Alaska
Department of
Transportation
and
Public Facilities

# Alaska Field Guide for Soil Classification

*Effective October 1, 2003*

# Table of Contents

# Preface

This *Field Guide for Soil Classification* is one of a series of guidelines that comprise the Alaska Department of Transportation and Public Facilities' (DOT&PF) *Geotechnical Procedures Manual*. This publication is intended to guide Department staff and consultants whose task is to obtain geotechnical data for use on Department projects.

Accurate classification and a detailed, complete field description of earth materials are essential to support design and construction of state facilities. The description and classification includes more than naming the soil – it includes consideration and reporting of the physical characteristics and engineering properties of the material, and ancillary information such as drilling action or presence of contaminants. The depth of detail of this process depends, in part, on the level of complexity of the project and the nature of the facility. However, the field geologist should always describe the soil as completely as possible.

Consistent adherence to standard terminology and procedures is important so that the geologists, engineers, designers, construction staff, and contractors throughout the design and construction process all have the same understanding of the earth materials used or affected by our projects. Note that interpretive information about materials should be reported separately from the factual classification and descriptive information. The factual data are reported on logs of test holes/test pits, in summary sheets, and in tables or other summary formats in the text of a geotechnical report. Interpretive commentary about the factual data should be clearly identified as such.

This guide contains numerous references to manuals and test methods. The guide refers to both "authoritative" and "advisory" references. Authoritative references may include American Society for Testing and Materials (ASTM) or American Association of State Highway Transportation Officials (AASHTO) standards or test methods or the Department's publications. Advisory references may include text books, FHWA guidance manuals and guides or manuals from other state DOTs. The reference list below is divided into authoritative and advisory references.

In some cases, we have excerpted, summarized, or copied text, charts, and tables into this guide. Unless otherwise noted, the original reference defines the appropriate action. The excerpts, summaries, and modified charts and graphs are presented for illustrative purposes.

### Authoritative References


- AASHTO (1988), *Manual on Subsurface Investigation*
- AASHTO (1978), *Manual on Foundation Investigations*
- Alaska Department of Transportation and Public Facilities (1993), *Engineering Geology & Geotechnical Exploration Procedures Manual*
- ASTM Standard Practice D 2487-00 (2000)*, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*


### Advisory References


- California Department of Transportation (1996), *Soil & Rock Logging Classification Manual (Field Guide)*
- Federal Highway Administration (2002), *Evaluation of Soil and Rock Properties*, Geotechnical Engineering Circular No. 5, FHWA-IF-02-034
- Hunt, Roy E. (1984) *Geotechnical Engineering Investigation Manual*
- Oregon Department of Transportation (1987), *Soil and Rock Classification Manual*

# 1. Field Classification and Description of Soil Laboratory Classification



## 1.1. Introduction

The Unified Soil Classification System (USCS; ASTM D2487 and D2488) is used to name and describe soils. The ASTM classification method "Classification of Soils for Engineering Purposes (Unified Soil Classification System)" (ASTM Method D2487) is a laboratory test-based classification system. Use the Standard D2487 procedure to confirm field soil classifications and clarify borderline or difficult-to-determine classifications. After the field work is completed, the geologist prepares a sample testing protocol tailored to the project for testing selected samples. The laboratory determines the soil classifications under ASTM D2487. The geologist summarizes the sample test results and classifications and integrates the results of the laboratory testing, the soil descriptions in the field logs, drilling notes, geologic mapping observations, and other pertinent information to arrive at a final soil group name, soil group symbol, and any additional description.

## 1.2. Field Classification

Field classification of soil follows the ASTM "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)" (ASTM Method D2488). The field procedure for classification is based on the size and distribution of soil particles and the properties of the fine-grained portion of the soil. ASTM D 2488 is used principally in the field, or where there is an absence of laboratory data. This procedure uses visual observations of the soil with simple manual tests to estimate the size and distribution of the coarse-grained fraction of the soil and to indicate the plasticity of the fine-grained fraction of the soil. The resulting soil group names (such as "sandy silt with gravel" or "poorly graded gravel with silt") and group symbols (such as "ML," "GP-GM") are entered into the field logs.

The best way to learn how to describe and classify soil is to carefully study the description and classification procedures, and then spend time in the field learning from a more experienced geologist. The inexperienced field geologist should repeatedly and systematically compare field classifications of various soil types to laboratory results until becoming familiar with the visual and manual characteristics that denote the common soil types, and achieve an acceptable level of competence.

The field description and classification of soil is based on the size and distribution of coarse-grained particles and on the behavior of fine-grained particles. Definitions of the various soil constituents follow in Table 1-1.

**Table 1-1**
**Definition of Soil Constituents**

| | |
|---|---|
| Boulders | Particles of rock that are retained on a 12-inch square opening. |
| Cobbles | Particles of rock that pass a 12-inch square opening, but are retained on a 3-inch square opening. |
| Gravel | Particles of rock that pass a 3-inch square opening and are retained on a No. 4 sieve. USCS Class GP or GW. |
| Sand | Particles of rock that pass a No. 4 sieve and are retained on a No. 200 sieve. USCS Class SM or SP. |
| Silt | Soil passing a No. 200 sieve that exhibits little or no plasticity and has little or no strength when air dry. USCS Class ML or MH. |
| Clay | Soil passing a No. 200 sieve that exhibits plasticity within a range of water contents and that has considerable strength when air dry. USCS Class CL or CH. |
| Organic Soil | A soil containing sufficient organic material to influence the soil properties. ASTM Class OL or OH. |
| Peat | A soil composed primarily of vegetable matter in various stages of decomposition that usually has a pronounced organic odor, a dark brown or black color, a spongy consistency, and a texture ranging from fibrous to amorphous. ASTM Class PT. |

# 2. Field Procedures



## 2.1. Introduction

Use the field procedures below to describe the soil characteristics in Table 2-1. A geologist who is experienced with identification and familiar with the visual-manual process and laboratory testing procedures can often make accurate field classifications with a minimum of field tests, based on experience. It is not necessary for an experienced field geologist to use each visual-manual test with each soil description. Generalized experience with soil types in the vicinity and specific project experience as the field program progresses may allow rapid identification of similar soil types without thorough field-testing.

Soils that appear similar may be grouped together by testing one sample and applying the results to several similar samples. The visual-manual procedure allows description of a large number of soil samples without running expensive laboratory tests on each. However, it is important for the field geologist to take abundant samples, even if the samples are not tested. The field geologist reexamines the samples after the laboratory test data are available, and other geologists, the geotechnical engineer, or the foundation engineer may also examine them.

Confirmation of the field classifications may require only a few laboratory tests where the soil horizons are relatively uniform and simple. In more difficult situations with numerous soil types and complex soil conditions, much more laboratory testing may be required. Less experienced geologists should request ample laboratory tests until they become experienced enough to make accurate field classifications.

**Table 2-1**
**Descriptive Soil Characteristics**

| Characteristic | Test Method or Reference |
|---|---|
| Soil name/group name | ASTM D2488 |
| Group symbol | ASTM D2488 |
| Coarse-grained soils: Particle Size/shape/angularity/gradation | ASTM D2488<br>DOT&PF cobble/boulder procedure (See page 15) |
| Fine-grained soils: consistency, dry strength, dilatancy, toughness, plasticity | ASTM D2488 - Tables 5, 9, 10, 11 & 12. |
| Organic soil/peat name | FHWA Geotechnical Engineering Circular No. 5, Section 7.4, ASTM D2974 |
| Color | Use simple color scheme. Use of color charts such as Munsell Color System is optional. |
| Odor | If organic or other condition is noticeable or unusual |
| Moisture condition | Table 3: ASTM D2488 |
| Reaction to hydrochloric acid | If calcium carbonate soil suspected (Table 4 - ASTM D2488) |
| Cementation | Table 6: ASTM D2488 |
| Structure of intact soil specimen | Table 7: ASTM D2488 |
| Density/consistency | Based on Standard Penetration Test blow counts |
| Description of frozen soil | ASTM D4083, Department Chart: Description and Classification of Frozen Soils |
| Other characteristics or information | Unit weight, sensitivity, hardness of particles, presence of contaminants, formation names, staining, etc. |
| Drilling characteristics | Heaving, sloughing or caving, bouncing, grinding, drilling speed, etc. |

## 2.2. Applying Group Names/Group Symbols

The first step in describing soil under the visual-manual method is to determine whether the soil is fine-grained, coarse-grained, or organic by visually estimating the percentage of gravel, sand, fines, and organic matter. Soils with more than 50 percent gravel or sand are coarse-grained. Soils with more than 50 percent fines are fine-grained. Soil with a notable presence of organic matter should be identified and described under separate procedures set out below. Laboratory tests for soils containing organic material may yield misleading results, particularly if the organic fraction is not recognized in the initial description.

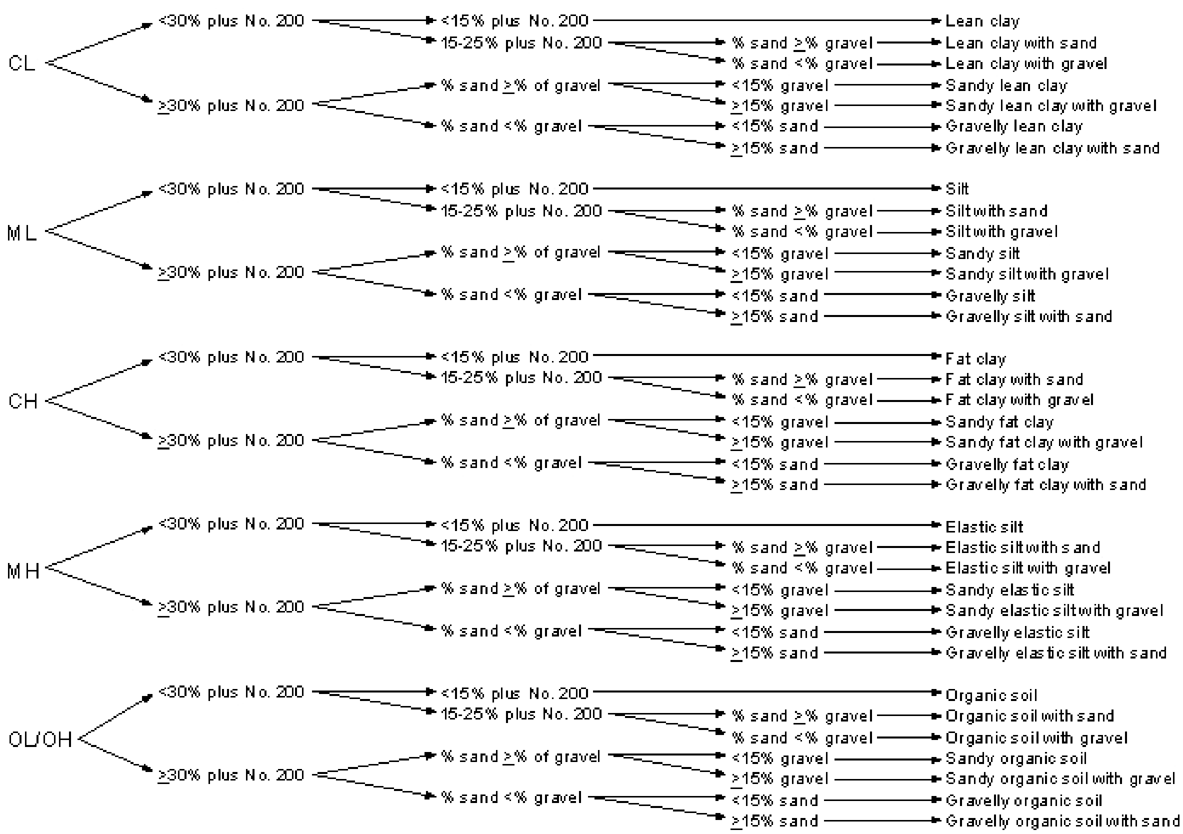
# 3. Field Description of Fine-Grained Soils



## 3.1. Introduction

For fine-grained soils, perform the visual manual field procedures described in ASTM D2488 for consistency, dry strength, dilatancy, toughness, and plasticity, and assess the presence or absence of organics, as outlined below. Use Figure 3-1 (ASTM D2488 - Figure 1a and 1b) to assist in assigning group names and symbols for fine-grained soils.

**Figure 3-1**
**Flow Chart for Identifying Fine-Grained Soil**
**(after ASTM D2488: Figure 1a and 1b)**



## 3.2. Consistency

Use this test for intact samples of fine-grained, cohesive soil. For soil with significant amounts of gravel, this test is inappropriate. Consistency is an indicator of shear strength. Field tests using a Torvane or Pocket Penetrometer may also be done to aid in this description. When run on SPT samples, these tests produce approximations of strength criteria. Where shear strength is important, the field geologist should collect undisturbed samples using thin wall tube sampling methods. The geotechnical engineer can then schedule a testing program.

**Table 3-1**
**Criteria for Describing Consistency**
**(ASTM D 2488 Table 5)**

| Description | Criteria |
|---|---|
| Very soft | Thumb will penetrate soil more than 1 inch. |
| Soft | Thumb will penetrate soil about 1 inch. |
| Firm | Thumb will indent soil about ¼ inch. |
| Hard | Thumb will not indent soil. Thumbnail readily indents soil. |
| Very hard | Thumbnail will not indent soil. |

## 3.3. Dry Strength

Dry strength of fine-grained soil can be related to soil type. It may be necessary to dry a sample of the soil on a heat source, such as an engine exhaust manifold.

**Table 3-2**
**Criteria for Describing Dry Strength**
**((ASTM D 2488 Table 8)**

| Description | Criteria |
|---|---|
| None | The dry specimen crumbles into powder with mere pressure of handling. |
| Low | The dry specimen crumbles into powder with some finger pressure. |
| Medium | The dry specimen breaks into pieces or crumbles with considerable finger pressure. |
| High | The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface. |
| Very high | The dry specimen cannot be broken between the thumb and a hard surface. |

## 3.4. Dilatancy

Dilatancy is a soil's reaction to shaking and indicates the characteristics of the movement of water in the soil voids. Form a small moist sample in the palm of the hand and strike the hand sharply against the other hand several times. Note the reaction of water appearing on the surface. Then, squeeze the sample and observe the characteristics of the water disappearing from the surface of the sample.

**Table 3-3**
**Criteria for Describing Dilatancy**
**(ASTM D 2488 Table 9)**

| Description | Criteria |
|---|---|
| None | There is no visible change in the specimen. |
| Slow | Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing. |
| Rapid | Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing. |

## 3.5. Toughness

Toughness is a measure of the soil's plasticity in its plastic state. After completing the dilatancy test, shape the specimen into an elongated pat or lump and roll out to a thread of about 1/8" diameter. Remold the soil and roll it out to 1/8" repeatedly until the thread crumbles at about 1/8" in diameter. At this point, note the pressure required to roll out the thread, the strength of the thread, and the toughness of the soil as it is kneaded together to form a pat or lump.

**Table 3-4**
**Criteria for Describing Toughness**
**(ASTM D 2488 Table 10)**

| Description | Criteria |
|---|---|
| Low | Only slight pressure is required to roll the thread near the plastic limit (the moisture content at which a rolled-out thread crumbles at 1/8" diameter). The thread and lump are weak and soft. |
| Medium | Medium pressure is required to roll the thread to knead the plastic limit. The thread and lump have medium stiffness. |
| High | Considerable pressure is required to roll the thread to knead the plastic limit. The thread and the lump have very high stiffness. |

Table 3-5 provides a summary of soil types versus characteristics to assist the geologist in describing and identifying fine-grained soil types.

## 3.6. Plasticity

The plasticity of a soil is an important indicator of characteristics of cohesive soils.

**Table 3-5**
**Criteria for Describing Plasticity**
**(ASTM D 2488 Table 11)**

| Description | Criteria |
|---|---|
| Nonplastic | A 1/8" thread cannot be rolled at any water content. |
| Low | The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit (the moisture content at which a rolled-out thread crumbles at 1/8" diameter). |
| Medium | The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit. |
| High | It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit. |

## 3.7. Fine-Grained Soil Name

Once you have assessed the characteristics described above, use Table 3-6 below and Chart 3-1 above to determine the soil name. Add descriptors for consistency (Table 3-1 above), color, moisture content, etc., to the root soil name.

**Table 3-6**
**Identification of Inorganic Fine-Grained Soils From Manual Tests**
**(ASTM D 2488: Table 12)**

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

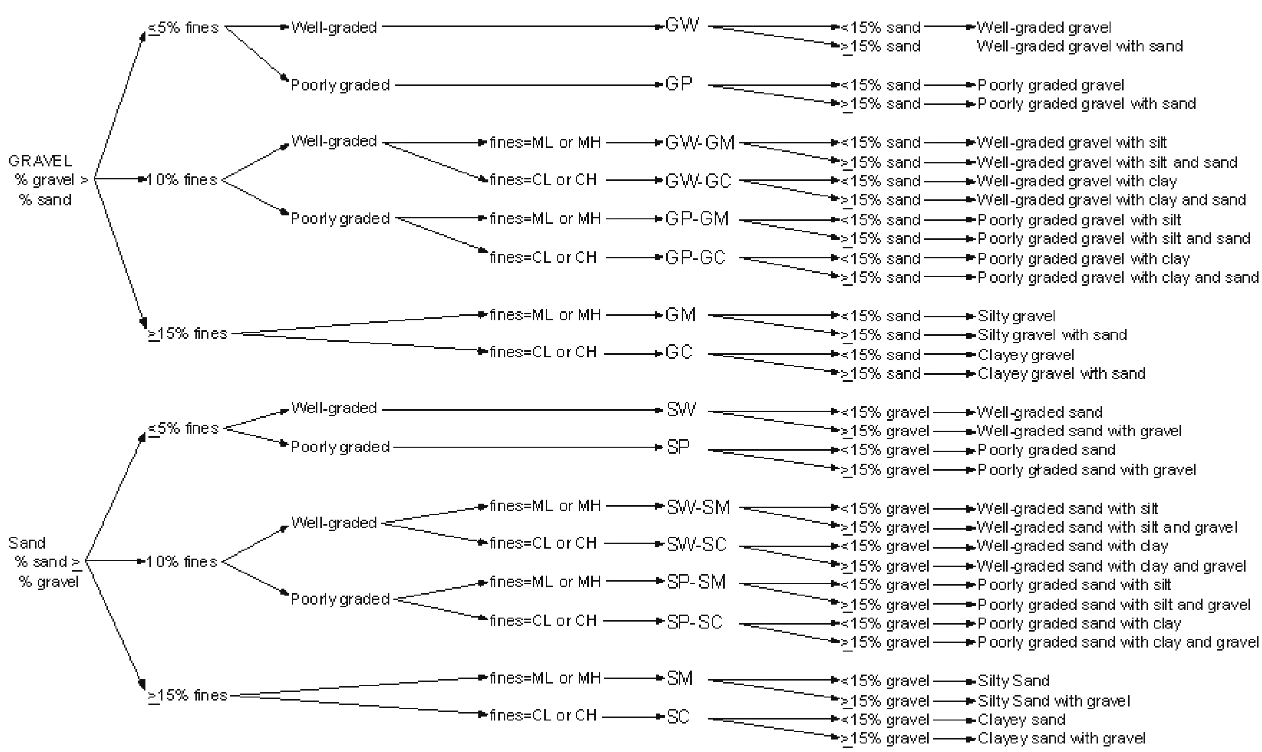
# 4. Field Description of Coarse-Grained Soils



## 4.1. Introduction

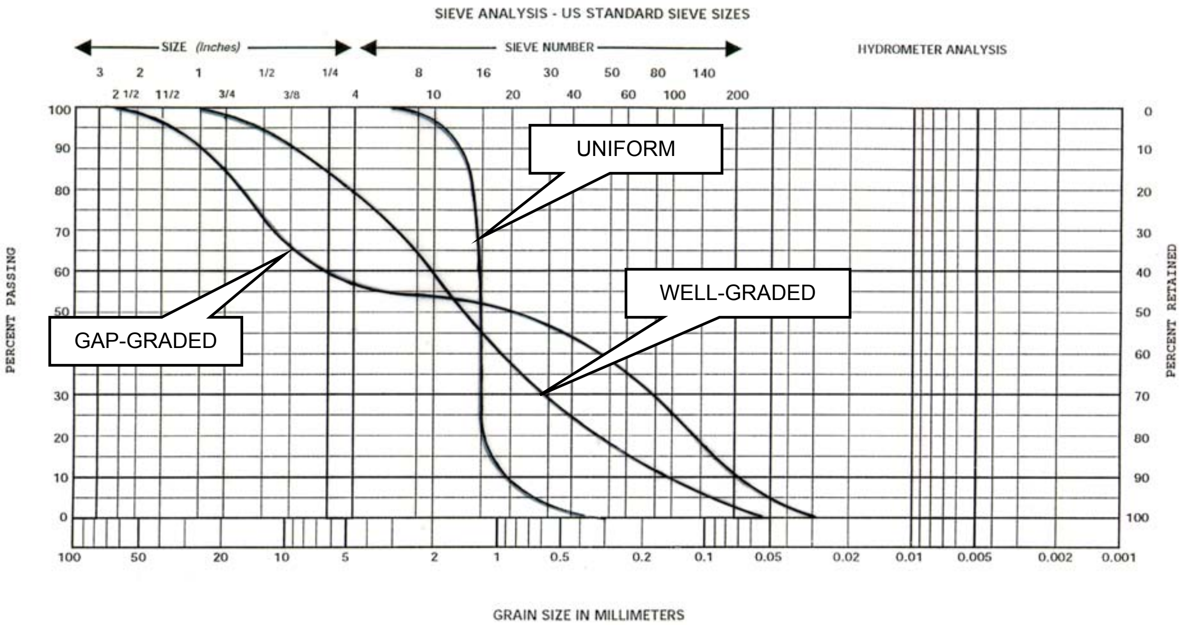
Field identification of soil that contains less than 50 percent fines (silt and clay) is made on the basis of the estimated percentage of soil constituents. If there is more sand than gravel, the soil is classified as sand. The percentage and characteristics of fines contained in coarse-grained soil also plays a role in the soil name. If there is more than 15 percent passing the No. 200 screen (P200), the soil is sand or gravel "with fines." Assess the characteristics of the fines to determine whether the soil should include a modifier "clayey" or "silty." Dual identifications are also included depending on the particular soil characteristics. Use Chart 4-1 below to determine the soil group name and group symbol.

**Chart 4-1**
**Identifying Coarse-Grained Soil**
**(after ASTM D2488: Figure 2)**




If the soil has less than 5 percent fines, the soil is called "clean" sand or gravel. The field geologist makes a field evaluation of grading characteristics, then later confirms the grading assessments based on laboratory test results. If the soil contains a wide range of particle sizes, it is called "well-graded." Soil that has a narrow range of grain sizes is "poorly-graded." Soil consisting predominantly of one size particle is "uniformly-graded." Soil missing some intermediates particle sizes is "gap-graded." The soil laboratory determines grading characteristics by computing coefficients of uniformity and curvature to determine under ASTM Method D 2487. See Figure 4-1 below. The laboratory results are used to confirm the field geologist's assessment of grading.

**Figure 4-1**
**(after ODOT Soil and Rock Classification Manual)**




## 4.2. Particle Characteristics of Coarse Fraction

The coarse fraction of the soil (greater than No. 200 sieve size) is described by observing the size, shape, and distribution of the particles. Table 4-1 (ASTM D 2488 Table 1) provides criteria for describing the angularity of particles. Figure 4-2 (Angularity) gives a visual means of identifying the various categories. Table 4-2 (ASTM D 2488 Table 2) and Figure 4-3 (Flat and Elongated Criteria), provide particle shape descriptions and criteria. A Department method for determining the percentage of cobbles and boulders is also described. Finally, the geologist must make observations of the grading characteristics of the soil to determine whether it is well graded or poorly graded.

**Table 4-1**
**Criteria for Describing Angularity of Coarse-Grained Particles**
**(ASTM D2488: Table 1)**

| Description | Criteria |
|---|---|
| Angular | Particles have sharp edges and relatively plane sides with unpolished surfaces. |
| Subangular | Particles are similar to angular description but have rounded edges and unpolished surfaces. |
| Subrounded | Particles have nearly plane sides but have well-rounded corners and edges. |
| Rounded | Particles have smooth curved sides and edges. |

The photo in Figure 4-2 shows a variety of gravel size particles, demonstrating the sometimes subtle distinctions between angularity classifications.

**Figure 4-2**
**Angularity**
**(See ASTM D2488: Figure 3)**


**Table 4-2**
**Criteria for Describing Particle Shape**
**(ASTM D2488: Table 2)**

| Description | Criteria |
|---|---|
| Describe the particle shape as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively. | |
| Flat | Particles with width/thickness > 3 |
| Elongated | Particles with length/width > 3 |
| Flat and Elongated | Particles meet criteria for both flat and elongated |

**Figure 4-3**
**Flat and Elongated Criteria**
**(ASTM D2488: Figure 4)**

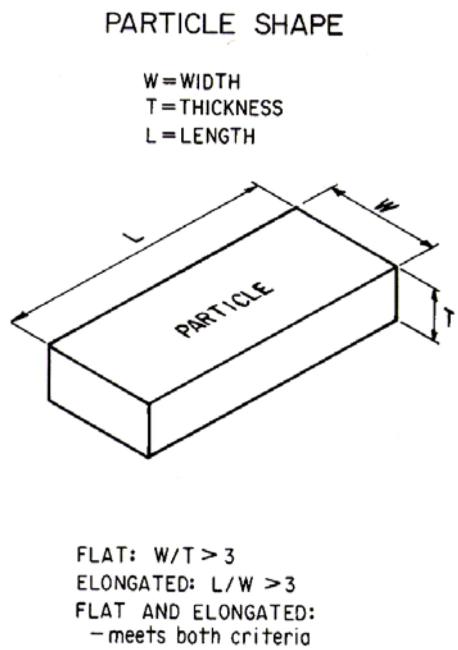



FIG. 4 Criteria for Particle Shape

## 4.3. Cobbles and Boulders

Cobbles and boulders are often present in soils in glacial terrain, and much of our highway system has been subject to glacial activity in the past. The presence of cobbles and boulders is often a source of claims in earthwork projects, so it is incumbent on geotechnical staff to carefully characterize the cobble and boulder content of soil layers. At a minimum, test hole logs must indicate where cobbles and boulders are suspected. In drilled test holes, it is not possible to accurately determine the percentage of cobbles and boulders, but the logs must indicate where drilling action suggests the presence of large rock. In test pits and other surface excavations, the percentage of cobbles and boulders by volume can be visually estimated and so indicated on the logs. Where warranted (as in materials site investigations, for example), the geologist should conduct a field test to more accurately determine the percentage of cobbles and boulders. The procedure is described below.

## 4.4. DOT&PF Cobble and Boulder Percentage Determination Procedure

Determine the percentage of cobbles and boulders in the field by collecting a large volume sample with a backhoe or other equipment and weighing the sample using a large capacity container (a cut-off 55-gallon drum is well suited) fitted with cable or chains for lifting, and a 500-pound capacity spring scale with suitable hooks. The field procedure is as follows:

- Record the tare weight of the container.
- Collect the sample using the backhoe bucket.
- Place the sample in the weighing container, connect the backhoe bucket to the scale, and lift the container with the backhoe bucket. Record the total weight of the sample.

- Empty the sample onto a tarp or other suitable surface. Separate the cobbles and boulders from the sample using a 3-inch square opening screen and tape measure.
- Count the number of boulders.
- Weigh the cobbles and boulders.
- Record the size of the largest cobble and boulder.
- Make note of any other pertinent information such as shape and composition of the cobbles and boulders, clay coatings, and other characteristics.
- Compute and record the cobble and boulder proportion as a weight percentage of the total. It might also be useful to submit the coarse particles for durability analyses and a sample representing the minus-3-inch aggregate for gradation analysis.

# 5. Supplementary Soil Descriptive Terms



## 5.1. Color

While soil color is not an engineering property, it may be indicative of other useful characteristics and properties. For example, iron staining or mottling may indicate repeated wet and dry cycles and the presence of groundwater. Yellow or red indicate iron oxides and significant weathering processes. Dark colors may indicate the presence of organic material. Color may also be useful in making correlations of strata between test holes. When applying color names, use simple colors and modifiers, such as brown, tan, light orange, and medium gray. Avoid using exotic, unusual, or invented color names or modifiers such as “coral,” “turquoise,” or “beige-ish.” Soil and rock color charts such as the Munsell Color System may be used.

## 5.2. Odor

If the presence of organic material or some other condition, such as chemical contaminants, results in a noticeable odor of organic matter, petroleum products, organic solvents, sewage, or other odors, record a description of the perceived odor.

## 5.3. Moisture

Describe the moisture content in the field using Table 5-1 below as a guide. Return samples to the soil laboratory for testing to confirm estimates. Moisture contents in soils containing organic material can be deceptive and require special care. If no organic content is noted in the field, but the laboratory moisture content is high, consider testing for organic content. Even a small percentage of organic material can affect the soil properties. Permeable (granular) soils from below the water table are not normally tested for moisture content. Moisture samples may be obtained from low permeability (fine-grained) soil from below the water table from undisturbed samples (thin-wall tube samples).

**Table 5-1**
**Criteria for Describing Moisture Condition**
**(ASTM D 2488: Table 3)**

| Description | Criteria |
|---|---|
| Dry | Absence of moisture, dusty, dry to the touch |
| Moist | Damp, but no visible water |
| Wet | Visible free water, usually soil is below the water table |

## 5.4. Reaction to Hydrochloric Acid (HCl)

This test is rarely used for soil, but is applicable if calcium carbonate or cemented soil is suspected. (See Table 4, ASTM D 2488.)

## 5.5. Cementation

Cementation is the bonding of grains by secondary minerals or degradation products. Cementation may be suspected if exposures of the soil stand at steeper angles than expected, if the soil is iron-stained, or if the soil appears to hold together more than expected for the soil type. Cementation by calcium carbonate may be detected by the soil's reaction to HCl. (See Table 4, ASTM D 2488). Cementation may play an important role in determining susceptibility to liquefaction under seismic loading.

**Table 5-2**
**Criteria for Describing Cementation at Field Moisture**
**(ASTM D 2488: Table 6)**

| Description | Criteria |
|---|---|
| Weak | Crumbles or breaks with handling or little finger pressure |
| Moderate | Crumbles or breaks with considerable finger pressure |
| Strong | Will not crumble or break with finger pressure |

## 5.6. Soil Structure

The field geologist should make every effort to fully describe the structure of the soil deposit, including its mode of occurrence (alluvial, glacial deposits, rock weathered in place). Describe the soil's structural features in terms of stratification, relict rock structure, lenses, voids, inclination of the layers, presence of varves, and other features. Structure may indicate differing strength for soil that has the same gradation. For example, water-deposited alluvial silt may have a significantly weaker structure than wind-deposited silt (loess) with a similar gradation. The design of a back slope for a cut in these two materials may be significantly different. Similarly, layering of sand deposits at a bridge site may have a significant impact on the liquefaction characteristics and the design of the bridge foundation.

**Table 5-3**
**Criteria for Describing Soil Structure**
**(ASTM D 2488: Table 7)**

| Description | Criteria |
|---|---|
| Varved | Thin repeating layers or laminae grading upward from coarse to fine within each layer. Normally includes a coarser summer layer and a finer winter layer deposited from still water. |
| Stratified | Alternating layers of varying material or color with layers at least ¼" thick |
| Laminated | Alternating layers of varying material or color with the layers less than ¼" thick |
| Fissured | Breaks along definite planes of fracture with little resistance to fracturing |
| Slickensided | Fracture planes appear polished or glossy, sometimes striated |
| Blocky | Cohesive soil that can be broken down into small angular lumps that resist further breakdown |
| Lensed | Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay |
| Homogeneous | Same color and appearance throughout |

## 5.7. Density/Consistency

Density and consistency descriptors are primarily based on sampler blow counts from the Standard Penetration Test (AASHTO T-206, ASTM D1586). Consistency of fine-grained soils may also be based on visual manual tests described in ASTM D2488. Record blow counts, and hammer and sampler details on the test hole logs along with notations about unusual conditions or events during sampling. Record blow counts for frozen and unfrozen soil. Do not use blow counts in frozen soil to determine density descriptors. Similarly, do not use blow counts to determine density descriptors where the sampling interval crosses a soil horizon.

Add additional detail by using the Pocket Penetrometer or the Torvane to arrive at rough strengths.

**Table 5-4**
**Density Based on Blow Count for Non-Cohesive Soils**
**(Adapted from several sources)**

| Number of blows per foot | Density |
|---|---|
| 0-4 | Very loose |
| 5-10 | Loose |
| 11-30 | Medium dense |
| 31-50 | Dense |
| >50 | Very dense |

**Table 5-5**
**Consistency Based on Blow Count for Cohesive Soils**
**(Adapted from several sources)**

| Number of blows per foot | Consistency |
|---|---|
| <2 | Very soft |
| 2-4 | Soft |
| 5-8 | Firm |
| 9-15 | Stiff |
| 16-30 | Very stiff |
| >30 | Hard |

# 6. Special Soil Conditions



## 6.1. Organic Soil

Peat soils are relatively easy to identify. However, soils that are predominately mineral matter but contain organic matter are more difficult to recognize. Where field relationships indicate the possibility of organics in the soil, the geologist should pay close attention to color and odor of the soil. Test dark-colored soils and soil with fine woody particles for organic content (ASTM D 2974) and for moisture content. Some gravel deposits contain small amounts of organic material (<2-3%), which render the gravel difficult or impossible to handle in the presence of water. For suspect fine-grained soils, specify both wet and dry preparation methods for testing for Atterberg Limits and maximum density/optimum moisture. Soils containing organic material may be classified as shown below.

**Table 6-1**
**Classification of Organic Soils**
**(After FHWA Geotechnical Engineering Circular No. 5, April 2002)**

| Material | Percent Organics (by weight) | Moisture Content | Specific Gravity | Fiber Content (by volume) |
|---|---|---|---|---|
| Peat (Pt) | >80% | >500% | <1.7 | >50% |
| Peaty Organic Soil (PtO) | 60-80% | 150 – 800% | 1.6 – 1.9 | <50% |
| Organic Soil (O) | 5-60% | 100 – 500% | >1.7 | Insignificant |
| Organic Silt (MO) Organic Clay (CO) | 1-5% | <100% | >2.4 | None |

Strength and consolidation testing may be critical for the design of roadways and embankments in peat and organic soil. Where organic soils are expected, the geotechnical engineer will provide an exploration plan for sampling and testing the organic materials. The sampling and testing may include in situ field testing with vane shear apparatus (ASTM D 2573), sampling with thin-walled tube sampler for consolidation and strength, and other testing in the laboratory. Geologists should be prepared to run field strength tests and take undisturbed samples when unexpectedly encountering thick (greater than 4') organic soil deposits. When organic soils are encountered, increase the frequency of test holes and sampling after consultation with the geotechnical engineer to provide ample data for analysis and design.

## 6.2. Frozen Soil

The principal reference for describing frozen soil is the ASTM D 4083-89 "Standard Practice for Description of Frozen Soils (Visual Manual Procedure)." This procedure, when used in conjunction with the Department's Figure 6-1: "Description and Classification of Frozen Soils," provides the geologist guidance in how to identify and describe frozen soils when encountered in the field. The chart is a modified and combined version of three charts that appear in the ASTM procedure. Use of the combined chart or the ASTM procedure is approved for use on Department projects.

# Figure 6-1
# Description and Classification of Frozen Soils
# (After ASTM D4083)

## DESCRIPTION AND CLASSIFICATION OF FROZEN SOILS

| Part I<br>Description of Soil Phase (a)<br>(Independent of Frozen State) | Major Group | | Sub-Group | | Field Identification (6) | Pertinent Properties of Frozen Materials which may be measured by physical tests to supplement field identification. (7) | Guide for Construction on Soils Subject to Freezing and Thawing | |
|---|---|---|---|---|---|---|---|---|
| | Description (2) | Designation (3) | Description (4) | Designation (5) | | | Thaw Characteristics (8) | Criteria (9) |
| Part II<br><br>Description of Frozen Soil | Segregated ice is not visible by eye **(b)** | **N** | Poorly Bonded or Friable | **Nf** | Identify by visual examination. To determine presence of excess ice, use procedure under note **(c)** below and hand magnifying lens as necessary. For soils not fully saturated, estimate degree of ice saturation: Medium, Low. Note presence of crystals, or of ice coatings around larger particles. | In-Place Temperature<br>Density and Void Ratio<br>a) In Frozen State<br>b) After Thawing in Place<br>Water Content (Total $H_20$, including ice) a) Average<br>b) Distribution<br><br>Strength<br>a) Compressive<br>b) Tensile<br>c) Shear<br>d) Adfreeze<br><br>Elastic Properties<br>Plastic Properties<br>Thermal Properties<br><br>Ice Crystal Structure (using optional instruments.)<br>a) Orientation of Axes<br>b) Crystal size<br>c) Crystal shape<br>d) Pattern of Arrangement | Usually Thaw-Stable | The potential intensity of ice segregation in a soil is dependent to a large degree on its void sizes and may be expressed as an empirical function of grain size as follows:<br><br>Most inorganic soils containing 3 percent or more of grains finer than 0.02 mm in diameter by weight are frost-susceptible. Gravels, well-graded sands and silty sands, especially those approaching the theoretical maximum density curve, which contain 1.5 to 3 percent finer than 0.02 mm by weight without being frost-susceptible. However, their tendency to occur interbedded with other soils usually makes it impractical to consider them separately.<br>Soils classed as frost-susceptible under the above criteria are likely to develop significant ice segregation and frost heave if frozen at normal rates with free water readily available. Soils so frozen will fall into the thaw-unstable category. However, they may also be classed as thaw-stable if frozen with insufficient water to permit ice segregation.<br><br>Soils classed as non-frost-susceptible (*NFS) under the above criteria usually occur without significant ice segregation and are not exact and may be inadequate for some structure applications: exceptions may also result from minor soil variations. |
| | | | No excess ice<br><br>Well Bonded<br><br>Excess ice | **Nb** — **n**<br>**Nb** — **e** | | | | |
| | Segregated ice is visible by eye. (Ice 1 inch or less in thickness) **(b)** | **V** | Individual ice crystals or inclusions | **Vx** | For ice phase, record the following as applicable:<br>Location — Size<br>Orientation — Shape Thickness<br>Spacing — Pattern of arrangement<br>Length<br>Hardness }<br>Structure } per part III Below<br>Color }<br>Estimate volume of visible segregated ice present as percent of total sample volume | | Usually Thaw-Unstable | |
| | | | Ice coatings on particles | **Vc** | | | | |
| | | | Random or irregularly oriented ice formations | **Vr** | | | | |
| | | | Stratified or distinctly oriented ice formations | **Vs** | | | | |
| Part III<br><br>Description of Substantial Ice Strata | Ice<br>(Greater than 1 inch in thickness) | **Ice** | Ice with soil inclusions | **Ice + Soil Type** | Designate material as ICE **(d)** and use descriptive terms as follows, usually one item from each group, as applicable: | Same as Part II above, as applicable, with special emphasis on Ice Crystal Structure. | | In permafrost areas, ice wedges, pockets, veins, or other ice bodies may be found whose mode of origin is different from that described above. Such ice may be the result of long-time surface expansion and contraction phenomena or may be glacial or other ice which has been buried under a protective earth cover. |
| | | | Ice without soil inclusions | **Ice** | Hardness: Hard, Soft (mass, not indi- crystals)<br>Structure: Clear, Cloudy, Porous, Candled, Granular, Stratified<br>Color: e.g.: Colorless, Gray, Blue<br>Admixtures: e.g.: Contains Thin Silt Inclusions | | | |

DEFINITIONS:

Ice Coatings on Particles are discernible layers of ice found on or below the larger soil particles in a frozen soil mass. They are sometimes associated with hoarfrost crystals, which have grown into voids produced by the freezing action.

Ice Crystal is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in a combination with other ice formations.

Clear ice is transparent and contains only a moderate number of air bubbles. **(e)**

Cloudy Ice is translucent, but essentially sound and non-pervious

Porous Ice contains numerous voids, usually interconnected and usually resulting from melting at air bubbles or along crystal interfaces from presence of salt or other materials in the water, or from the freezing of saturated snow. Though porous, the mass retains its structural unity.

Candled ice is ice which has rotted or otherwise formed into long columnar crystals, very loosely bonded together.

Granular Ice is composed of coarse, more or less equidimensional, ice crystals weakly bonded together.

Ice Lenses are lenticular ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss and commonly in repeated layers.

Ice Segregation is the growth of ice as distinct lenses, layers, veins and masses in soils, commonly but not always oriented normal to direction of heat loss.

Well-bonded signifies that the soil particles are strongly held together by the ice and that the frozen soil possesses relatively high resistance to chipping or breaking.

Poorly-bonded signifies that the soil particles are weakly held together by the ice and that the frozen soil consequently has poor resistance to chipping or breaking.

Friable denotes a condition in which material is easily broken up under light to moderate pressure.

Thaw-Stable frozen soils do not, on thawing, show loss of strength below normal, long-time thawed values nor produce detrimental settlement.

Thaw-Unstable frozen soils show on thawing, significant loss of strength below normal, long-time thawed values and/or significant settlement, as a direct result of the melting of the excess ice in the soil.

Modified from: Linell, K. A. and Kaplar, C. W., 1966, *Description and Classification of Frozen Soils,* Proc. International Conference on Permafrost (1963), Lafayette, IN, U.S. National Academy of Sciences, Publ. 1287, pp 481-487.

**NOTES:**

**(a)** When rock is encountered, standard rock classification terminology should be used.

**(b)** Frozen soils in the N group may on close examination indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. However, the impression to the unaided eye is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of frozen soils in the V group.

**(c)** When visual methods may be inadequate, a simple field test to aid evaluation of volume of excess ice can be made by placing some frozen soil in a small jar, allowing it to melt and observing the quantity of supernatant water as a percent of total volume.

**(d)** Where special forms of ice, such as hoarfrost, can be distinguished, more explicit description should be given.

**(e)** Observer should be careful to avoid being misled by surface scratches or frost coating on the ice.