geology should precede major subsurface exploration to identify potential site challenges.

Table 1-1: Principal Soil Deposits in Terms of Origin

Major Division	Principal Soil Deposits	Pertinent Engineering Characteristics
Organic: Accumulation of highly organic material formed in place by the growth and subsequent decay of plant life	<i>Peats</i> : Somewhat fibrous aggregate of decayed and decaying vegetation matter having a dark color and odor of decay	Very compressible; entirely unsuitable for supporting building foundations
	<i>Mucks</i> : Peat deposits which have advanced in stage of decomposition to such extent that the botanical character is no longer evident	
Pyroclastic: Material ejected from volcanoes and transported by gravity, wind and air	<i>Ejecta</i> : Loose deposits of volcanic ash, lapilli, bombs, etc.	Typically, shard-like particles of silt size with larger volcanic debris; weathering and redeposition produce high plasticity, compressible clay; unusual and difficult foundation conditions
	<i>Pumice</i> : Highly porous volcanic rock that is frequently associated with lava flows and mud flows, or may be mixed with nonvolcanic sediments	
Residual: Material formed by disintegration of underlying parent rock or partially indurated material	Residual sands and fragments of gravel-sized material formed by dissolution and leaching of cementing material, leaving behind the more resistant particles, commonly quartz	Generally favorable foundation conditions
	Residual clays formed by the decomposition of silicate rocks, disintegration of shales, and solution of carbonates in limestone; with few exceptions, becomes more compact, rockier and less weathered with increasing depth; at intermediate stage may reflect composition, structure and stratification of parent rock	Variable properties requiring detailed investigation; deposits present favorable foundation conditions except in humid and tropical climates, where depth and rate of weathering are very great
	Transported soils: See Table 1-2	

Table 1-2: Principal Soil Deposits by Mode of Occurrence

Major Division	Principal Soil Deposits	Pertinent Engineering Characteristics
Aeolian: Material transported and deposited by wind.	<i>Loess</i> : A calcareous unstratified deposit of silts or sandy or clayey silt traversed by a network of tubes formed by root fibers now decayed	Relatively uniform deposits characterized by ability to stand in vertical cuts; collapsible structure; deep weathering or saturation can modify characteristics
	<i>Dune sands</i> : Mounds, ridges, and hills of uniform fine sand characteristically exhibiting rounded grains	Very uniform grain size; may exist in relatively loose condition
Alluvial: Materials transported and deposited by running water.	<i>Floodplain</i> : Low-lying stream or river deposits that are subject to inundation by floodwaters	
	<i>Point bar</i> : Alternating deposits of arcuate ridges and swales (lows) formed on the inside or convex bank of meandering river bends; ridge deposits consist primarily of silt and sand, swales are clay filled	Generally favorable foundation conditions; however, detailed investigations are necessary to locate discontinuities; flow slides may be a problem along riverbanks; soils are quite pervious
	<i>Channel fill</i> : Deposits laid down in abandoned meander loops isolated when rivers shorten their courses; composed primarily of clay; however, silty and sandy soils are found at the upstream and downstream ends	Fine-grained soils are usually compressible; portions may be very heterogeneous; silty soils generally present favorable foundation conditions
	<i>Backswamp</i> : The prolonged accumulation of floodwater sediments in flood basins bordering a river; materials are generally clays but tend to become siltier near riverbank	Relatively uniform in a horizontal direction; clays are usually subjected to seasonal volume changes
	<i>Terrace</i> : Relatively narrow, flat-surfaced, river-flanking remnants of floodplain deposits formed by entrenchment of rivers and associated processes	Usually drained and oxidized; generally favorable foundation conditions
	<i>Estuarine</i> : Mixed deposits of marine and alluvial origin laid down in widened channels at mouths of rivers and influenced by tide of body of water into which they are deposited	Generally fine grained and compressible; many local variations in soil conditions
	<i>Lacustrine</i> : Material deposited within lakes (other than those associated with glaciation) by waves, currents, and organo-chemical processes; deposits consist of unstratified organic clay or clay in central portions of the lake and typically grade to stratified silts and sands in peripheral zones	Usually very uniform in horizontal direction; fine-grained soils generally compressible
	<i>Deltaic</i> : Deposits formed at the mouths of rivers, which result in extension of the shoreline	Generally fine-grained and compressible; many local variations in soil condition
<i>Piedmont</i> : Alluvial deposits at foot of hills or mountains; extensive plains or alluvial fans	Generally favorable foundation conditions	

Table 1-2: Principal Soil Deposits by Mode of Occurrence (Continued)

Major Division	Principal Soil Deposits	Pertinent Engineering Characteristics
Colluvial: Material transported and deposited by gravity	<i>Talus</i> : Deposits created by gradual accumulation of unsorted rock fragments and debris at base of cliffs	Previous movement indicates possible future difficulties; generally unstable foundation conditions
	<i>Hillwash</i> : Fine colluvium consisting of clayey sand, sand silt, or clay	
	<i>Landslide deposits</i> : Considerable masses of soil or rock that have slipped down, more or less as units, from their former position on steep slopes	
Glacial: Material transported and deposited by glaciers, or by meltwater from the glacier.	<i>Glacial till</i> : An accumulation of debris, deposited beneath, at the side (lateral moraines), or at the lower limit of a glacier (terminal moraine); material lowered to ground surface in an irregular sheet by a melting glacier is known as a ground moraine.	Consists of material from <i>boulder</i> and <i>gravel</i> to clay; deposits are unstratified; present generally favorable foundation conditions but rapid changes in conditions are common.
	<i>Glacio-fluvial deposits</i> : Coarse and fine-grained material deposited by streams of meltwater from glaciers; material deposited on ground surface beyond terminal edge of a glacier is known as an outwash plain; gravel ridges known as kames and eskers; depressions known as kettles can be filled with peat	Many local variations; generally present favorable foundation conditions
	<i>Glacio-lacustrine deposits</i> : Material deposited within lakes by meltwater from glaciers; consisting of clay in central portions of lake and alternate layers of silty clay or silt and clay (varved clay) in peripheral zones	Very uniform in the horizontal direction
Marine: Material transported and deposited by ocean waves and currents in shores and offshore areas.	<i>Shore deposits</i> : Deposits of sands and/or gravels formed by the transporting, destructive, and sorting action of waves on the shoreline	Relatively uniform and of moderate to high density
	Marine clays: Organic and inorganic deposits of fine-grained material	Generally, very uniform, compressible and usually very sensitive to remolding

Soil Visual Description, Identification, and Classification

Professional practice distinguishes between **Visual Description** (sensory), **Identification** (field determination), and **Classification** (laboratory tests).

Definitions (ASTM D2487)

- **Boulders**: Particles not passing 12-inch square opening.
- **Cobbles**: Passing 12-inch, retained on 3-inch sieve.
- **Gravel**: Passing 3-inch, retained on No. 4 sieve.
 - *Coarse*: Retained on 3/4-inch. *Fine*: Passing 3/4-inch.
- **Sand**: Passing No. 4, retained on No. 200 sieve.
 - *Coarse*: Retained on No. 10. *Medium*: No. 10 to No. 40. *Fine*: No. 40 to No. 200.
- **Clay**: Particles passing No. 200 exhibiting plasticity and dry strength.
- **Silt**: Nonplastic particles passing No. 200 with little dry strength.

Visual Description and Identification (ASTM D2488)

Visual examination and simple manual tests are used to describe and identify soils in the field.

Descriptors for All Soils

- **Color:** Describe moist sample; Munsell charts are helpful.
- **HCl Reaction:** Describe as **None** (no bubbles), **Weak** (slow bubbles), or **Strong** (violent reaction).
- **Moisture:** **Dry** (dusty), **Moist** (damp), or **Wet** (visible free water).
- **Odor:** Describe if organic or unusual.

Descriptors for Fine-Grained Soils

- **Consistency:** * **Very Soft:** Thumb penetrates > 1 inch.
 - **Soft:** Thumb penetrates ~ 1 inch.
 - **Firm:** Thumb indents ~ 1/4 inch.
 - **Hard:** Indented by thumbnail.
 - **Very Hard:** Cannot be indented by thumbnail.
- **Structure:** Stratified, Laminated, Fissured, Slicken-sided, Blocky, Lensed, or Homogeneous.

Descriptors for Coarse-Grained Soils

- **Angularity:** Angular, Subangular, Subrounded, or Rounded.

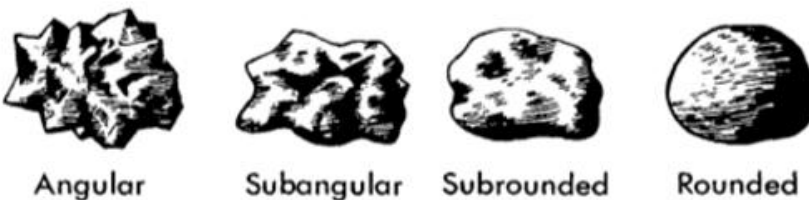


Figure 1-1: Typical Angularity of Bulky Grains (after Sowers 1979)

- **Cementation:** Weak, Moderate, or Strong.
- **Hardness:** Describe if particles fracture when struck by a hammer.

Identification of Fine-Grained Soils

Identification is based on four manual tests:

1. **Dry Strength:** Crushing an air-dried ball.
2. **Dilatancy:** Water reaction upon shaking/squeezing.
3. **Toughness:** Rolling 1/8-inch threads at the plastic limit.
4. **Plasticity:** Classification based on thread rolling and kneading.

Table 1-3: Classification of Fine-grained Soils

Soil Symbol	Dry Strength	Dilatancy	Toughness and Plasticity
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

Unified Soil Classification System (ASTM D2487)

The USCS uses grain-size distribution and Atterberg Limits (Liquid Limit and Plasticity Index) to categorize soil into 15 groups.

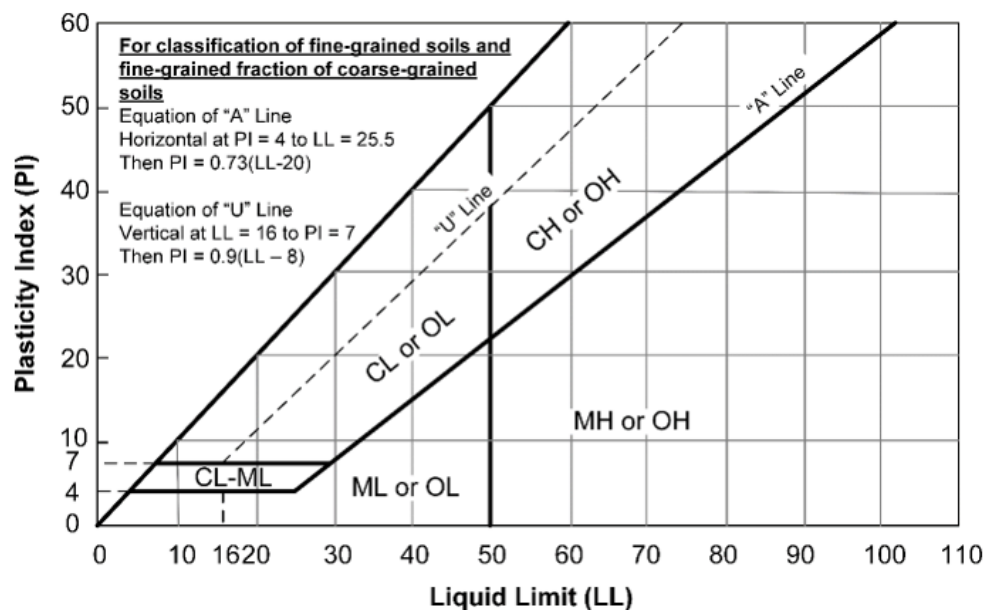


Figure 1-2: Plasticity Chart



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