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CHAPTER TWO: *MATERIALS*

All materials used in the construction of highway embankments, fills, subgrades, and subbases originate from the Earth. Most of these materials are natural in origin, i.e. they are the result of geologic processes that occur naturally as opposed to synthetic materials which are the result of industrial processes (i.e. slag, flyash). This chapter focuses on the natural earth materials.

Earth materials consist of two types: soil and rock. **AASHTO M 146** defines soil as, "*sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks, and which may or may not contain organic matter.*" Soil may also be defined as all unconsolidated materials overlying bedrock. The key word in these definitions is "unconsolidated". Soil is essentially natural material that is not indurated (hardened, cemented) into a cohesive mass. Soil exists in a loose, unbound condition and therefore may be easily excavated with construction equipment.

AASHTO M 146 defines rock as, "*natural solid mineral matter occurring in large masses or fragments.*" Rock may be composed of hardened or cemented soil. The process of converting soil into rock is called lithification. Since lithification takes time and may be incomplete, the distinction between rock and soil may be unclear. For example, soil hardpans have been indurated by chemical action and may be quite hard, but are not considered to be rock. Shale is another example. Shale is considered to be rock by Geologists and soil by Engineers.

Soil and rock may be processed into aggregates by excavating, blasting, dredging, crushing, washing, and screening. These aggregates are considered natural aggregates since the chemical and mineralogical composition of the individual fragments or grains has not been altered. Natural aggregates are used extensively as materials for highway construction and are discussed in this chapter as well.

The following references are required to be reviewed in detail:

AASHTO

1) **M 145**--Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

2) **M 146**--Terms Relating to Subgrade, Soil-Aggregate, and Fill Materials

INDOT Standard Specifications

1) Section **101**

2) Sections **203.03, 203.08** and **203.20**

3) Section **211.02**

4) Sections **301.02, 302.02** and **303.02**

5) Section **903**

6) Section **904**

PEDOLOGY

Pedology is the study of the morphology, origin, and classification of soils. This section discusses the following:

1) Soil origin and geology

2) Soil profiles

3) Soil composition and texture

4) Soil classification

ORIGIN AND GEOLOGY OF SOILS

Based on origin, the two types of soils in Indiana are residual and transported soils. Residual soils are soils formed in-place by the decomposition of the bedrock they overlay. Residual soils result from the accumulation of sediments weathered from rocks native to the area where the soils are found. The sediments are not eroded and carried away by various geologic agents such as water or wind. Therefore, residual soils are essentially formed in-place. Residual soils are found in the southern 1/5 of the state, originating from the shale, sandstone and limestone formations that comprise the bedrock.

Transported soils are just that, transported. The sediments produced by the decomposition of rocks are not accumulated in-place, but are transported from somewhere else and deposited by various geologic agents. The most influential of these agents is water. Most transported soils in Indiana are glacial, though some are wind blown (eolian), some are deposited by rivers and streams (fluvial), and some are lake bed deposits (lacustrine).

Most of the soils in Indiana are Quaternary and are comprised of two geologic Epochs: the Pleistocene (glacial) and the Holocene (modern day).

Glacial Soils

Glacial soils and their associated landforms are found all over the state, except in south central Indiana where bedrock is close to or at the surface. Glacial soils dominate the northern 2/3 of the state. During the Pleistocene epoch, which occurred 1.8 million to 11,000 years ago, North America was in the ice ages. Global cooling resulted in greater amounts of water being frozen into ice. As a result, the polar ice caps had a larger percentage of seawater contained as ice. This caused a dramatic fall in sea level, as much as 250 ft, exposing landmasses previously underwater and unleashing the polar ice upon the Northern Hemisphere. These great sheets of ice, or glaciers, surged southward from the North Pole on a continental scale. As the glaciers advanced, they scoured the landscape, picking up huge amounts of rock and soil and carrying the material with them. Once the climate warmed, the glaciers would melt and retreat northward dropping the materials they carried. The meltwaters from the retreating glaciers created vast river and stream systems, which further scoured the landscape and dispersed the glacial materials.

During the Pleistocene Epoch there were four major glacial advances. The Wisconsin glacier, which was the last glacier, accounted for the majority of the soil deposits. This result occurred because with each glacial advance, the previous glacial deposits were destroyed and reworked by the new glacier, which added fresh material to the mix as well.

Glacial soil deposits are collectively called drift. Drift is the term for all rock material deposited by glaciers or their associated meltwaters. Drift is extremely varied and may consist of well-graded sands and gravels resulting from the meltwaters and mingling of boulders, gravel, sand, silt, and clay dumped directly by the glaciers. The following are examples of glacial soil deposits:

1) Till -- A mixture of clay, silt, sand, gravel and boulders deposited by the glaciers directly without reworking from glacial meltwaters. Extensive areas of till are the landform called a till plain. Another landform made of till is a moraine.

2) Stratified Drift -- Sorted and layered material deposited by meltwaters or glacial lakes

3) Outwash -- Deposits of sand and gravel from meltwater streams. An extensive area of outwash deposits is the landform called an outwash plain.

4) Lacustrine -- Lake deposits resulting from the lakes formed by the glaciers and their meltwater streams

Eolian Soils

Eolian or wind blown soil deposits are the result of the wind eroding, transporting, depositing, and stratifying sediments. Dune sands, blanket sands, and loess (fine-grained silt) deposits are examples of soil deposits that are eolian. Dune and blanket sands are found predominately in northern Indiana. From Newton to Lake Counties in the west and Elkhart and LaGrange Counties in the east dune sands may be found. Newton County in the west to Marshall and Fulton Counties in the east contain blanket sands. Eolian sand deposits are also found to a lesser degree in central and southern Indiana, with dune sands found in Vigo and Clay Counties in central Indiana and Posey and Spencer Counties in southwestern Indiana. Both dune and blanket sands are found in southeastern Indiana in Jackson County as well. Extensive loess deposits are found in southwestern Indiana, extending from Posey to Spencer Counties in the south to Vigo and Clay Counties in the north.

Fluvial Soils

Fluvial or river and stream deposits are the result of present-day rivers and streams. These deposits consist of alluvium material (silt or silty-clay), sand, and gravel.

Lacustrine Soils

Lacustrine or lake deposits are fine grained soils deposited by fresh water lakes. These deposits are mainly fine silts and clays. Some lacustrine soils may be recent as well.

Organic Soils

Organic soils, such as peat, muck, and marl, generally occur in lakes, swamps, and bogs and therefore are associated with lacustrine and fluvial deposits. These soils are composed of organic material, mostly plants except for marl, in various stages of decay.

SOIL PROFILES

Soils tend to be layered or stratified in vertical sequences or horizons. A horizon is a layer of soil that is distinguishable from other layers in the profile by physical properties of structure, texture, color, consistency, and pore distribution or by chemical or mineralogical composition. These horizons form the soil profile. Only unstable and shifting soils, newly developing soils, or layered sand and gravel deposits do not have the recognizable horizons described herein. The following are the major horizons found in a well developed soil:

1) O-horizon
2) A-horizon
3) B-horizon
4) C-horizon
5) D-horizon

O-horizon

The O-horizon is the undecomposed organic debris and humas found at the very top of the soil. This horizon is absent in unvegetated, erosional areas and may be well developed in highly vegetated areas.

A-horizon

The A-horizon is the top layer of the soil profile and is synonymous with the layman’s term "topsoil". The A-horizon usually contains large amounts of organic material in various stages of decomposition. Soluble salts, finer silts, clays, and colloids (small, insoluble particles) tend to be leached out of this layer by percolating surface water. The A-horizon may be dark due to the high organic content and is friable (easily crumbled) due to lack of consolidation.

B-horizon

The soluble salts, fine silts, clays and colloids leached from the A-horizon collect here. The B-horizon is known as the "zone of accumulation" for this reason. The B-horizon is usually more impermeable than the A-horizon due to the chemical and colloidal accumulation. The resulting soil of the B-horizon is usually lighter, denser and more uniform than that of the A-horizon.

C-horizon

The C-horizon is the parent material of the overlying horizons, either the weathered bedrock directly underlying the soil or the glacial drift below the developing profiles

D-horizon

The D-horizon is the unweathered bedrock which is not the parent material of the overlying soils. The D-horizon may influence the overlying soils by controlling drainage and surface morphology.

Soil horizons tend to be thick and strongly developed in soils found in areas of low topography. These areas collect more surface water, consequently depositing more silt, clays, and organic matter in the O and A-horizons. The more surface water accumulation, the more leaching action that occurs on the A-horizon. Combining more deposition with increased leaching action results in thicker, well-developed O, A, and B-horizons. Areas of high topography are areas of erosion instead of deposition. The surface water and materials are carried away reducing leaching and deposition of materials which results in the formation of thin, poorly defined soil profiles or none at all.

SOIL COMPOSITION AND TEXTURE

Soil is made up of the following components:

1) Boulders

2) Gravel

3) Sand

4) Silt

5) Clay

6) Colloids

7) Organic material

With the exception of organic material, the components listed denote grain size and not origin or chemical/mineralogical composition. **AASHTO M 146** and Section **903.01** define grain size limits. Organic materials are largely decayed plant matter and may be found in any state of decay.

Soil texture refers to the size and distribution of the components that comprise the soil. This is commonly referred to as the gradation of the soil.

SOIL CLASSIFICATION

Section **903** and **AASHTO M 145** detail the classification system INDOT uses for all soils. Section **903** is strictly a textural classification system. **AASHTO M 145** has a textural component as well as an engineering property component. The liquid limit (**AASHTO T 89**) and plasticity index (**AASHTO T 90**) parameters are included in the classification system. When classification of a soil is required, a sample is submitted to the Office of Geotechnical Engineering or the District Testing Laboratory if the District is capable of conducting the tests.

Organic and Marly Soils

When discussing organic and marly soils, peat, marl, and muck are required to be understood. Peat is a highly organic substance composed of decaying plant matter. Marl is calcareous (calcium carbonate, calcium or lime) clay that commonly has shell fragments. Muck is an organic soil with dark, decomposed organic material intermixed with high amounts of silt.

Organic soils are classified in accordance with **AASHTO T 267** and Section **903.05**. **AASHTO T 267** is used to determine the amount of organic matter in the soil and Section **903.05** classifies the soil based on the percentage of organic matter.

Marly soils are classified in accordance with Section **903.06**.

FIELD INDENTIFICATION AND CLASSIFICATION OF SOILS

Field classifications are generally conducted by the Office of Geotechnical Engineering or Consultant Geotechnical Companies. Though procedures for field classification are outlined herein, the Technician is required to interpret soil-boring descriptions as opposed to actually describing and classifying soils. Soil boring logs from the geotechnical investigation accompany the contract proposal and plan sheets. These logs provide vital information concerning the soil types and potential material problems. Therefore, the Technician is required to read and interpret the soil descriptions, understand how the soil descriptions are written, and interpet what the terms mean.

Soil identification and classification in the field is based on visual inspection and simple field tests. The identification contains the following descriptions in this order:

1) Color
2) Moisture
3) Consistency or density
4) Textural classification
5) Modifying terms

Color

The color of the soil is described in a wet condition. Use of the Munsell Soil Color Chart may be helpful.

Moisture

The soil moisture condition is described as:

1) Wet
2) Very moist
3) Moist
4) Slightly moist
5) Dry

Consistency or Density

The relative consistency of silt-clay material is described as:

1) Very soft -- easily penetrated several inches by thumb. Exudes between thumb and fingers when squeezed in hand.

2) Soft -- easily penetrated 1 in. by thumb. Molded by light finger pressure

3) Medium stiff -- may be penetrated over 1/4 in. by thumb with moderate effort. Molded by strong finger pressure

4) Stiff -- indented about 1/4 in. by thumb but penetrated only with great effort

5) Very stiff -- readily indented by thumbnail

6) Hard -- indented with difficulty by thumbnail

The relative density of granular material is described as:

1) Very loose -- easily penetrated with 1/2 in. rebar pushed by hand

2) Loose -- easily penetrated with 1/2 in. rebar pushed by hand

3) Medium dense -- penetrated 1 ft with 1/2 in. rebar driven with 5 lb hammer

4) Dense -- penetrated 1 ft with 1/2 in. rebar driven with 5 lb hammer

5) Very dense -- penetrated only a few inches with 1/2 in. rebar driven with 5 lb hammer

Textural Classification

Textural classification is determined by estimating the amounts of gravel, sand, silt, and clay in the soil and then classifying the material in accordance with Section **903**. Since laboratory testing for particle size is not conducted, a few simple techniques for distinguishing fines are as follows:

1) Fine sand when rubbed between the fingers feels gritty and does not stain the fingers, whereas, silt and clay materials feel smooth and leave a stain.

2) Silt does not stick to your teeth when a piece of the soil is bit but clay tends to stick. Also, small amounts of sand may be detected this way, as the sand has a gritty texture against the teeth.

3) Silt, when rinsed lightly with water, tends to wash off hands while clay sticks to hands

The following methods may be used in the field to estimate the soil texture, which is defined as the relative size and distribution of the individual soil particles or grains.

1) Visual Examination. By carefully looking at the soil, the material may be divided into at least the gravel, sand, and fines (silt and clay combined) components. Since the naked eye only distinguishes particle sizes down to about 0.05 millimeters, silt and clay sized particles cannot be separated without further magnification.

   The examination is done by drying a sample, spreading the material on a flat surface, segregating the material into various components, and estimating the relative percentage of each. The percentage refers to the dry weight of each soil fraction, as compared to the dry weight of the original sample. Figure 2-1 provides the defined particle sizes for each component and a common reference to aid in identifying the various particle sizes.

2) Sedimentation/Dispersion. This test is done by shaking a portion of the sample into a jar of water and allowing the material to settle. The material settles in layers. The gravel and coarse sand settle almost immediately, the fine sand within about a minute, the silt requiring as much as about an hour, and the clay remaining in suspension indefinitely. The percentage of each component is estimated by comparing the relative thickness of each of the layers in the bottom of the jar. The larger size particles typically settle into a denser mass than the fines.

Approximate Size Limits			
Classification	**Measured**	**Sieve**	**Comparison Example**
Boulders and Cobbles	Over 3 in.	> 3 in.	Grapefruit size
Gravel Coarse	3 in. to 1 in.	3 in. to 1in.	Lemon
Medium	1 in. to 3/8 in.	1 in. to 3/8 in.	Diameter of penny
Fine	3/8 in. to 2.0 mm	3/8 in. to 2.0 mm	Pencil diameter to pea or rock salt
Sand Coarse	2.0 mm to 0.42 mm	No. 10 to No. 200	Broom straw diameter to sugar or table salt
Fine	0.42 mm to 0.075 mm	No .40 to No. 200	Human hair to powdered sugar
Silt	-.075 mm to 0.002 mm	< No. 200	Cannot be discerned with naked eye
Clay	< 0.002 mm	< No. 200	Cannot be discerned with naked eye

Figure 2-1. Visual Grain Size Identification

Granular Materials

Granular materials per **AASHTO M 145** have 35 % or less passing the No. 200 sieve. These materials are sand and gravels with or without an appreciable amount of fines. These limits do not apply in field classification. Since texture is based on visually estimating percentages of the components, granular materials are more loosely defined in the field as materials that are composed predominantly (≥ 50 %) of sand size or larger material. The general character of the soil is more granular than cohesive. The following are guidelines for properly describing and classifying granular materials:

1) Estimate the largest particle in sample

2) Remove any gravel in the sample if present and estimate the amount.

3) Determine if the gravel or sand is clean or dirty

4) If the sample contains appreciable fines, determine if the fines are silty or clayey as outlined in Silt-Clay Material

Determination of clean verses dirty may be made by two simple field tests as follows:

1) Settlement Rate Test -- Place a small amount of the material in a container filled with water. The water clears in 30 seconds for clean sands and remains cloudy for dirty sands.

2) Dust Formation Test -- Dry out the granular material if moist. Sift the dry, granular material through your fingers and let the material fall on a hard, clean surface. If large amounts of silt and clay are present, the material that strikes the hard surface is dust.

Silt-Clay Materials

Silt-clay soils are composed predominantly of grains that visually cannot be distinguished in size. Besides the general techniques described earlier, several field tests may be used to distinguish silty from clayey soils as follows:

1) Plasticity Test -- The ability to be molded within a certain range of moisture contents is termed plasticity. Plasticity is dependent upon the percentage and type of clay component, and therefore requires differentiation between silt (non-plastic fines) and clay (plastic fines).

   For the ribbon/thread test, a roll of soil moist enough to have workability, approximately 1/2 in. to 3/4 in. in diameter and about 3 in. to 5 in. in length, is pressed between the thumb and index finger into a ribbon of about 1/8 in. thick. The longer the ribbon may be formed before the soil breaks under the soil's weight, the higher the plasticity of the soil. Highly plastic clays may be ribboned to 4 in. longer than the original material. Clay of low plasticity may be ribboned only with some difficulty into short lengths. Predominately silty soils do not ribbon or have ribbons that are delicate, softer, and easily crumbled. Non-plastic materials cannot be ribboned.

Plasticity	Length of Ribbon (in.)
Non Plastic	0
Slightly Plastic to Plastic	0 – ½
	½ - 1
	¼ - 1
	0 - 1
Plastic to Highly Plastic	1 – 2
Highly Plastic	> 2

2) Dry Strength / Breaking Test -- The dry strength/breaking test is normally made on a dry pat of soil about 1/2 in. thick and about 1 1/4 in. in diameter that has been allowed to air dry completely. Attempts are made to break the pat between the thumb and fingers. Very highly plastic clays are resistant to breakage and highly plastic clays are broken with great effort. Caution is exercised with highly plastic clays to distinguish between shrinkage cracks, which are common in such soils, and a fresh break. Clays of low plasticity may be broken with ease, therefore, clayey soils have medium to very high dry strength. Silty soils break readily and have no strength (non-plastic) to medium strength (slightly plastic). Non-plastic soils have very little dry strength, crumbling on being picked up by the hands.

3) Shaking / Dilatency Test -- In the shaking / dilatency test, a pat of soil about 3/4 in. in diameter is moistened to a putty-like state and placed in the palm of the hand. The hand is then shaken vigorously or jarred on a table or other firm object. If the surface of the sample begins to glisten, this is an indication that moisture within the sample has risen to the surface. When this does not occur, the soil is probably clayey. Where this occurs sluggishly or slowly, the soil is predominately silty, perhaps with a small amount of clay. For silts or very fine sands, the moisture rises to the surface rapidly, and the test may be repeated over and over by simply remolding and then reshaking the pat. This test is not generally done by INDOT.

Marl, and Peat

Marl and peat may be identified by visual inspection, color, smell, density, and compressibility. Peat is a highly organic soil characterized by undecayed to decaying plant matter, which gives the material a fibrous texture. Marl tends to have animal remains, predominantly shells. Organic soils are dull brown to black in color, spongy, and have a slight to strong odor of decay.

Modifying Terms

When describing soils in the field, modifiers are used and included in the description, when appropriate. These modifiers are either textural or general.

Textural modifiers are used to indicate components that were not considered in the textural classification of the material. These include such materials as rock fragments, gravel particles, pieces of shale, etc. and are indicated as follows:

1) Trace amounts -- component comprises 0-10 % of soil

2) Little -- component comprises 11-19 % of soil

3) Some -- component comprises 20-35 % of soil

4) And -- component comprises 36-50 % of soil

General modifiers may be very helpful and accompany the soil description whenever possible. They are noted in parenthesis after the usual soil classification.

Some examples of general modifiers are:

1) Fill material

2) Apparently natural ground

3) Peat

4) Marl

5) Till

6) Old lake bed (lacustrine)

Examples and Interpretations of Field Descriptions

All soil descriptions follow the same format. The color is described first, then the moisture, followed by consistency or density, and finally the textural classification, which is in all capital letters. The following is an example from an actual soil-boring log:

1) Topsoil (visual)

2) Brown, moist, very loose to medium dense, LOAM

3) Brown, moist, very loose, SANDY LOAM

4) Gray, moist, medium dense to loose, LOAM with little organic matter (LOI = 8.5 %)

5) Gray, moist, very soft to medium stiff, SILTY CLAY LOAM

6) Brown and gray, weathered SHALE with interbedded layers of sandstone (visual), % recovery, and Rock Quality Description.

Number 1 is the topsoil.

Number 2 is a granular material. Granular soils have the density described, not the consistency. A range of densities may be used to describe the soil.

Section **903.02** defines a loam as having as much as 50 % sand and gravel. Therefore, since loam was considered granular, the sand-sized material probably was around 50 %. Since the material obviously had large amounts of fines (≈ 50 %), the material was classified as a loam as opposed to a sandy loam. Obviously, the sand was dirty.

Number 3 is a granular material. Sandy loams have between 50-80 % sand and gravel. This material was obviously granular to be classified as a sandy loam. Since the density was described as very loose, the material had considerably fewer fines than the sample above; however, there was enough to classify the sand as dirty and consequently the material is a sandy loam as opposed to sand.

Number 4 is a granular material. Again, the material was composed predominantly of sand. The sample had a textural modifier, concerning the organic matter (LOI = 8.5 %). The LOI is the "loss on ignition" of organic material (**AASHTO T 267**). The sample was tested in the laboratory for organic content and had obvious organic material in the material.

Number 5 is a silt-clay material. The consistency of the material was described as opposed to the density. Again, a range of consistencies was given as opposed to a single consistency. The material obviously had considerably less sand than the previous samples and the fines were predominantly silt, not clay.

Number 6 is the top of bedrock.

The granular soils were apparently not gravelly. If they were gravelly (≥ 20 %), the textural modifiers "*with some gravel*" or "*and gravel*" would have been used. No gravel was found in the soils at all since no textural modifiers were used.

Based on visual classifications and laboratory testing, Geotechnical Engineers refine the field boring logs.

Classification	% Sand & Gravel	% Silt	% Clay
Sand	80 - 100	0 - 20	0 – 20
Sandy Loam	50 – 80	0 – 50	0 – 20
Loam	30 – 50	30 – 50	0 – 20
Silty Loam	0 - 50	50 - 80	0 - 20
Silt	0 – 20	80 – 100	0 – 20
Sandy Clay Loam	50 – 80	0 – 30	20 – 30
Clay Loam	20 – 50	20 – 50	20 – 30
Silty Clay Loam	0 - 30	50 - 80	20 - 30
Sandy Clay	50 – 70	0 – 20	30 – 50
Silty Clay	0 – 20	50 – 70	30 – 50
Clay	0 - 50	0 - 50	30 - 100

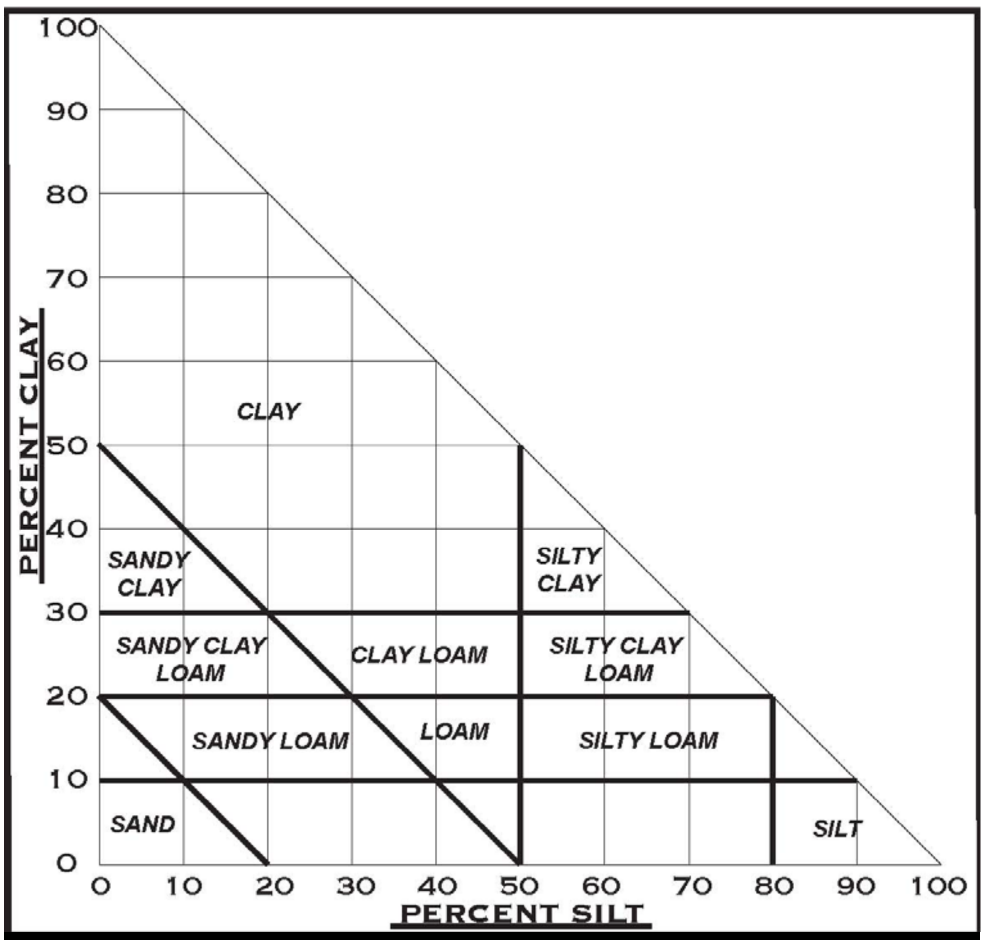

Fig. 2-2. Soil Classification

ROCK AND SHALE EMBANKMENT

Rock and shale embankment is covered in Section **203.20.** INDOT considers three categories of rock and shale as follows:

1) Rock

2) Shale, Shale and Soft Rock Mixtures, or Soft Rock

3) Shale and Thinly Layered Limestone

In order to understand the differences in the materials, a greater understanding of rocks, Indiana geology, and the INDOT specifications is required.

PRINCIPAL ROCK TYPES

There are three general classes of rock: Igneous, Sedimentary, and Metamorphic. All of the rocks on earth fit into one of these classes.

Igneous rocks are rocks that were formed from cooled molten rock material called magma and are considered the original rock type. The rate of cooling and chemical composition of the magma determined the type of igneous rock. Examples of igneous rocks are granite and basalt.

Sedimentary rocks are rocks that were formed from the accumulation, compaction, and cementation of fragmented earth materials, organic remains, and or chemical precipitates. These materials are collectively called sediments, hence the name. Sedimentary rocks are derived rock types that require the weathering and erosion of existing rocks for their formation. Examples of sedimentary rock are sandstone, limestone, and shale.

Metamorphic rocks are rocks that were formed from existing rocks that have been subjected to heat and/or pressure. This process metamorphoses or changes the rock mineralogically, texturally, and structurally. An existing metamorphic rock may be metamorphosed again by the geologic conditions. Examples of metamorphic rocks are marble (metamorphosed limestone), slate (metamorphosed shale), and gneiss (metamorphosed granite).

INDIANA GEOLOGY

All of the bedrock in Indiana is sedimentary. Indiana bedrock dips to the southwest and to the northeast because the Cincinnati Arch extends through the central portion of Indiana. This uplift of material throughout central Indiana resulted in the bedrock layers gradually dipping away. Since the dip is gradual, the bedrock appears flat lying in any one area.

The bedrock of Indiana is quite old, ranging from 505 million to 286 million years old, and comprises five geologic periods. These geologic periods, listed from oldest to youngest, are the Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian periods.

The rocks of the Ordovician to Mississippian age are almost exclusively marine in origin and consist primarily of limestone and dolomite with some shale, sandstone, and siltstone. Rocks of Pennsylvanian age are mostly non-marine in origin and consist primarily of sandstone and shale with minor amounts of marine limestone.

ROCK

Rock, as defined in **AASHTO M 146,** does not distinguish between soft rock and hard or durable rock. Section **203.03** defines what materials would classify as rock. Generally, materials meeting **203.03** are to be treated in accordance with section **203.20(a)** rock embankment. This is not always the case, however, since some shale requires blasting as opposed to ripping with a bulldozer and all shale is covered under Section **203.20(b)** unless written permission is obtained to incorporate shale in accordance with Section **203.20(a)**. Therefore, careful consideration of the type of rock material in question is required before incorporating the material in embankments. When in doubt as to which section applies to the material, the Area Engineer, District Construction Engineer, Testing Engineer, or the Office of Geotechnical Engineering is consulted.

SHALE, SHALE AND SOFT ROCK MIXTURES, OR SOFT ROCK

Shale is a sedimentary rock composed of clay, silt, or mud that is finely laminated. Shale appears in a variety of colors and may be highly variable in hardness. Shale belongs to a class of sedimentary rocks termed mudrocks. Mudrocks comprise all rocks composed of silt and clay. Besides shale, mudrocks include siltstones, mudstones, and claystones. The term shale has a specific geologic definition; however, all mudrocks are generally called shale in the field. This definition is appropriate for highway construction since all mudrocks in Indiana are either shale or should be considered soft rock.

The problem with mudrocks is that this material has an affinity for water. Because of the high clay content in mudrocks, they readily absorb water; however, these types of rocks are impermeable and do not allow the water to leave. This absorption of water results in a significant volume change in the material, causing the material to slake. Slaking is defined as the crumbling and disintegration of clay-rich materials when exposed to water. Clay-rich rocks, or argillaceous rocks, readily slake under alternate cycles of wetting and drying. Therefore, all mudrocks are properly treated in accordance with Section **203.20 (b)**.

Because of the propensity of shale or soft rock to slake, embankments constructed with these materials may experience problems as follows:

1) Settlement

2) Heaving, either from frost or alternating cycles of wetting and drying

3) Slope instability

4) Surface and subsurface erosion

Large pieces of unslaked material produce large voids when they eventually slake. The large voids cause settlement and possible eventual failure of the fill or embankment.

Heaving may also induce embankment failure. Shale and soft rock have a tendency to heave when an increase in moisture occurs or during freeze-thaw conditions. Heaving loosens the material, thereby decreasing the compaction of the lifts so the material no longer has the proper density. Again, settlement and failure of the fill may happen.

SHALE AND THINLY LAYERED LIMESTONE

Shale and thinly layered limestone may be common in some geographical areas in Indiana. When two rock types such as shale and limestone are found mixed together, they are termed interbedded.

Interbedded shale and limestone is essentially shale as defined in Section **203.20(b)** and rock as defined in Section **203.20(a)** intermixed. Therefore, the potential for slaking is present. Section **203.20 (c)** describes the construction requirements for these materials.

OTHER EMBANKMENT AND FILL MATERIALS

Embankment and fill materials may or may not be aggregates and therefore are not required to originate from a Certified Aggregate Producer (CAP). In the case of borrow, there is no testing requirement for acceptance; however, the top 2 ft below the pavement is required to meet the requirements of the Section **207.03**.

BORROW

Borrow is defined in Section **203.08**

B-BORROW

B-borrow is defined in Section **211.02**.

STRUCTURE BACKFILL

Structure backfill is defined in Section **904.05**.

ROCK BACKFILL

Rock backfill is used for contracts that have slide repairs. Recurring Special Provision **203-R-155** defines this material as follows:

"*Rock backfill shall consist of placement of quarried limestone or dolomite, Class E or higher in accordance with 904 at the locations shown on the plans. The maximum size shall be 18 in. Larger sizes will be permitted only if they can be readily loaded with a 1 cu yd shovel. The material shall not have more than 10% passing the 1 ½ in. sieve.*"

The Specification lists both a quality requirement (Class E) and a gradation requirement. These two factors require that the rock backfill be a CAP product. Generally, rock backfill is shot rock. Because this material is not processed through a plant (crushers, screens, etc.), production quality results from a quarry are not applicable to determine the ledges that may be used. The Summary of Ledge Quality Results are used to determine the ledge combinations that are acceptable. Only ledges of Class E quality or higher are used in the rock backfill because large pieces of lower quality materials may exist in the shot rock if lower quality ledges are included. These large pieces of unacceptable quality may produce the same problems associated with untreated shale and soft rock. These materials are undesirable in a slide repair since the rock backfill may settle and slide.

Finally, although revetment riprap meets the gradation requirements for rock backfill this material has a minimum quality rating of Class F. Before allowing riprap for rock backfill, the ledges from which the material originates are investigated to insure no lower quality materials are present.

AGGREGATE MATERIALS

Aggregate materials are required to originate from a Certified Aggregate Producer in accordance with Section **917**. Since these materials are certified, no testing for gradation by INDOT is required.

AGGREGATE BASE

The requirements for this material are listed in Section **301.02**.

SUBBASE

The requirements for these materials are listed in Section **302.02**.

AGGREGATE PAVEMENTS OR SHOULDERS

The requirements for these materials are listed in Section **303.02**.

SYNTHETIC MATERIALS

Synthetic materials are by-products or waste materials that have been reclaimed and/or processed to be used in highway construction. Generally their usage is very limited and restricted.

COAL COMBUSTION BY-PRODUCTS.

Coal combustion by-products are recovered from coal-fired power plants and include fly ash, bottom ash, and boiler slag. The requirements for these materials are included in Recurring Special Provision **203-R-360.**

CRUSHED GLASS

Crushed glass is recycled glass containers processed to meet specific gradation requirements and are used for bedding beneath pipes and storm sewers. The material requirements are listed in Recurring Special Provision **211-R-415.**

RECYCLED CONCRETE PAVEMENT

Recycled concrete pavement is reclaimed and processed concrete pavement from a contract by the Contractor to be used in embankments on the contract. The material requirements are listed in Recurring Special Provision **202-R-430.**

RECYCLED FOUNDRY SAND

Recycled foundry sand is a mixture of residual materials from metal castings and natural sand. The requirements for these materials are listed in Recurring Special Provision **200-R-401**.