RETURN TO TOC

Chapter 2

Soils

The soil in an area is an important consideration in selecting the exact location of a structure. Military engineers, construction supervisors, and members of engineer reconnaissance parties must be capable of properly identifying soils in the field to determine their engineering characteristics. Because a military engineer must be economical with time, equipment, material, and money, site selection for a project must be made with these factors in mind.

SECTION I. FORMATION, CLASSIFICATION, AND FIELD IDENTIFICATION

The word soil has numerous meanings and connotations to different groups of professionals who deal with this material. To most soil engineers (and for the purpose of this text), soil is the entire unconsolidated earthen material that overlies and excludes bedrock. It is composed of loosely-bound mineral grains of various sizes and shapes. Due to its nature of being loosely bound, it contains many voids of varying sizes. These voids may contain air, water, organic matter, or different combinations of these materials. Therefore, an engineer must be concerned not only with the sizes of the particles but also with the voids between them and particularly what these voids enclose (water, air, or organic materials).

SOIL FORMATION

Soil formation is a continuous process and is still in action today. The great number of original rocks, the variety of soil-forming forces, and the length of time that these forces have acted all produce many different soils. For engineering purposes, soils are evaluated by the following basic physical properties:

- Gradation of sizes of the different particles.
- Bearing capacity as reflected by soil density.
- Particle shapes.

An engineer extends soil evaluation by considering the effect of water action on the soils. With a complete evaluation, an engineer can determine whether or not the soil is adequate for the project.

ROCKS

Soil forms when rocks that are exposed to the atmosphere disintegrate and decompose, either by mechanical action (wind, water, ice, and vegetation), chemical action, or both. The resulting material may remain where it is formed or it may be transported by water, glaciers, wind, or gravity and deposited at a distance from the parent rock.

Geologists classify rocks into three basic groups:

- Igneous (formed by cooling from a molten state).
- Sedimentary (formed by the accumulation and cementation of existing particles and remains of plants and animals).
- Metamorphic (formed from existing rocks subjected to heat and pressure).

STRATA

At a particular location are usually several layers (strata), one above the other, each composed of a different kind of soil. Strata may be a fraction of an inch or many feet thick. The upper layer is called the topsoil or agricultural soil since it supports plant growth. For an adequate soil evaluation for engineering uses, identify all strata to whatever depth may be affected by the construction. A vertical cross section through the earth, with the depths and types of soil indicated, is called a soil profile.

PHYSICAL PROPERTIES

A soil's physical properties help determine the engineering characteristics. The following properties are the basis for the soil-classification system used in engineering identification of soil types. The discussion of the physical properties of soil focuses on the soil particles themselves. The terms *particle* and *grain* are used interchangeably.

- Grain size.
- Particle shape.
- Gradation.
- Density.
- Specific gravity.
- Moisture.
- Consistency.
- Organic soil.

Physical characteristics of soil particles include size and shape. The proportions of different-sized particles determine an aggregate's gradation. Density or compactness refers to the closeness of packing of soil particles; the closer the packing, the greater the compactness and the larger the soil weight per unit of volume. Plasticity characteristics of fine-grained soil components include the liquid limit (LL) and the plastic limit (PL); shrinkage ratios; dry strength; and unconfined, compressive strength. Specific gravity of soil particles aids in their identification. The presence of organic matter is important to the engineering use of soils. Color, texture, odor, structure, and consistency are readily observed factors that aid in soil description.

GRAIN OR PARTICLE SIZE

Soils are divided into groups based on the size of the particle grains in the soil mass. Common practice is to distinguish the sizes by using sieves. A sieve is a screen attached across the end of a shallow, cylindrical frame. The screen permits smaller particles to fall through and retains the larger particles on the sieve. Sieves with screen openings of different sizes (the largest on the top and the smallest at the bottom) separate the soil into particle groups based on size. The amount remaining on each sieve is measured and described as a percentage by weight of the entire sample. The size groups that are designated by the USCS are cobbles, gravels, sands, and fines (silt or clay), as shown in *Table 2-1*. Further discussion on these size groups can be found later in this chapter and in Appendix B.

Table 2-1. Grain-size groups

Size Group	Sieve Size	
	Passing	Retained On
Cobbles	No maximum size*	3 inches
Gravels	3 inches	No. 4
Sands	No. 4	No. 200
Fines (clay or silt)	No. 200	No minimum size

*** In military engineering, the maximum size of cobbles is accepted as 40 inches, based on the maximum jaw opening of a rock-crushing unit.**

GRAIN OR PARTICLE SHAPE

The shape of the particles influences a soil's strength and stability. Two general shapes are normally recognized—bulky and platy.

Bulky

The bulky shapes include particles that are relatively equal in all three dimensions. In platy shapes, one dimension is very small compared to the other two. For example, a thick book would be considered bulky, but a page of the book would be platy. Bulky shapes are subdivided into four groups: angular, subangular, subrounded, and well-rounded (see *Figure 2-1, page 2-4)*. These four subdivisions are dependent on the amount of weathering that has occurred. Cobbles, gravel, sand, and silt usually fall into this bulky-shape group. These groups are discussed in the order of desirability for construction.

Angular-shaped particles are those that have recently broken up. They are characterized by jagged projections, sharp ridges, and flat surfaces. The interlocking characteristics of angular gravels and sands generally make them the best materials for construction. These particles are seldom found in nature because weathering processes normally wear them down in a relatively short time. Angular material may be produced artificially by crushing, but because of the time and equipment required for such an operation, natural materials with other grain shapes are frequently used.

Subangular-shaped particles have been weathered to a point that the sharper points and ridges of their original angular shape have been worn off. These

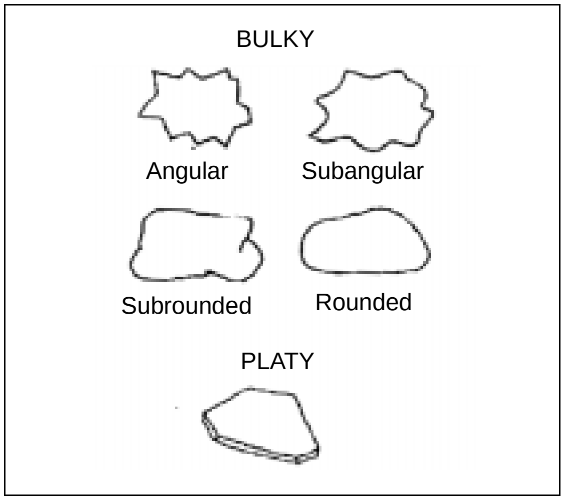


Figure 2-1. Shapes of soil grains

particles are still very irregular in shape with some flat surfaces and are excellent for construction.

Subrounded particles are those on which weathering has progressed even further. While they are still somewhat irregular in shape, they have no sharp corners and few flat areas. These particles are frequently found in streambeds. They may be composed of hard, durable particles that are adequate for most construction needs.

Rounded particles are those in which all projections have been removed and few irregularities in shape remain. The particles approach spheres of varying sizes. Rounded particles are usually found in or near streambeds, beaches, or dunes. Possibly the most extensive deposits exist at the beaches where repeated wave action produces almost perfectly rounded particles that may be uniform in size. They may also be found in arid environments due to wind action and the resulting abrasion between particles. They are not desirable for use in asphalt or concrete construction until the rounded shape is altered by crushing.

Platy

The platy shapes have one dimension relatively small compared to the other two. They have the general shape of a flake of mica or a sheet of paper. Particles of clay soil exhibit this shape, although they are too small to be seen with the naked eye. Coarse-grained soil particles are individually discernible to the naked eye; fine-grained particles with platy or bulky shapes are not.

GRADATION

Gradation describes the distribution of the different size groups within a soil sample. The soil may be well-graded or poorly graded.

Well-Graded Soils

Well-graded soils must have a good range of all representative particle sizes between the largest and the smallest. All sizes are represented, and no one size is either overabundant or missing (see *Figure 2-2*).

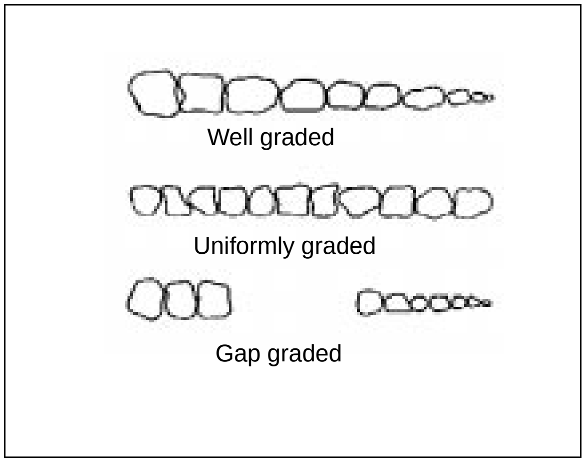


Figure 2-2. Soil gradation

Poorly Graded Soils

Poorly graded soils can be classified as either uniformly graded or gap graded. A uniformly graded soil consists primarily of particles of nearly the same size. A gap-graded soil contains both large and small particles, but the gradation continuity is broken by the absence of some particle sizes (see *Figure 2-2*).

DENSITY

The structure of the aggregate of soil particles may be dense (closely packed) or loose (lacking compactness). A dense structure provides interlocking of particles with smaller grains filling the voids between the larger particles. When each particle is closely surrounded by other particles, the grain-to-grain contacts are increased, the tendency for displacement of individual grains under a load is lessened, and the soil is capable of supporting heavier loads. Coarse materials that are well-graded usually are dense and have strength and stability under a load. Loose, open structures have large voids and will compact under a load, leading to settlement or disintegration under foundation or traffic loads.

SPECIFIC GRAVITY

The specific gravity is the ratio between the weight-per-unit volume of the material and the weight-per-unit volume of water at a stated temperature. There are three ways of determining and expressing specific gravity:

- Specific gravity of solids.
- Apparent specific gravity.
- Bulk specific gravity.

The specific gravity of solids is the method most widely used when testing soils. The apparent and bulk specific-gravity methods are used in testing fine and coarse aggregates. The specific gravity of solids is explained further in Section IV of this chapter, along with the test procedure.

MOISTURE

The term moisture content (w) is used to define the amount of water present in a soil sample. It is the proportion of the weight of water to the weight of the solid mineral grains (weight of dry soil) expressed as a percentage.

The moisture content of a soil mass is often the most important factor affecting the engineering behavior of the soil. Water may enter from the surface or may move through the subsurface layers either by gravitational pull, capillary action, or hygroscopic action. This moisture influences various soils differently and usually has its greatest effect on the behavior of fine-grained soils. The fine grains and their small voids retard the movement of water and also tend to hold the water by surface tension.

Many fine-grained soils made from certain minerals exhibit plasticity (putty-like properties) within a range of moisture contents. These soils are called clays, and their properties may vary from essentially liquid to almost brick hard with different amounts of moisture. Further, clays are basically impervious to the passage of free or capillary moisture. Coarse-grained soils with larger voids permit easy drainage of water. They are less susceptible to capillary action. The amount of water held in these soils is less than in fine-grained soils, since the surface area is smaller and excess water tends to drain off.

Surface Water

Surface water from precipitation or runoff enters the soil through the openings between the particles. This moisture may adhere to the different particles or it may penetrate the soil to some lower layer.

Subsurface Water

Subsurface water is collected or held in pools or layers beneath the surface by a restricting layer of soil or rock. This water is constantly acted on by one or more external forces.

Gravitational Pull

Water controlled by gravity (free or gravitational water) seeks a lower layer and moves through the voids until it reaches some restriction. This restriction may be bedrock or an impervious soil layer with openings or voids so small that they prevent water passage.

Capillary Action

Voids in soil may form continuous tunnels or tubes and cause the water to rise in the tubes by capillary action (capillary moisture). Since the smaller the tube, the stronger the capillary action, the water rises higher in the finer soils that have smaller interconnected voids. This area of moisture above the free water layer or pool is called the capillary fringe.

Adsorbed Water and Hygroscopic Moisture

In general terms, adsorbed water is water that may be present as thin films surrounding separate soil particles. When soil is in an air-dried condition, the adsorbed water present is called hygroscopic moisture. Adsorbed water is present because soil particles carry a negative electrical charge. Water is dipolar; it is attracted to the surface of a particle and bound to it. The water films are affected by the soil particle's chemical and physical structures and its relative surface area. The relative surface area of a particle of fine-grained soil, particularly if it has a platy shape, is much greater than for coarse soils composed of bulky grains. The electrical forces that bind adsorbed water to a soil particle also are much greater.

In coarse soils, the adsorbed layer of water on a particle is quite thin in comparison to the overall particle size. This, coupled with the fact that the contact area with adjacent grains is quite small, leads to the conclusion that the presence of the adsorbed water has little effect on the physical properties of coarse-grained soils. By contrast, for finer soils and particularly in clays, the adsorbed water film is thick in comparison to the particle size. The effect is very pronounced when the particles are of colloidal size.

Plasticity and Cohesion

Two important aspects of the engineering behavior of fine-grained soils are directly associated with the existence of adsorbed water films. These aspects are plasticity and cohesion.

Plasticity is a soil's ability to deform without cracking or breaking. Soils in which the adsorbed films are relatively thick compared to particle size (such as clays) are plastic over a wide range of moisture contents. This is presumably because the particles themselves are not in direct contact with one another. Coarse soils (such as clean sands and gravels) are nonplastic. Silts also are essentially nonplastic materials, since they are usually composed predominantly of bulky grains; if platy grains are present, they may be slightly plastic.

A plasticity index (PI) is used to determine whether soil is cohesive. Not all plastic soils are cohesive. Soil is considered cohesive if its PI is greater than 5. That is, it possesses some cohesion or resistance to deformation because of the surface tension present in the water films. Thus, wet clays can be molded into various shapes without breaking and will retain these shapes. Gravels, sands, and most silts are not cohesive and are called cohesionless soils.

In engineering practice, soil plasticity is determined by observing the different physical states that a plastic soil passes through as the moisture conditions change. The boundaries between the different states, as described by the moisture content at the time of changes, are called consistency limits or Atterberg limits, named after the Swedish scientist who defined them years ago.

CONSISTENCY

Atterberg established four states of consistency for fine-grained soils: liquid, plastic, semisolid, and solid. The dividing lines between these states are called the LL, the PL, and the shrinkage limit. These limits are quantified in terms of water content.

Liquid Limit

The LL is the moisture content at an arbitrary limit between a soil's liquid and plastic states of consistency. Above this value, a soil is presumed to be a liquid and flows freely under its own weight. Below this value, it will deform under pressure without crumbling, provided it exhibits a plastic state.

Plastic Limit

The PL is the moisture content at an arbitrary limit between the plastic and semisolid states. As a sample is dried, the semisolid state is reached when the soil is no longer pliable and crumbles under pressure. Between the LL and PL is the plastic range. The PI is the numerical difference in moisture contents between the two limits (PI = LL - PL). It defines a soil's range of moisture content in a plastic state.

Shrinkage Limit

The shrinkage limit is the boundary moisture content between the semisolid and solid states. This boundary is determined when a soil sample, upon being dried, finally reaches a limiting or minimum volume. Beyond this point, further drying will not reduce the volume, but may cause cracking.

ORGANIC SOIL

Soil having a high content of organic material is described as organic soil. It is usually very compressible and has poor load-maintaining properties.

EFFECTS OF SOIL CHARACTERISTICS

Soil characteristics are a measure of a soil's suitability to serve an intended purpose. Generally, a dense soil will withstand greater applied loads (having greater bearing capacity) than a loose soil. Particle size has a definite relation to this capacity. Empirical tests show that well-graded, coarse-grained soils generally can be compacted to a greater density than fine-grained soils because the smaller particles tend to fill the spaces between the larger ones. The shape of the grains also affects the bearing capacity. Angular particles tend to interlock and form a denser mass. They are more stable than the rounded particles which can roll or slide past one another. Poorly graded soils, with their lack of one or more sizes, leave more or greater voids and therefore a less-dense mass. Moisture content and consistency limits aid in describing a soil's suitability. A coarse-grained, sandy or gravelly soil generally has good drainage characteristics and may be used in its natural state. A fine-grained, clayey soil with a high PI may require considerable treatment, especially if used in a moist location.

SOIL CLASSIFICATION

Soil seldom exists separately as sand, gravel, or any other single component in nature. It is usually a mixture with varying proportions of different-sized particles. Each component contributes to the mixture's characteristics. Once the principal characteristics are identified within this system (by both visual examination and laboratory tests), a descriptive name and letter symbol are assigned to the soil.

Before soil can be classified properly, it is necessary to establish a basic terminology for the various soil components and to define the terms used. As mentioned earlier, the USCS uses specific names to designate the size ranges of soil particles. These basic designations are cobbles, gravel, sand, and fines (silt or clay).

CLASSIFICATION

To start the classification process, become familiar with the USCS (see Appendix B) and the classification sheet used in the classification process (see *Table B-1, page B-2*). The first three columns of the classification sheet show the major divisions of the classification and the symbols that distinguish the individual soil types. Names of typical and representative soil types found in each group are shown in column 4. The field procedures for identifying soils by general characteristics and from pertinent tests and visual observations are shown in column 5. The desired descriptive information for a complete identification of a soil is presented in column 6. Column 7 presents the laboratory classification criteria by which the various soil groups are identified and distinguished.

CATEGORIES

In the USCS, soils are divided into three major soil divisions: coarse-grained, fine-grained, and highly organic. Coarse-grained soils are those having 50 percent or less material passing the number (No.) 200 sieve; fine-grained soils are those having more than 50 percent passing the No. 200 sieve. Highly organic soils can generally be identified by visual examination. This system recognizes 15 soil groups and uses names and letter symbols to distinguish between these groups. The letter symbols used are relatively easy to remember. They are derived either from the terms descriptive of the soil fractions, the relative value of the LL (high or low), or the relative gradation (well-graded or poorly graded). *Table 2-2* shows these individual letter symbols. The symbols are combined to form the group symbols that correspond to the names of typical soils as seen in columns 3 and 4 of the classification sheet. These symbols are also used in combination to describe borderline soils.

Table 2-2. Soil-classification symbols

Soil Groups	Symbol
Gravel	G
Sand	S
Silt	M
Clay	C
Organic (silts and clays)	O
Organic (peat)	Pt
Soil Characteristics	**Symbol**
Well graded	W
Poorly graded	P
Low LL (less than 50)	L
High LL (50 or greater)	H

Coarse-Grained Soils

Coarse-grained soils are subdivided into two divisions—

- Gravels and gravelly soils (G).
- Sands and sandy soils (S).

A coarse-grained soil is classified as a gravel if more than half the coarse fraction, by weight, is larger than a No. 4 sieve. It is a sand if more than half the coarse fraction, by weight, is smaller than a No. 4 sieve. In general, there is no clear-cut boundary between gravelly and sandy soils. As far as behavior is concerned, the exact point of division is relatively unimportant. Where a mixture occurs, the primary name is the predominant fraction, in percent by weight, and the minor fraction is used as an adjective. For example, a sandy gravel would be a mixture containing more gravel than sand, by weight. It is desirable to further divide coarse-grained soils into three groups based on the amount of fines (materials passing a No. 200 sieve) they contain.

NOTE: If fines interfere with free-draining properties (as may occur with plastic fines), use the double symbol (GW-GM, GW-GC, and so on) indicating that such soils will be classed with soils having from 5 to 12 percent fines.

Less-Than-5-Percent Nonplastic Fines

These soils may fall into the groups GW, GP, SW, or SP, where the shape of the grain-size-distribution curve determines the symbol's second letter. The terms well graded (W) and poorly graded (P) have been discussed earlier. However, as noted above, if the fines interfere with the free-drainage properties, a dual or double symbol is used.

- GW and SW groups. The GW and SW groups include well-graded, gravelly soils and sandy soils with little or no nonplastic fines (less than 5 percent passing the No. 200 sieve). The presence of the fines must not noticeably change the strength characteristics of the coarse-grained fraction and must not interfere with its free-draining characteristics.
- GP and SP groups. The GP and SP groups include poorly graded gravels and sands with little or no nonplastic fines. These materials may be classed as uniform gravels, uniform sand, or gap-graded materials.

More-Than-12-Percent Fines

These soils may fall into the groups designated GM, GC, SM, and SC. The use of the symbols M and C is based on the plasticity characteristics of the material passing the No. 40 sieve. Use the LL and PI in specifying the laboratory criteria for these groups. The symbol M is used to indicate that the material passing the No. 40 sieve is silty in character. An M usually designates a fine-grained soil of little or no plasticity. The symbol C is used to indicate that the binder soil is predominantly clayey in character.

- GM and SM groups. The GM and SM groups comprise silty (M) gravels and silty sands with fines (more than 12 percent passing the No. 200 sieve) having low or no plasticity. For both of these groups, the LL and PI will plot below the A line on the plasticity chart or the PI will be less than 4. Both well-graded and poorly graded materials are included in these two groups. Normally these soils have little to no dry strength, but occasionally the fine or binder materials will contain a natural cementing agent that will increase dry strength.

- GC and SC groups. The GC and SC groups include gravelly or sandy soils with fines (more than 12 percent passing the No. 200 sieve) that are more clay-like and that range in plasticity from low to high. For both of these groups, the LL and PL will plot above the A line with a PI of more than 7 (see Section VI of this chapter).

Borderline Soils

Coarse-grained soils of which between 5 and 12 percent of material passes the No. 200 sieve are classed as borderline and are given a dual symbol (for example, GW-GM). Similarly, coarse-grained soils of which more than 12 percent of material passes the No. 200 sieve, and for which the limits plot in the shaded portion of the plasticity chart, are classed as borderline and require dual symbols (for example, SM-SC). It is possible, in rare instances, for a soil to fall into more than one borderline zone. If appropriate symbols were used for each possible classification, the result would be a multiple designation consisting of three or more symbols. This approach is unnecessarily complicated.

It is best to use only a double symbol in these cases, selecting the two that are believed to be most representative of the soil's probable behavior. In cases of doubt, the symbols representing the poorer of the possible groupings should be used. For example, a well-graded sandy soil with 8 percent passing the No. 200 sieve, with an LL of 28 and a PI of 9, would be designated as SW-SC. If the soil's LL and PI were plotted in the shaded portion of the plasticity chart (for example, an LL of 20 and a PI of 5), the soil would be designated either SW-SC or SW-SM, depending on the engineer's judgment from the standpoint of the climatic region.

Fine-Grained Soils

Fine-grained soils are subdivided into two divisions—

- Silts (M).
- Clays (C).

Fine-grained soils are not classified on the basis of grain-size distribution, but according to plasticity and consistency. Like the coarse-grained soils, laboratory classification criteria are based on the relationship between the LL and PI designated in the plasticity chart. The L groups, which have LLs less than 50, and the H groups, which have LLs greater than 50, are the two major groupings of fine-grained soils. The symbols L and H have general meanings of low and high LLs, respectively.

Fine-grained soils are further divided by their position above or below the plasticity chart's A line.

- ML and MH groups. Typical soils of the ML and MH groups are inorganic silts. Those that have an LL less than 50 are in the ML group; others are in the MH group. All of these soils plot below the A line. The ML group includes very fine sands; rock flours (rock dust); and silty or clayey, fine sands or clayey silts with slight plasticity. Loess-type soils usually fall into this group. Micaceous and diatomaceous soils generally fall into the MH group, but they may extend into the ML group when their LLs are less than 50. This is true of certain types of kaolin clays which have relatively low plasticity. Plastic silts fall into the MH group.

- CL and CH groups. In these groups, the symbol C stands for clay, while L and H denote low or high LLs. These soils plot above the A line and are principally inorganic clays. The CL group includes gravelly, sandy, silty, and lean clays. The CH group contains inorganic clays of medium to high plasticity including fat clays, the gumbo clays of the southern United States (US), volcanic clays, and bentonite. The glacial clays of the northern US cover a wide area in the CL and CH groups.
- OL and OH groups. The soils in these two groups are characterized by the presence of organic matter, hence the symbol O. All of these soils generally plot below the A line. Organic silts and organic silt-clays of low plasticity fall into the OL group. Organic clays of high plasticity plot in the OH zone of the plasticity chart. Many of the organic silts, silt-clays, and clays deposited by the rivers along the lower reaches of the Atlantic seaboard have LLs above 40 and plot below the A line. Peaty soils may have LLs of several hundred percent and will plot well below the A line due to their high percentage of decomposed vegetation. However, an LL test is not a true indicator where a considerable portion consists of other than soil matter.
- Borderline soils. Fine-grained soils with limits that plot in the shaded portion of the plasticity chart are borderline cases and are given dual symbols (for example, CL-ML). Several soil types that exhibit low plasticity plot in this general region on the chart where no definite boundary between silty and clayey soils exists.

Highly-Organic Soils

A special classification is reserved for the highly organic soils (Pt), such as peat, which have many characteristics undesirable for use as foundations and construction materials. No laboratory criteria are established for these soils, as they can be identified in the field by their distinctive color, odor, spongy feel, and fibrous textures. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils.

IDENTIFICATION OF SOIL GROUPS

The USCS is designed so that most soils may be classified into the three primary or major divisions (coarse-grained, fine-grained, and highly organic) by means of visual inspection and simple field tests. Classification into the subdivisions can be made by visual examination only with some degree of success. More positive identification may be made by means of laboratory tests on the materials. However, in many instances a tentative classification determined in the field is of great benefit and may be all the identification that is necessary, depending on the purpose for which the soil is to be used.

Methods of general identification of soils are discussed in the following paragraphs as well as a laboratory testing procedure. It is emphasized that the two methods of identification are never entirely separated. Certain characteristics can only be estimated by visual examination, and in borderline cases it may be necessary to verify a classification by laboratory tests. The field methods are entirely practical for preliminary laboratory identification and may be used to advantage in grouping soils in such a way that only a minimum number of laboratory tests need to be conducted. The field methods of classification should never be used as the end product for performing design.

FIELD IDENTIFICATION

Field identification is an excellent tool when an engineer needs to have an idea of the general type of soil being dealt with. One excellent use of these procedures is during a preliminary construction-site analysis.

Several simple tests are used in field identification. The number of tests depends on the soil type and the experience of the individual employing them. Experience is the greatest asset in field identification, and learning the techniques from an experienced technician is the best way to acquire experience. Lacking such assistance, experience is gained during laboratory testing by systematically comparing the numerical test results for typical soils in each group with the “look” and “feel” of the material. An approximate identification can be made by examining a dry sample spread on a flat surface.

All lumps should be separated until individual grains are exposed. Individual grains, no matter how large, should not be broken to a smaller size since this changes the soil’s grain size and character. A rubber-faced or wooden pestle and a mixing bowl are recommended, but separating the sample underfoot on a smooth surface will suffice for an approximate identification. Examining the characteristics of the particles in the sample makes it possible to assign the soil to one of the three principal groups. Classification derived from these tests should be recognized as approximations.

An approximate identification of a coarse-grained soil is made by observing—

- Grain size.
- Gradation.
- Grain shape.
- Hardness.

Tests for identifying the fine-grained portions of a soil are performed on the portion of material that passes a No. 40 sieve. This is the same soil fraction used in the laboratory for the LL and PL tests. If this sieve is not available, a rough separation may be made by spreading the material on a flat surface and removing the gravel and larger sand particles. Fine-grained soils are examined primarily for characteristics related to plasticity.

Organic soils are identified by significant quantities of organic matter. When decayed roots, leaves, grasses, and other vegetable matter are present, they produce a highly organic soil, which is usually dark-colored when moist and has a soft, spongy feel and a distinctive odor of rotting organic matter. Partly-organic soils may contain finely divided organic matter detectable by color or odor.

TEST EQUIPMENT

Field tests may be performed with little or no equipment other than a small amount of water. However, accuracy and uniformity of results will be increased greatly by properly using the following equipment available in nearly all engineer units:

- A No. 4 and a No. 40 sieve. (A No. 200 sieve is useful but not required.)
- A digging instrument such as a pick, shovel, or entrenching tool. (A hand earth auger or posthole digger is useful in obtaining samples from depths a few feet or more below the surface.)
- A stirrer.
- A knife.
- Several sheets of heavy, nonabsorbent paper.
- A mixing bowl and a pestle (a canteen cup and a wooden dowel).
- A pan and a heating element.
- Scales or balances.

TEST FACTORS

The USCS considers three soil properties:

- The percentage of gravel, sand, or fines.
- The shape of the grain-size-distribution curve.
- The plasticity.

These are the primary factors to be considered, but other observed properties, whether made in the field or in the laboratory, should also be included in the soil description. The following information can be determined from field identification:

- Color (in moist condition).
- Grain size (estimated maximum grain size and estimated percent, by weight, of gravel, sands, and fines).
- Gradation (well or poorly graded).
- Grain shape (bulky or platy and angular, subangular, rounded, or subrounded).
- Plasticity (nonplastic, low, medium, or high).
- Predominant soil type.
- Secondary components.
- Identification or classification symbol.
- Organic, chemical, or metallic content.
- Compactness (dense or loose).
- Consistency.

- Cohesiveness (ability to hold together without cementation).
- Dry strength.
- Source (residual or transported).

SOIL-DESCRIPTION EXAMPLE

A complete description with proper classification symbols conveys more to the user of the data than the symbol of any isolated portion of the description. An example of a soil description, using the sequence and considering the properties, is—

- Dark brown to white.
- Coarse-grained (maximum particle size 3 inches; estimated 60 percent gravel, 36 percent sand, and 4 percent fines passing through the No. 200 sieve).
- Poorly graded (gap-graded, insufficient fine gravel).
- Subrounded to rounded gravel particles.
- Nonplastic.
- Predominantly gravel.
- Considerable sand and a small amount of nonplastic fines (silt).
- GP (identification symbol).
- Slightly calcareous, no dry strength, dense in the undisturbed state.

FIELD-IDENTIFICATION TESTS

The following tests produce observations that pertain to the USCS and permit field identification as well as classification. Tests appropriate to the given soil sample should be made. Some tests appear to yield duplicate results. The purpose of these tests is to get the best possible identification in the field. Thus, if a simple visual examination will define the soil type, only one or two of the other tests have to be made to verify the identification. When the results from a test are inconclusive, some of the similar tests should be tried to establish the best identification.

Figure 2-3, pages 2-16 and 2-17, gives the suggested sequence of tests for identifying and classifying a soil sample using the hasty field procedures described in the following paragraphs.

VISUAL TEST

This test should establish the color, grain sizes, grain shapes of the coarse-grained portion, some idea of the gradation, and some properties of the undisturbed soil.

Determine the color, grain size, and grain shape of the material and estimate, if possible, the grain-size distribution by visual examination. The following paragraphs provide methods and information concerning identification of these properties.

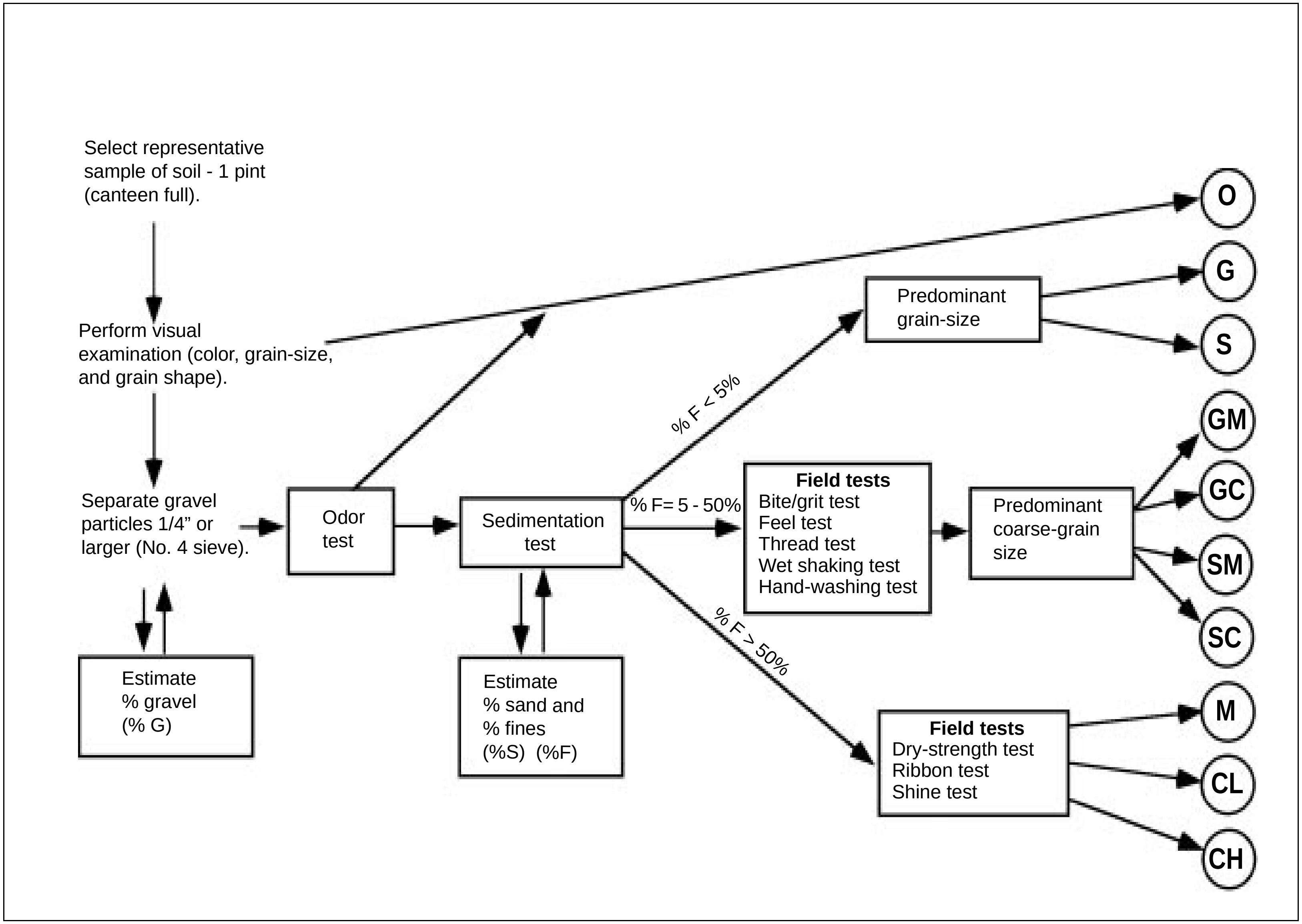


Figure 2-3. Suggested procedures for hasty field identification

1. Perform a visual examination of the sample.
   a. Color.
   b. Grain size.
   c. Grain shape.
   d. Contents— leaves, grass, and other possible organic material.

2. Separate the gravel.
   a. Remove from the sample all particles larger than 1/4 inch in diameter (No. 4 sieve).
   b. Estimate the % G.

3. Perform the odor test.
   a. Heat the sample (less gravel) with a match or open flame.
   b. If the odor becomes musty or foul smelling, there is a strong indication that organic material is present.

4. Perform the sedimentation test to determine the % S.
   a. Place approximately 1 inch of the sample (less gravel) in a glass jar.
   b. Mark the depth of the sample with a grease pencil.
   c. Cover the sample with 5 inches of water with at least 1 inch space to the top of the jar.
   d. Cover and shake the mixture for 3 to 4 minutes.
   e. Place on a flat surface and allow sand particles to settle for 30 seconds.
   f. Compare the settled material after 30 seconds to the grease-pencil mark and estimate the percent that has settled.
   g. Determine % S for the overall sample.
      % S = (% settled) x (100% - % G)
   h. Determine % F for the overall sample.
      % F = 100% - (% S + % G)

*5. Perform the bite or grit test. Place a pinch of the sample between the teeth and bite.
- If the sample feels gritty, the sample is silt (M).
- If the sample feels floury, the sample is clay (C).

*6. Perform the feel test. Rub a portion of dry soil over a sensitive part of the skin, such as the inside of the wrist.
- If the feel is harsh and irritating, the sample is silt (M).
- If the feel is smooth and floury, the sample is clay (C).

*7. Perform the roll or thread test.
   a. Form a ball of moist soil (marble size).
   b. Attempt to roll the ball into a thread 1/8 inch in diameter.
      - If a thread is easily obtained, it is clay (C).
      - If a thread cannot be obtained, it is silt (M).

*8. Perform the wet shaking test.
   a. Place the pat of moist (not sticky) soil in the palm of your hand (the volume is about 1/2 cu in).
   b. Shake the hand vigorously and strike it against the other hand.
   c. Observe how rapidly water rises to the surface.
      - If it is fast, the sample is silty (M).
      - If there is no reaction, the sample is clayey (C).

*9. Perform the breaking or dry-strength test.
   a. Form a moist pat 2 inches in diameter by 1/2 inch thick.
   b. Allow it to dry with low heat.
   c. Place the dry pat between the thumb and index finger only and attempt to break it.
      - If breakage is easy, it is a silt (M).
      - If breakage is difficult, it is a clay of low plasticity (CL).
      - If breakage is impossible, it is a clay of high plasticity (CH).

*10. Perform the ribbon test.
   a. Form a cylinder of moist soil, approximately cigar shape and size.
   b. Flatten the cylinder over the index finger with the thumb, attempting to form a ribbon 8 to 9 inches long, 1/8 to 1/4 inch thick, and 1 inch wide.
      - If 8 to 9 inches is obtained, it is (CH).
      - If 3 to 8 inches is obtained, it is (CL).
      - If less than 3 inches is obtained, it is silt (M).

*11. Perform the shine test. Draw a smooth surface, such as a knife blade or a thumbnail, over a pat of slightly moist soil.
- If the surface becomes shiny and lighter in texture, the sample is a highly plastic clay (CH).
- If the surface remains dull, the sample is a low plasticity clay (CL).
- If the surface remains very dull or granular, the sample is silt or sand (M).

***These tests are conducted only with material that passes the No. 40 sieve.**

Figure 2-3. Suggested procedures for hasty field identification (continued)

Color

Color helps in distinguishing between soil types and, with experience, aids in identifying the particular soil type. Color may also indicate the presence of certain chemicals or impurities. Color often varies with the soil's moisture content. Thus, the moisture content at the time of color identification should be included. Some of the more familiar color properties are stated below. Colors in general become darker as the moisture content increases and lighter as the soil dries. Some fine-grained soil (OL and OH) with dark, drab shades of brown or gray (including almost black) contain organic colloidal matter. In contrast, clean, bright shades of gray, olive green, brown, red, yellow, and white are associated with inorganic soils. Gray-blue or gray-and-yellow mottled colors frequently result from poor drainage. Red, yellow, and yellowish-brown colors result from the presence of iron oxides. White to pink may indicate considerable silica, calcium carbonate, or aluminum compounds.

Grain Size

The maximum particle size of each sample considered should always be estimated if not measured. This establishes the gradation curve's upper limit. Gravels range down to the size of peas. Sands start just below this size and decrease until the individual grains are just distinguishable by the naked eye. The eye can normally see individual grains about 0.07 millimeter in size, or about the size of the No. 200 sieve. Silt and clay particles, which are smaller than sands, are indistinguishable as individual particles.

Grain Shape

While the sample is examined for grain sizes, the shapes of the visible particles can be determined. Sharp edges and flat surfaces indicate an angular shape; smooth, curved surfaces indicate a rounded shape. Particles may not be completely angular or completely rounded. These particles are called subangular or subrounded, depending on which shape predominates.

Grain-Size Distribution

A laboratory analysis must be performed to determine accurate distribution; however, an approximation can be made during the visual examination. Perform the following steps to obtain the grain-size distribution:

Step 1. Separate the larger grains (+4 gravel or coarse grains and some sand particles) from the remainder of the soil by picking them out individually.

Step 2. Examine the remainder of the soil, and estimate the proportion of visible individual particles (larger than the No. 200 sieve) and the fines (smaller than the No. 200 sieve).

Step 3. Convert these estimates into percentages by weight of the total sample. If the fines exceed 50 percent, the soil is considered fine-grained (M, C, or O). If the coarse material exceeds 50 percent, the soil is coarse-grained (G or S).

Step 4. Examine coarse-grained soil for gradation of particle sizes from the largest to the smallest. A good distribution of all sizes means the soil is well graded (W). Overabundance or lack of any size means the material is poorly graded (P).

Step 5. Estimate the percentage of the fine-grained portion of the coarse-grained soil.

If less than 5 percent (nonplastic fines) of the total, the soil may be classified either as a GW, GP, SW, or SP type, depending on the other information noted above. If the fine-grained portion exceeds 12 percent, the soil is either M or C and requires further testing to identify.

Fine-grained portions, between 5 and 12 percent (nonplastic fines or fines not interfering with free drainage) are borderline and require double symbols such as GW-GM or SW-SM.

Fine-grained soils (M, C, or O) require other tests to distinguish them further. Grain-size distribution of fine portions is not normally performed in field identification. However, if necessary, make an approximation by shaking the fine portions in a jar of water and allowing the material to settle. The material will settle in layers of different sizes from which the proportion can be estimated. Gravel and sand settle into a much denser mass than either clay or silt settles.

Undisturbed Soil Properties

Using characteristics determined up to this point, it is possible to evaluate the soil as it appeared in place. Gravels or sands can be described qualitatively as loose, medium, or dense. Clays may be hard, stiff, or soft. The ease of difficulty with which the sample was removed from the ground is a good indicator. Soils that have been cultivated or farmed can be further evaluated as loose or compressible. Highly-organic soils can be spongy or elastic. In addition, the soil's moisture content influences the in-place characteristics. This condition should be recognized and reported with the undisturbed soil properties.

ODOR TEST

Organic soils (OL and OH) usually have a distinctive, musty, slightly offensive odor. The odor can help identify such materials. This odor is especially apparent from fresh samples but becomes less pronounced as the sample is exposed to air. The odor can be made stronger by heating a wet sample.

SEDIMENTATION TEST

From the visual-examination tests, it is easy to approximate the proportions of sand and gravel in a soil by spreading the dry sample out on a flat surface and separating the gravel particles by hand. Separating the fines from the sand particles however, is more difficult, although just as important. Smaller particles settle through water at a slower rate than large particles.

To perform this test, place about 1 inch of the fine fraction of soil (passing the No. 4 sieve) in a transparent cup or jar. Mark the height of the sample with a grease pencil. Place about 5 inches of water into the jar, ensuring that at least 1 inch is still remaining above the water line to the top of the jar. Cover and shake the water and soil mixture for 3 to 4 minutes. Place the jar on a flat surface. After 30 seconds compare the level of material that settled to the bottom with the height of the original sample (grease pencil line). This comparison should indicate the proportion of sand within the mixture as indicated in *Table 2-3, page 2-20*. For example, if the level of the settled material comes halfway from the bottom of the jar to the grease-pencil line after 30 seconds, then it can be estimated that the amount of sand in this fraction of the soil is about 50 percent.

Table 2-3. Sedimentation test

Approximate Time of Settlement Through 5 Inches of Water	Grain Diameter (mm)	Differentiates
2 seconds	0.400	Coarse sand, fine sand
30 seconds	0.072	Sand, fines
10 minutes	0.030	Coarse silt, fine sand
1 hour	0.010	Silt, clay

Once this determination is complete, estimating the amount of sand and fines of the overall sample is made easy, providing the approximate percentage of gravel was obtained from the visual examination. Use the following equation to determine the percent of sand for the overall sample:

$$\%\ S\ =\ \text{percent of sand in jar} \times (100\% - \%G)$$

where—

% S = percent of sand

% G = percent of gravel

Using the information from the example in the previous paragraph and given the percent gravel as 40 percent, this equation would yield the following information:

$$\%S\ =\ 50\% \times (100\% - 40\text{-}\%)$$

$$\%S\ =\ 30\%$$

Additionally, once this information is obtained, the percent of fines (% F) can be determined by subtracting the percent of gravel and the percent of sand from 100 percent as follows:

$$\%F\ =\ 100\% - (40\% + 30\%)$$

$$\%F\ =\ 30\%$$

The most important use of the sedimentation test is to differentiate the coarse (0.072 millimeter) fraction from the fine fraction of a soil. Since all of the particles of soil larger than 0.072 millimeter will have settled to the bottom of the cup or jar 30 seconds after the mixture has been agitated, it follows that the particles still remaining in suspension are fines. Alternatively, if the water containing the suspended fines is carefully poured into another jar 30 seconds after agitation, if more water is added to the cup or jar containing the coarse fraction, and if the procedure is repeated until the water-soil mixture becomes clear 30 seconds after mixing, then the cup or jar will contain the coarse fraction of soil only, and the jar containing the suspension will hold the fines. If the water can be wicked or evaporated off, the relative amounts of fines and sand can be determined fairly accurately. Otherwise, a direct measurement of the settled-out fines can be obtained as a guide. Thus, in a sense, the test acts like the No. 200 sieve.

Difficulty may be encountered with many clay soils because the clay particles often form small lumps (flocculate) that will not break up in water. Usually this condition can be detected by examining the coarse fraction of the soil after several repetitions of the test. If substantial amounts of clay are still present, the sand will feel slippery and further mixing and grinding with a good stick will be necessary to break up the lumps.

BITE OR GRIT TEST

The bite or grit test is a quick and useful test in identifying sand, silt, or clay. A small pinch of soil is ground lightly between the teeth.

The results of this test indicate the following:

- Sandy soils. The sharp, hard particles of sand grate very harshly between the teeth and are highly objectionable. This is true even of the fine sands.
- Silty soils. Silt grains are so much smaller than sand grains that they do not feel nearly as harsh between the teeth. They are not particularly gritty, although their presence is still quite unpleasant and easily detected.
- Clayey soils. Clay grains are not gritty, but feel smooth and powdery like flour between the teeth. Dry lumps of clayey soils stick when lightly touched with the tongue.

FEEL TEST

This is a general-purpose test requiring considerable experience and practice before reliable results can be expected. Its use will increase with growing familiarity with soils. Consistency and texture are two characteristics that can be determined.

Consistency

The natural moisture content is an indicator of the soil drainage which may affect this characteristic. For the consistency test, squeeze a piece of undisturbed soil between the thumb and forefinger to determine its consistency. Consistency is described by such terms as hard, stiff, brittle, friable, sticky, plastic, and soft. Remold the soil by working it between the hands and observe the results. This can indicate the natural water content. Clays that become fluid on remolding are probably near their LL. If they remain stiff and crumble when reworked, they are probably below their PL.

Texture

This term is applied to the soil's fine-grained portion and refers to the degree of fineness and uniformity. Rub a portion of the soil between the fingers, observe the texture, and describe it as floury, smooth, gritty, or sharp. To increase sensitivity, rub the soil on a more tender skin area, such as the inside of the wrist. Typical results are similar to the bite test—sand feels gritty; silts, if dry, dust readily and feel soft and silky to the touch; and clays powder only with difficulty but feel smooth and gritless like flour.

ROLL OR THREAD TEST

This test is performed only on the material passing the No. 40 sieve. Mix a representative portion of the sample with water until it can be molded or shaped without sticking to the fingers. This moisture content is referred to as being just below the sticky limit.

Prepare a nonabsorbent rolling surface by placing a sheet of glass or heavy waxed paper on a flat or level support, shape the sample into an elongated cylinder, and roll the prepared soil cylinder on the surface rapidly into a thread about 1/8 inch in diameter. The technique is shown in *Figure 2-4*.

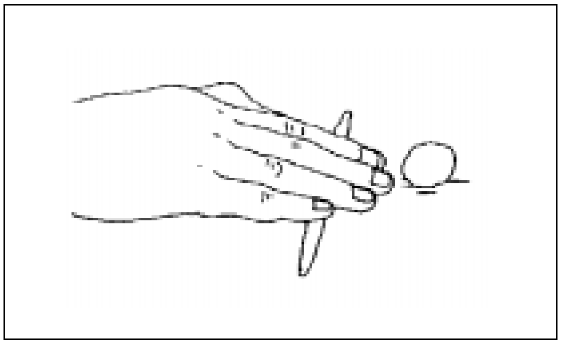


Figure 2-4. Roll or thread test

If the moist soil rolls into a thread, it has some plasticity. The number of times it can be rolled into a thread without crumbling is a measure of the soil's degree of plasticity. Materials that cannot be rolled in this manner are nonplastic or have a very low plasticity.

The results of this test indicate the following:

- If the soil can be molded into a ball or cylinder and deformed under very firm finger pressure without crumbling or cracking, it is of high plasticity (CH).
- If the soil can be molded but cracks or crumbles without breaking up, it is of low plasticity (CL, ML, or MH).
- If the soil forms a soft, spongy ball or thread when molded, it is organic material (OL or OH), also peat.
- If the soil cannot be rolled into a thread at any moisture content, it is nonplastic soil (ML or MH).

From the thread test, the cohesiveness of the material near the PL may also be described as weak, firm, or tough. The higher the soil is on the plasticity chart, the stiffer the threads are as they dry out and the tougher the lumps are if the soil is remolded after rolling.

WET SHAKING TEST

Perform the wet shaking test only on the material passing the No. 40 sieve. For this test, moisten enough material to form a ball of material about 3/4 inch in diameter. This sample should be just wet enough that the soil will not stick to the fingers when remolding or just below the sticky limit.

Smooth the soil pat in the palm of the hand with a knife blade or a small spatula. Shake it horizontally and strike the back of the hand vigorously against the other hand. The soil reacts to this test when, on shaking, water comes to the surface of the sample, producing a smooth, shiny appearance. This appearance is frequently described as livery (see *Figure 2-5a* and *2-5b*). Squeeze the sample between the thumb and forefinger of the other hand and the surface water will quickly disappear. The surface becomes dull (see *Figure 2-5c*) and the material becomes firm, resisting deformation. Cracks occur as pressure is continued, with the sample finally crumbling like a brittle material (see *Figure 2-5d*).

The vibration caused by the shaking of the soil sample tends to reorient the soil grains, decrease the voids, and force water within these voids to come to

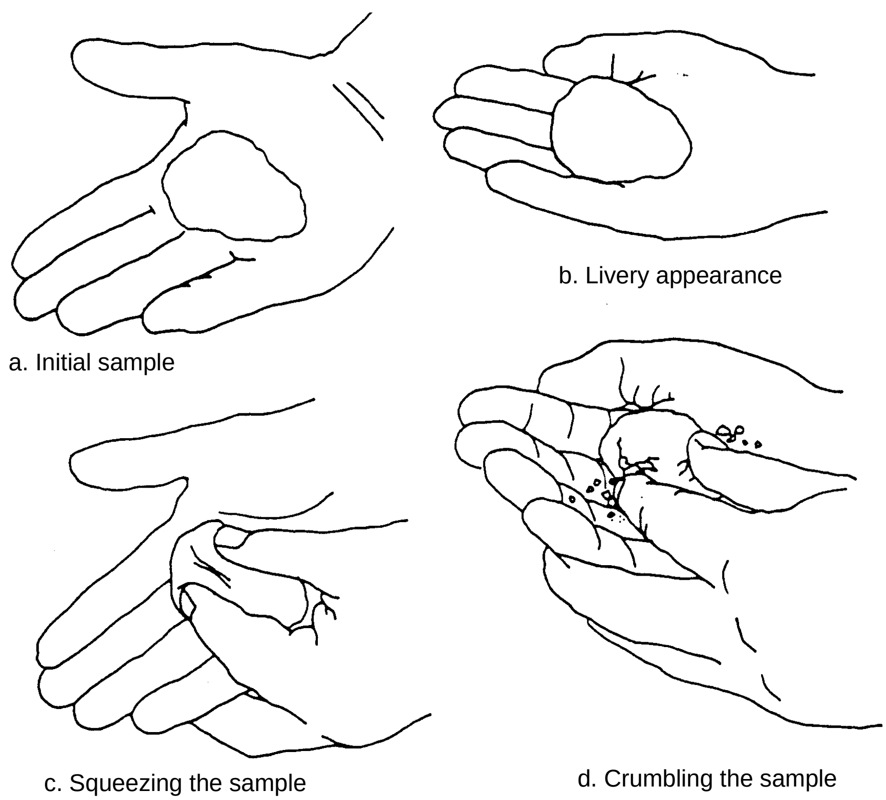


Figure 2-5. Wet shaking test

the surface. Pressing the sample between the fingers tends to disarrange the soil grains, increase the voids space, and draw the water into the soil. If the water content is still adequate, shaking the broken pieces will cause them to liquefy again and flow together, and the complete cycle may be repeated. This process can occur only when the soil grains are bulky in shape and noncohesive in character.

Very fine sands and silts fall into this category and are readily identified by the wet shaking test. Since it is rare that fine sands and silts occur without some amount of clay mixed with them, there are varying reactions to this test. Even a small amount of clay tends to greatly retard this reaction.

The results of this test indicate the following:

- A rapid reaction to the shaking test is typical of nonplastic, fine sands and silts.
- A sluggish reaction indicates slight plasticity (such as might be found from a test of some organic silts) or silts containing a small amount of clay.
- No reaction at all to this test does not indicate a complete absence of silt or fine sand.

BREAKING OR DRY-STRENGTH TEST

This test is performed only on the material passing the No. 40 sieve. It is used to measure the soil's cohesive and plastic characteristics. The test distinguishes between the clayey (C) and silty (M) soils.

Separate the selected soil sample on the No. 40 sieve and prepare a pat of soil about 2 inches in diameter and 1/2 inch thick by molding it in a wet, plastic state. Natural samples may be found in pats that are of the proper size but that may yield incorrect results. This is due to the variations in the natural drying and compaction processes. If natural samples are used, the results must be treated as approximations and verified later.

Allow the pat to dry completely, then grasp it between the thumbs and forefingers of both hands and attempt to break it. See *Figure 2-6* for the proper way to hold the pat. If the pat breaks, powder it by rubbing it between the thumb and forefinger of one hand.

The results of this test indicate the following:

- If the pat cannot be broken nor powdered by finger pressure, it is very highly-plastic soil (CH).
- If the pat can be broken with great effort, but cannot be powdered, it is highly-plastic soil (CL).
- If the pat can be broken and powdered with some effort, it is medium-plastic soil (CL).
- If the pat breaks easily and powders readily, it is slightly-plastic soil (ML, MH, or CL).
- If the pat has little or no dry strength and crumbles or powders when picked up, it is nonplastic soil (ML or MH) or (OL or OH).

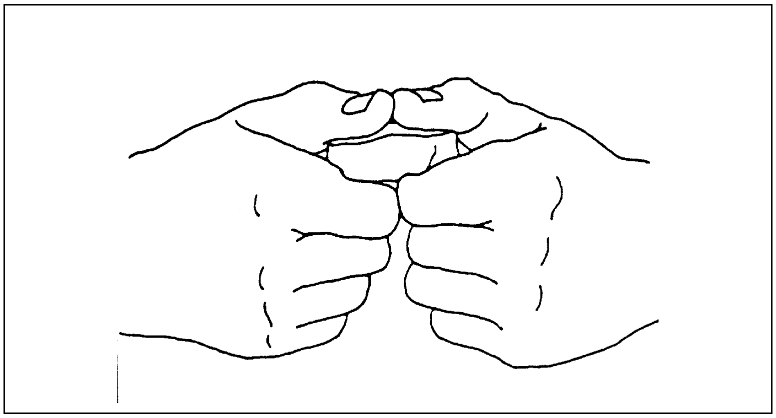


Figure 2-6. Breaking or dry-strength test

NOTE: Dry pats of highly-plastic clays often display shrinkage cracks. Breaking the sample along such a crack gives an indication of only a very small part of the soil's true dry strength. It is important to distinguish between a break along such a crack and a clean, fresh break that indicates the soil's true dry strength.

RIBBON TEST

The ribbon test is also performed only on material passing the No. 40 sieve. The sample is prepared as for the roll or thread test until the moisture content is just below the sticky limit. This test and the roll test complement each other and give a clearer picture of the soil.

Form a roll of soil 1/2 to 3/4 inch in diameter and 3 to 5 inches long. Lay the roll across the palm of one hand (palm up). Starting at one end, squeeze the roll between the thumb and forefinger over the edge of the hand to form a flat, unbroken ribbon about 1/8 to 1/4 inch thick. Allow the ribbon as formed to hang free and unsupported (see *Figure 2-7, page 2-26*). Continue squeezing and handling the roll carefully to form the maximum length of ribbon that can be supported only by the cohesive properties of the soil.

The results of this test indicate the following:

- If the sample holds together for a length of 8 to 10 inches without breaking, it is considered to be plastic having a high LL (CH).
- If the soil can be ribboned only with difficulty into 3- to 8-inch lengths, it is of low plasticity (CL).
- If the soil cannot be ribboned, it is nonplastic (ML) or (MH).

SHINE TEST

The shine test is another means of determining the soil's plasticity. A slightly moist or dry piece of highly-plastic clay (CH) produces a definite shine when rubbed with a fingernail or a smooth, metal surface such as a knife blade. Lean clay remains dull after this treatment (CL).

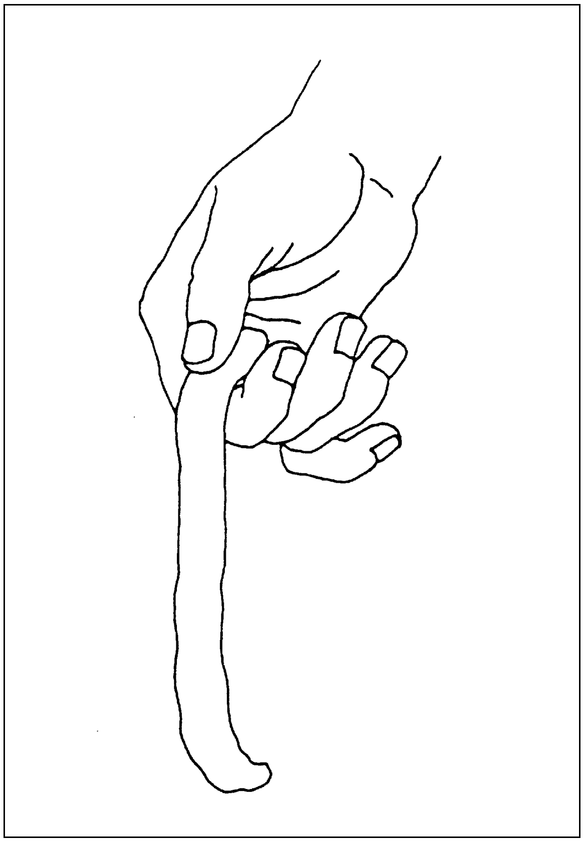


Figure 2-7. Ribbon test

SECTION II. SOIL SURVEYS AND SAMPLING

Surveying soil conditions at proposed military construction sites provides information about the nature, extent, and condition of soil layers; the position of the water table and drainage characteristics; and the sources of possible construction materials. A soil survey is vital to planning and executing military construction operations. The information obtained from a soil survey is the basis for a project's success.

TYPES OF SOIL SURVEYS

A soil survey consists of gathering soil samples for examining, testing, and classifying soils and developing a soil profile. The two types of soil surveys commonly associated with military construction are the hasty and deliberate surveys.

A hasty survey—made either under expedient conditions or when time is very limited—is a type of survey that usually accompanies a preliminary site analysis. A deliberate survey is made when adequate equipment and time are available. When possible, a hasty survey should be followed by a deliberate survey.

Hasty Survey

A hasty survey should be preceded by as careful a study of all available sources of information as conditions permit. If aerial observation is possible, a trained person may observe soil conditions in the proposed construction area. This gives a better overall picture, which is often difficult to secure at ground level because important features may be hidden in rough or wooded terrain. Rapid ground observation along the proposed road location or at the proposed airfield site also yields useful information. The soil profile may be observed along a stream's natural banks, eroded areas, bomb craters, and other exposed places. As construction proceeds, additional soil studies will augment the basic data gained through the hasty survey and will dictate necessary modifications in location, design, and construction.

Deliberate Survey

A deliberate survey does not dismiss the fact that the time factor may be important. Therefore, the scope of a deliberate survey may be limited in some cases. A deliberate survey is often performed while topographical data is being obtained so that the results of the soil survey may be integrated with other pertinent information. The principal method of exploration used in soil surveys for roads, airfields, and borrow areas is soil samples obtained either by using hand augers or by digging a test pit. Other methods that may be used are power-driven earth augers, sounding rods, or earthmoving equipment under expedient conditions to permit a hasty approach to the underlying soil.

OBJECTIVE OF A SOIL SURVEY

The objective of a soil survey, whether hasty or deliberate, is to explore and gather as much information of engineering significance as possible about the subsurface conditions of a specified area. The explorations are conducted to determine the—

- Location, nature, and classification of soil layers.
- Condition of soils in place.
- Drainage characteristics.
- Groundwater and bedrock.

Location, Nature, and Classification of Soil Layers

Information regarding the location, nature, and classification of soil layers is required for adequate and economical earthwork and foundation design of a structure. By classifying the soils encountered, a prediction can be made as to the extent of problems concerning drainage, frost action, settlement, stability, and similar factors. An estimate of the soil characteristics may be obtained by field observations, but samples of the major soil types and the less-extensive deposits that may influence design should be obtained for laboratory testing.

Condition of Soils in Place

Soil conditions, such as moisture content and density of a soil in its natural state, play an important part in design and construction. The moisture content may be so high in some soils in place that the selection of another site should be considered for an airfield or other structure. If the natural soil is dense enough to meet the required specifications, no further compaction of the subgrade is required. Very compact soils in cut sections may be difficult to excavate with ordinary tractor-scraper units, so scarifying or rooting may be needed before excavation.

DRAINAGE CHARACTERISTICS

Drainage characteristics in both surface and subsurface soils are controlled by a combination of factors, such as the void ratio, soil structure and stratification, the temperature of the soil, the depth to the water table, the height of capillary rise, and the extent of local disturbances by roots and worms. Remolding a soil also may change its drainage properties. Coarse-grained soils have better internal drainage than fine-grained soils. Observations of the soil should be made in both disturbed and undisturbed conditions.

GROUNDWATER AND BEDROCK

All structures must be constructed at such an elevation that they will not be adversely affected by the groundwater table. The grade line can be raised or the groundwater table lowered when a structure may be adversely affected by capillary rise or by the groundwater table itself. Bedrock within the excavation depth tremendously increases the time and equipment required for excavation. If the amount is very extensive, it may be necessary to change the grade or even the site location.

SOURCES OF INFORMATION

There are many sources of information available to soils engineers, and they should all be used to the fullest extent to eliminate as much detailed investigation as possible. These sources can be used to locate small areas within a large general area that are suitable for further investigation. Field information requires general observation of road cuts, stream banks, eroded slopes, earth cellars, mine shafts, and existing pits and quarries. A field party must obtain reliable data rapidly, since final decisions on site selection are based on field observations. These sources include—

- Intelligence reports.
- Local inhabitants.
- Maps.
- Aerial photographs.

INTELLIGENCE REPORTS

Intelligence reports that include maps and studies of soil conditions usually are available for areas in which military operations have been planned. Among the best and most comprehensive of these are the National Intelligence Surveys and Engineer Intelligence Studies. These reports are a source of information on geology, topography, terrain conditions, climate and weather conditions, and sources of construction materials.

LOCAL INHABITANTS

Local inhabitants (preferably trained observers), such as contractors, engineers, and quarry workers, may provide information to supplement intelligence reports or provide information about areas for which intelligence reports are unavailable. Data obtained from this source may include the possible location of borrow material, sand and gravel deposits, and peat or highly organic soils, as well as information on the area's climate and topography.

MAPS

Maps provide valuable information, especially when planning a soil survey. Maps showing the suitability of terrain for various military purposes, prepared by enemy or friendly foreign agencies, may be useful. Some of the maps that provide different types of information about an area under investigation are—

- Geological maps.
- Topographic maps.
- Agricultural soil maps.

Geological Maps

Geological maps and brief descriptions of regions and quadrangles are available from the *US Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202*. Generally, the smallest rock unit mapped is a formation, and a geological map indicates the extent of the formation by means of symbolic letters, colors, or patterns. Letter symbols on the map also indicate the locations of sand and gravel pits. The rear of the map sheet sometimes has a brief discussion entitled "Mineral Resources" that describes the location of construction materials.

Topographic Maps

Ordinary topographic maps may be helpful in estimating soil conditions, but they give only a generalized view of the land surface, especially when the contour interval is 20 feet or more. Therefore, they should be used with geological maps. An inspection of the drainage pattern and slopes can provide clues to the nature of rocks, the depth of weathering, soil characteristics, and drainage. For example, sinkholes may indicate limestone or glacial topography; hills and mountains with gently rounded slopes usually indicate deeply weathered rocks; and parallel ridges are commonly related to steeply folded, bedded rock with hard rock along the ridges. Features such as levees, sand dunes, beach ridges, and alluvial fans can be recognized by their characteristic shapes and geographic location.

Agricultural Soil Maps

Agricultural soil maps and reports are available for many of the developed agricultural areas of the world. These studies are concerned primarily with surface soils usually to a depth of 6 feet and are valuable as aids in the engineering study of surface soils. For example, if the same soil occurs in two different areas, it can be sampled and evaluated for engineering purposes in one area, and the amount of sampling and testing can then be reduced in the second area. Maps are based on field survey factors that include the careful study of the soil horizons in test pits, highway and railway cuts, auger borings, and other exposed places. Information on topography, drainage, vegetation, temperature, rainfall, water sources, and rock location may be found in an agricultural report. Soil usually is classified according to its texture, color, structure, chemical and physical compositions, and morphology.

AERIAL PHOTOGRAPHS

Aerial photographs may be used to predict subsurface conditions and previous explorations for nearby construction projects. The photographs aid in delineating and identifying soils based on the recognition of typical patterns formed under similar conditions of soil profile and weathering. Principal elements that can be identified on a photograph and that provide clues to the identification of soils to a trained observer are—

- Landforms.
- Slopes.
- Drainage patterns.
- Erosion patterns.
- Soil color.
- Vegetation.
- Agricultural land use.

Landforms

The landform or land configuration in different types of deposits is characteristic and can be identified on aerial photographs. For example, glacial forms such as moraines, kames, eskers, and terraces are readily identifiable. In desert areas, characteristic dune shapes indicate areas covered by sands subject to movement by wind. In areas underlaid by flat-lying, soluble limestone, the air photograph typically shows sinkholes.

Slopes

Prevailing ground slopes usually represent the soil’s texture. Steep slopes are characteristic of granular materials, while relatively flat and smoothly rounded slopes may indicate more plastic soils.

Drainage Patterns

A simple drainage pattern is frequently indicative of pervious soils. A highly integrated drainage pattern frequently indicates impervious soils, which in turn are plastic and lose strength when wet. Drainage patterns also reflect the underlying rock structure. For example, alternately hard and soft layers of rock cause major streams to flow in valleys cut in the softer rock.

Erosion Patterns

Erosion patterns provide information from the careful study of gullies. The cross section or shape of a gully is controlled primarily by the soil’s cohesiveness. Each abrupt change in grade, direction, or cross section indicates a change in the soil profile or rock layers. Short, V-shaped gullies with steep gradients are typical of cohesionless soils. U-shaped gullies with steep gradients indicate deep, uniform silt deposits such as loess. Cohesive soils generally develop round, saucer-shaped gullies.

Soil Color

Soil color is shown on photographs by shades of gray, ranging from white to black. Soft, light tones generally indicate pervious, well-drained soils. Large, flat areas of sand are frequently marked by uniform, light-gray tones; a very flat appearance; and no natural surface drainage. Clays and organic soils often appear as dark-gray to black areas. In general, sharp changes in the tone represent changes in soil texture. These interpretations should be used with care.

Vegetation

Vegetation may reflect surface soil types, although its significance is difficult to interpret because of the effects of climate and other factors. To interpreters with local experience, both cultivated and natural vegetation cover may be reliable indicators of soil type.

Agricultural Land Use

Agricultural land use also facilitates soil identification. For example, orchards require well-drained soils, and the presence of an orchard on level ground would imply a sandy soil. Wheat is frequently grown on loess-type soils. Rice is usually found in poorly draining soils underlain by impervious soils, such as clay. Tea grows in well-draining soils.

FIELD INVESTIGATIONS

A field investigation consists of the sampling operation in the field.

SAMPLING METHODS

The extent and methods of sampling used depend on the time available. Military engineers obtain samples from—

- The surface.
- Excavations already in existence.
- Test pits.
- Auger borings or holes.

In a hasty survey, the number of test pits and test holes is kept to a minimum by using existing excavations for sampling operations. In a deliberate survey, where a more thorough sampling operation is conducted, auger borings or holes are used extensively and are augmented by test pits, governed by the engineer's judgment. The following paragraphs describe this method of sampling.

Test Pit

A test pit is an open excavation large enough for a person to enter and study the soil in its undisturbed condition. This method provides the most satisfactory results for observing the soil's natural condition and collecting undisturbed samples. The test pit usually is dug by hand. Power excavation by dragline, clamshell, bulldozer, backhoe, or a power-driven earth auger can expedite the digging, if the equipment is available. Excavations below the groundwater table require pneumatic caissons or the lowering of the water table. Load-bearing tests can also be performed on the soil in the bottom of the pit. Extra precaution must be taken while digging or working in a test pit to minimize potentially fatal earth slides or cave-ins. The walls must be supported or sloped to prevent collapse. A good rule of thumb for sloping the pit sides is to use a 1:1 slope. For additional guidance on excavation, refer to Engineering Manual (EM) 385-1-1, Section 23B.

Auger Boring

A hand auger is most commonly used for digging borings. It is best suited to cohesive soils; however, it can be used on cohesionless soils above the water table, provided the diameter of the individual aggregate particles is smaller than the bit clearance of the auger. The auger borings are principally used at shallow depths. By adding pipe extensions, the earth auger may be used to a depth of about 30 feet in relatively soft soils. The sample is completely disturbed but is satisfactory for determining the soil profile, classification, moisture content, compaction capabilities, and similar soil properties.

Table 2-4 shows methods of underground exploration and sampling in a condensed form.

Table 2-4. Methods of underground exploration and sampling

Method	Materials in Which Used	Method of Advancing Hole	Sampling Method	Value for Foundation Purposes
Auger boring	Cohesive soils and cohesionless soils above ground-water elevation	Augers rotated until filled with soil and then removed to surface	Samples recovered from materials brought up on augers	Satisfactory for highway exploration at shallow depths
Well drilling	All soils, rock, and boulders	Churn drilling with power machines	Bailed sample of churned material or clay socket	Clay socket samples are dry samples. Bailed samples are of no value.
Rotary drilling	All soils, rock, and boulders	Rotating bits operating in a heavy, circulating liquid	Samples recovered from circulating liquid	Samples are of no value.
Test pits	All soils—lowering of groundwater may be necessary	Hand digging or power excavation	Samples taken by hand from original position in ground	Materials can be inspected in natural condition and place.

PREPARING SAMPLES

The location of auger holes or test pits depends on the particular situation. In any case, the method described in the following paragraphs locates the minimum number of holes. The completeness of the exploration depends on the time available. A procedure is described for road, airfield, and borrow-area investigations. Make soil tests on samples representing the major soil types in the area.

First, develop a general picture of the subgrade conditions. Conduct a field reconnaissance to study landforms and soil conditions in ditches and cuts. Techniques using aerial photographs can delineate areas of similar soil conditions. Make full use of existing data in agricultural spill maps for learning subsurface conditions.

Next, determine subgrade conditions in the area to be used for runway, taxiway, and apron construction. This usually consists of preliminary borings spaced at strategic points. Arbitrary spacing of these borings at regular intervals does not give a true picture and is not recommended. Using these procedures (especially the technique of identifying soil boundaries from aerial photographs) permits strategic spacing of the preliminary borings to obtain the most information with the least number of borings. In theater-of-operations (TO) cut areas, extend all holes 4 feet below the final subgrade elevation. In TO fill areas, extend all holes 4 feet below the natural ground elevation. These holes usually result in borings below the depth of maximum frost penetration (or thaw in permafrost areas). Where the above requirements do not achieve this result, extend the borings to the depth of maximum frost (or thaw in permafrost areas).

Obtain soil samples in these preliminary borings. After classifying these samples, develop soil profiles and select representative soils for detailed testing. Make test pits (or large-diameter borings) to obtain the samples needed for testing or to permit in-place tests. The types and number of samples required depend on the characteristics of the subgrade soils. In subsoil investigations in the areas of proposed pavement, include measurements of the in-place water content, density, and strength. Use these to determine the depth of compaction and the presence of any soft layers in the subsoil.

In borrow areas, where material is to be borrowed from adjacent areas, make holes and extend them 2 to 4 feet below the anticipated depth of borrow. Classify and test samples for water content, density, and strength.

Select material and subbase from areas within the airfield site and within a reasonable haul distance from the site. Exploration procedures for possible sources of select material and subbase are similar to those described for subgrades since the select material and subbase usually are natural materials (unprocessed). Test pits or large borings put down with power augers are needed in gravelly materials.

Base and pavement aggregates are materials that generally are crushed and processed. Make a survey of existing producers plus other possible sources in the general area. Significant savings can be made by developing possible quarry sites near the airfield location. This is particularly important in remote areas where no commercial producers are operating and in areas where commercial production is limited.

RECORDING SAMPLES

The engineer in charge of the soil survey is responsible for properly surveying, numbering, and recording each auger boring, test pit, or other investigation. Keep a log of each boring, showing the elevation (or depth below the surface) of the top and bottom of each soil layer, the field identification of each soil encountered, and the number and type of each sample taken. Include other information in the log that relates to the density of each soil, the changes in moisture content, the depth to groundwater, and the depth to rock. A typical boring log (as recorded on Department of Defense [DD] Form 2464) is shown in *Figure 2-8*.

OBTAINING REPRESENTATIVE SOIL SAMPLES

Planning the general layout determines the extent of the various soil types (vertically and laterally) within the zone where earthwork may occur. Large cuts and fills are the most important areas for detailed exploration. See Chapter 4 for procedures on obtaining soil or aggregate samples from a stockpile.

Place borings at high and low spots, in places where a soil change is expected, and in transitions from cut to fill. There is no maximum or minimum spacing requirement between holes; however, the number of holes must be sufficient to give a complete and continuous picture of the soil layers throughout the area of interest. As a general rule, the number of exploration borings required on a flat terrain with uniform soil conditions is less than in a terrain where the soil conditions change frequently.

Conduct exploration borings at the point of interest and locate them in a manner to get the maximum value from each boring. This may require exploration borings in the centerline as well as edges of runways or roads, but no specific pattern should be employed except perhaps a staggered or offset pattern to permit the greatest coverage. Exploration borings may be conducted at the edge of existing pavements, unless these pavements have failed completely. In this case, find the reason for the failure.

Purpose

Conduct exploration borings to—

- Obtain individual soil samples and a composite sample by investigating a borehole/test pit to a minimum depth of 4 feet.
- Prepare soil and moisture-content samples of each soil layer encountered for transportation.
- Record all information detailing the soils encountered, such as their location in the pit and the pit location within the excavation site, in a project log book.

Before beginning, ensure that digging is permitted at the testing site.

Steps

Perform the following steps to obtain a representative soil sample:

Step 1. Locate the boreholes or test pit. (The location of auger holes depends on the particular situation.)

a. Draw a site sketch recording the borehole's location, elevation, azimuth, and distance from a benchmark or reference point.

b. Determine and record a number for each borehole and record it on the diagram.

Step 2. Dig the borehole or test pit.

a. Remove the overburden.

REPORT OF FOUNDATION AND BORROW INVESTIGATION

1. PROJECT ENGINEER CENTER EXPANSION		2. DATE *(YYYYMMDD)*
3. JOB NUMBER 16-P-T	4. TEST SITE NORTH CORNER	5. LOCATION NORTH CORNER
6. TYPE OF EXPLORATION DELIBERATE	7. BORING NUMBER 5-C	8. GROUND ELEVATION 214.63'
9. PURPOSE OF EXPLORATION DETERMINE SOIL IN-PLACE USCS		

10. DEPTH BELOW SURFACE	11. ELEVATION	12. SAMPLE NUMBER	13. GRAPHIC LOG	14. GROUP SYMBOL	15. IN-PLACE CBR LIMITS	16. DESCRIPTION, TEST DATA, AND REMARKS
0.75'	213.88'	1		OH	7.6	DARK BROWN AND VERY PLASTIC. TYPICAL TOPSOIL OF THE AREA.
5.0'	209.63'	2		SC	34	LIGHT BROWN COARSE-GRAINED SANDY SOIL W/PLASTIC CLAY FINES. MAXIMUM PARTICLE SIZE 1 3/4". HIGH DRY STRENGTH. DENSE IN UNDISTURBED STATE.
6.0'	208.63'	3		CL	29	BROWN STICKY CLAY, VERY HIGH PLASTIC QUALITIES.
						BOTTOM OF HOLE

17. DEPTH TO WATER TABLE 4.73' ELEV = 209.90'	18. PREPARED BY *(Signature)* SGT Butler	19. CHECKED BY *(Signature)* SSG Dobbs WD

DD FORM 2464, DEC 1999 PREVIOUS EDITION IS OBSOLETE.

Figure 2-8. Typical boring log

b. Extend boreholes 4 feet below the final subgrade elevation in cut areas.

c. Extend boreholes 4 feet below the natural ground elevation in fill areas.

d. Make an effort to locate the groundwater table.

NOTE: The depth may be deeper depending on the depth of thaw penetration.

Step 3. Obtain an individual soil sample for each soil layer encountered (see *Figures 2-9* and *2-10*.)

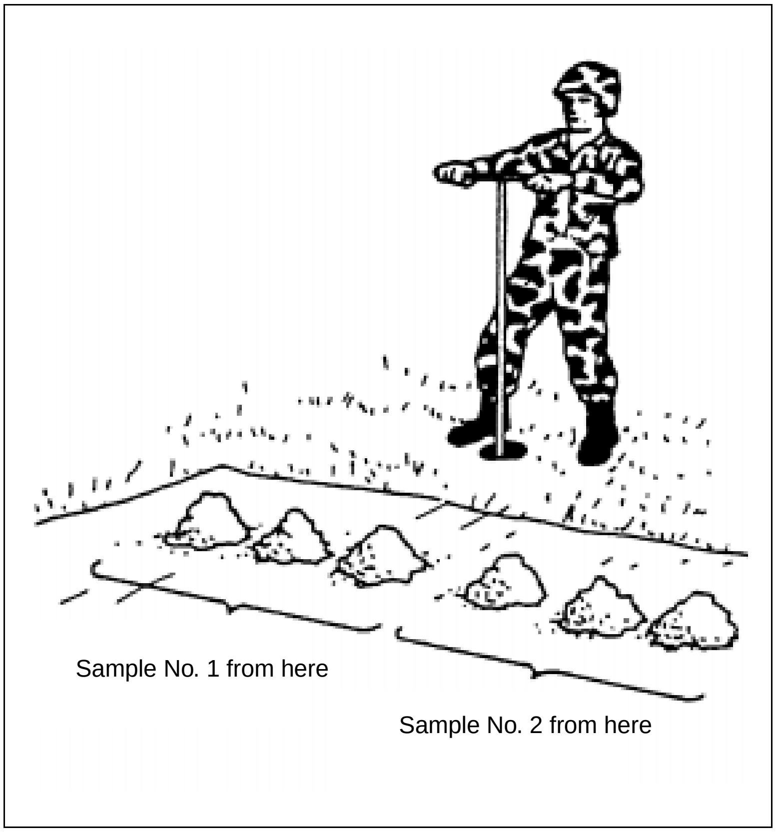


Figure 2-9. Obtaining individual bag samples

a. Place the soil from the borehole in a row in the order it was excavated, keeping soil layers separated for borings. If in a test pit, obtain samples from each layer encountered.

b. Obtain moisture-determination samples from each soil layer, ensuring that the moisture-tare sample number corresponds with the soil-sample bag number when labeled.

Step 4. Obtain data on the borehole and record the information.

a. Determine the elevation or depth below the surface of the top and bottom of each soil layer encountered.

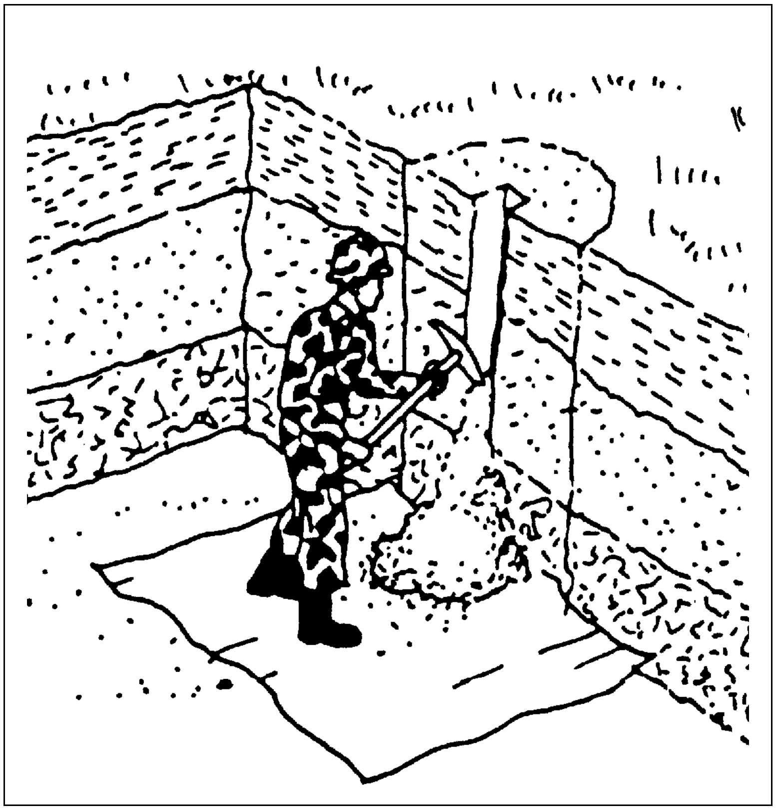


Figure 2-10. Taking a composite sample with an exposed face

b. Record a description of the type of soil encountered.

c. Record the depth of the water table, if encountered.

d. Record the depth of bedrock, if encountered.

e. Record other pertinent facts such as borehole number, date, noncommissioned officer in charge (NCOIC), project number, and project location.

Step 5. Bag individual soil samples for transportation.

a. Place each soil layer encountered in separate bags. For a deliberate survey, ensure that there is enough material to perform the testing required (at a minimum, the sieve-analysis, LL, PL, and compaction tests).

b. Label two shipping tags for each bag, indicating the project, borehole, and sample numbers (indicating the order in which it was obtained) and the total number of bags included in the sample.

c. Place one tag inside the bag and tie the other to the outside when the bag is secured (see *Figure 2-11, page 2-38*).

Step 6. Take a composite sample.

a. Remove any overburden or surface soil that is to be wasted.

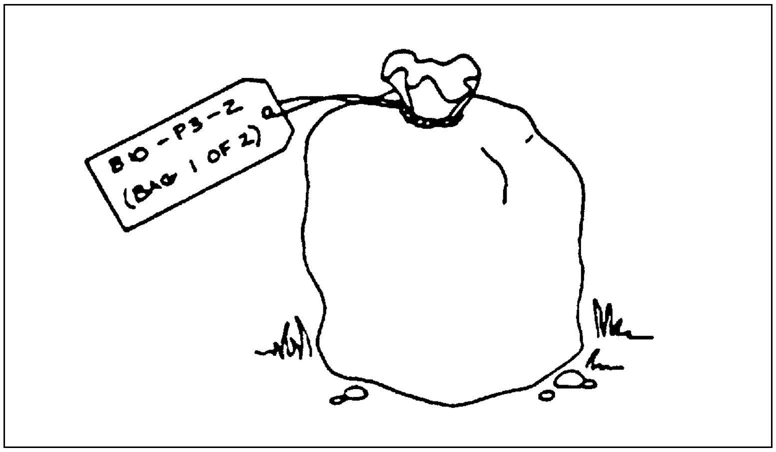


Figure 2-11. Labeling bag samples

b. Shave off any loose or dried material to provide a fresh face.

c. Spread a quartering cloth or tarpaulin at the toe of the bank.

d. Cut a channel of uniform cross section from top to bottom and deposit the soil on the canvas.

e. Bag all material that was removed to ensure that the sample contains the appropriate proportions.

NOTE: It is important that sample numbering be recorded carefully and accurately so that the diagram borehole number, sample bags, and moisture tares all correspond.

MOISTURE-CONTENT SAMPLES

Soil's natural moisture content is determined from samples taken in the field and placed in a container that is sealed to prevent moisture loss by evaporation. Natural moisture-content determinations are valuable in interpreting information obtained from test borings or pits, in drawing the soil profile, and in estimating the physical properties of soils encountered in the field. Generally, 100 grams of soil are enough to determine the moisture content of fine-grained soils. Larger samples are required for soils that contain gravel. The soil test set contains three sizes of metal dishes that have tight-fitting covers and do not require sealing if the test is made within one day after the sample is taken. If a longer time interval elapses between sampling and testing, the boxes may be sealed by the method shown in *Figure 2-12*. Other clean containers that can be sealed adequately may be used for moisture-content samples.

UNDISTURBED SAMPLES

Undisturbed soil samples are those in which the natural structures, void ratio, and moisture content are preserved as carefully as possible. They are cut, removed, and packed with the least possible disturbance. Samples of this type are used for determining the density (unit weight) of soil in the laboratory and for investigating the strength of undisturbed soils in the laboratory by the CBR or unconfined compression tests. These samples may be shipped to more

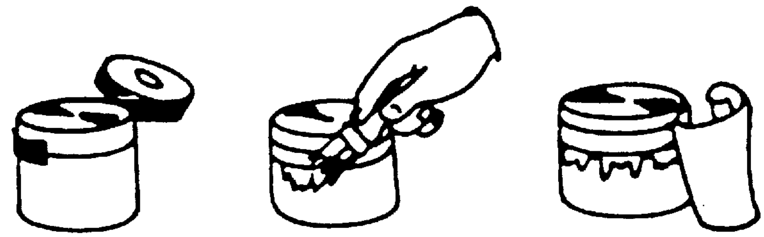


Figure 2-12. Sealing a container to retain a sample's moisture content

completely equipped laboratories for shear, consolidation, or other strength tests.

The types of undisturbed samples are—

- Chunk.
- Cylinder.

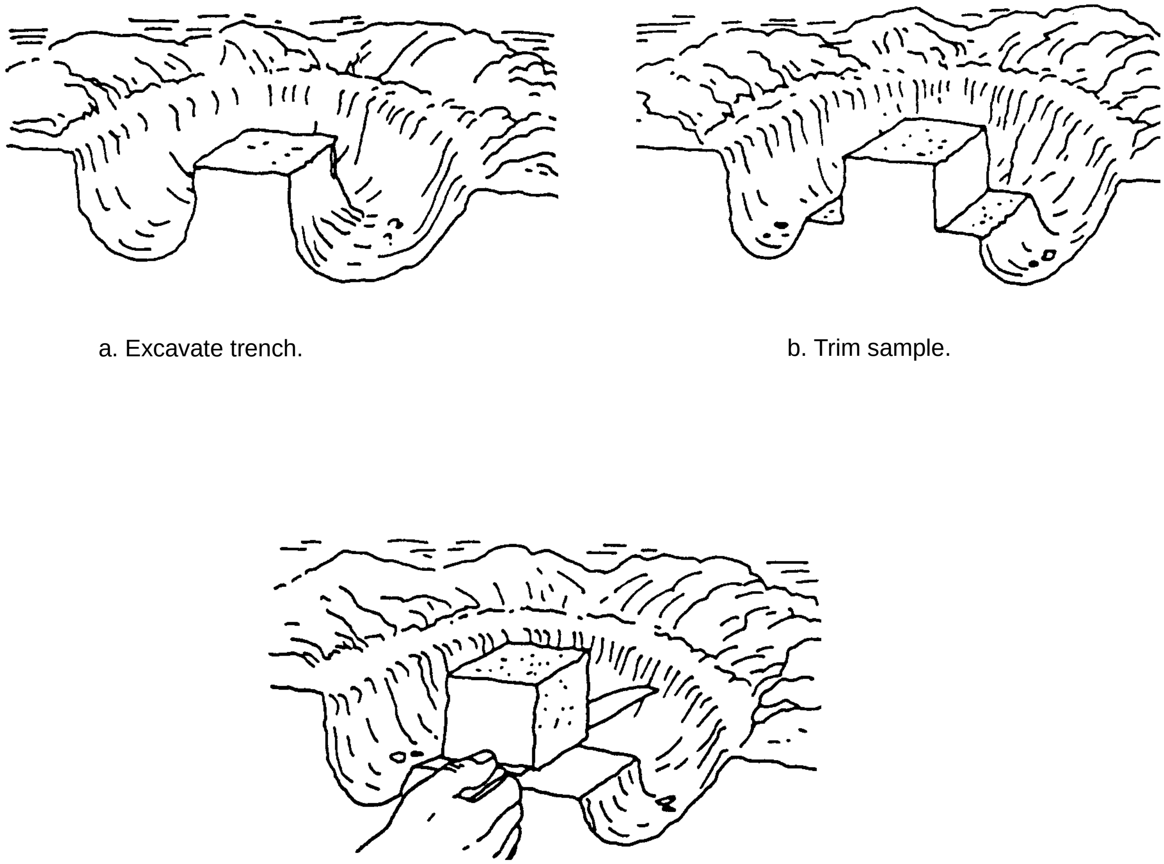
Choose the method of sampling based on the equipment available, the tests required, and the type of soil. Handle all undisturbed samples with care. Keep cohesionless soil samples in the container until ready for testing. Handle the container without jarring or vibration. Some soils are too hard or contain too many stones to permit sampling with the cylindrical samplers and can be sampled only by cutting out chunks by hand. Taking undisturbed samples frequently requires a great deal of ingenuity in adapting the sampling devices to job conditions and in devising schemes for their use. Whatever method is used, pack the sample in the container for shipment without allowing its structure to change. Protect the sample against change in moisture content during sampling and shipment.

CHUNK SAMPLES

Obtain the simplest type of undisturbed sample by cutting out a chunk of soil the desired size; cover it to prevent loss of moisture and breakage. Use this method only with soils that will not deform, break, or crumble while being removed. Cut chunk samples by hand with a shovel and knife.

The process of obtaining a chunk sample from a subgrade or other level surface, such as the bottom of a test pit, is shown in *Figure 2-13, page 2-40*. The first step is to smooth the ground surface and mark the outline of the chunk. Excavate a trench around the chunk (see *Figure 2-13a*), then deepen the excavation and trim the sides of the chunk with a knife (see *Figure 2-13b*). Cut off the chunk at the bottom with a knife, trowel, or hacksaw blade, and carefully remove it from the hole (see *Figure 2-13c*).

To obtain a chunk sample from the vertical face of a test pit or trench, carefully smooth the surface of the face and mark the outline of the chunk (see *Figure 2-14, page 2-41*). Excavate soil from the sides and back of the chunk



a. Excavate trench.

b. Trim sample.

c. Cut off and remove.

Figure 2-13. Taking a chunk sample from a level surface

(see *Figure 2-14a*). Shape the chunk with a knife (see *Figure 2-14b*), then cut off the chunk and carefully remove it from the hole (see *Figure 2-14c*).

Seal the chunk sample after removing it from the hole. One method is to apply three coats of melted paraffin (see *Figure 2-15*). Allow each coat to cool and become firm before applying the next coat. This gives adequate protection for strong samples that are to be used within a few days. Samples that are weak or that may not be used soon require additional protection. Wrap them with cheesecloth or other soft cloth and seal them in paraffin (see *Figure 2-16, page 2-42*). If cloth is not available, reinforce the sample with several loops of friction tape or twine, and apply three more coats of paraffin. Use extreme care to prevent damaging the sample while performing these operations.

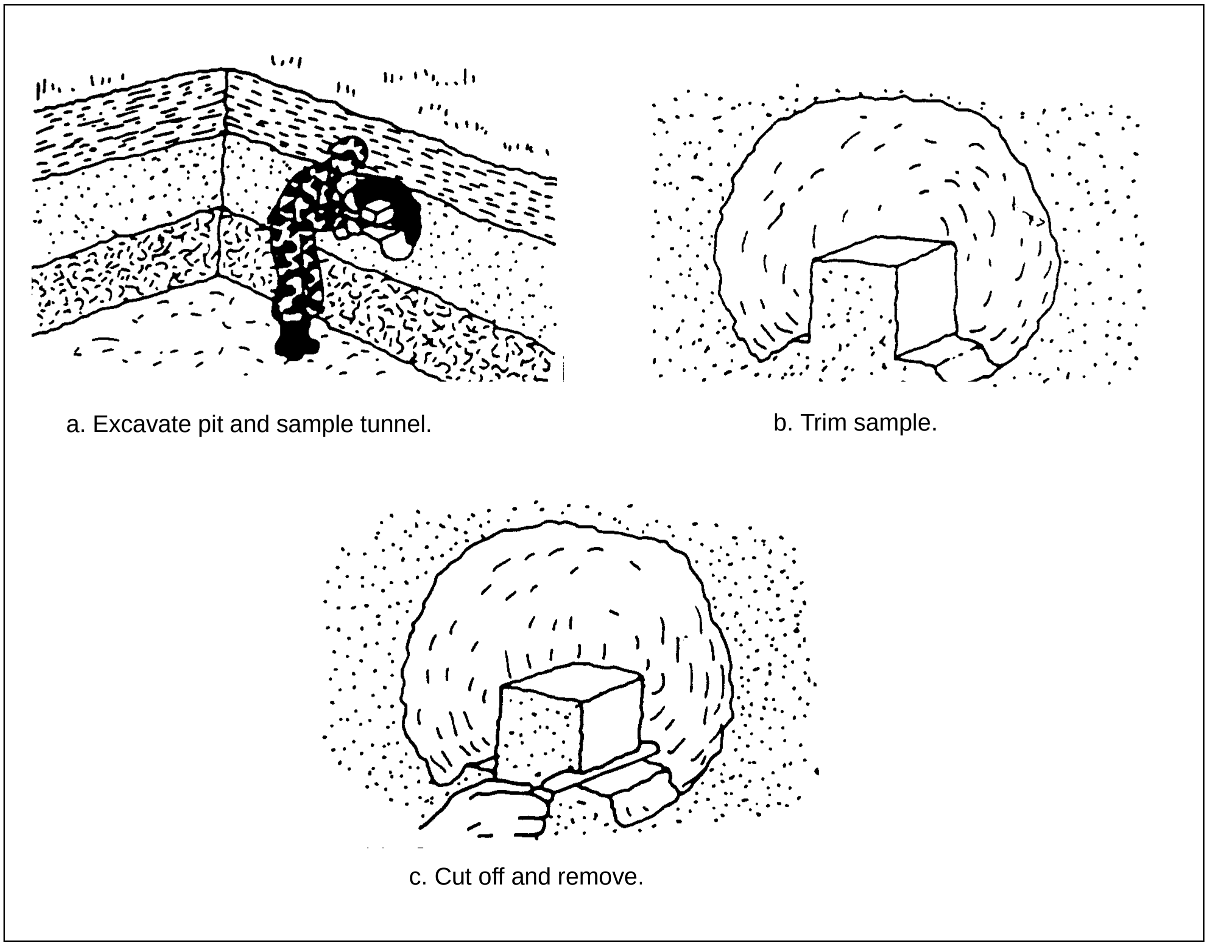


Figure 2-14. Taking a chunk sample from a vertical face

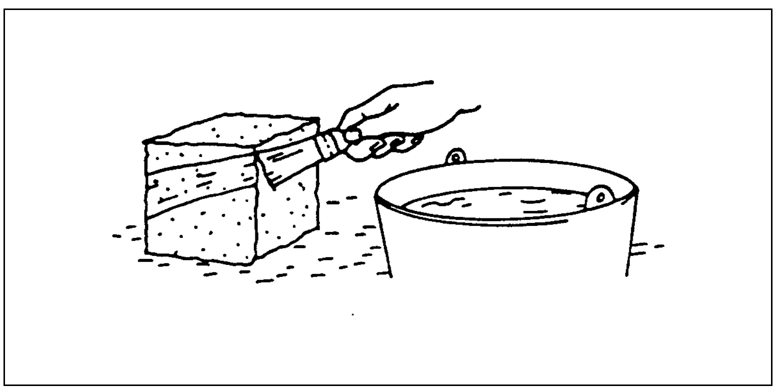


Figure 2-15. Applying paraffin to seal a chunk sample

An alternate method of sealing the chunk sample is to dip the entire sample in melted paraffin after the first brush coat has been applied and the sample has been wrapped (see *Figure 2-17, page 2-42*). This requires a large container and

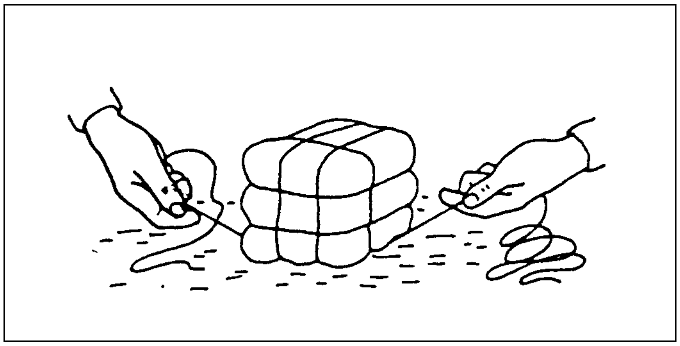


Figure 2-16. Wrapping a weak chunk sample before final sealing

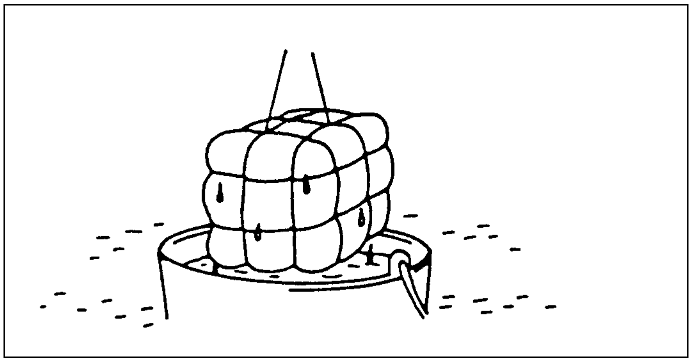


Figure 2-17. Dipping a chunk sample into melted paraffin

more paraffin but gives a more uniform coating. Build up the layer of paraffin to a minimum 1/8 inch thickness by dipping repeatedly. Provide additional protection for samples that are to be shipped by placing the chunk in a small box and packing (see *Figure 2-18*) or by applying many coats of cloth and paraffin.

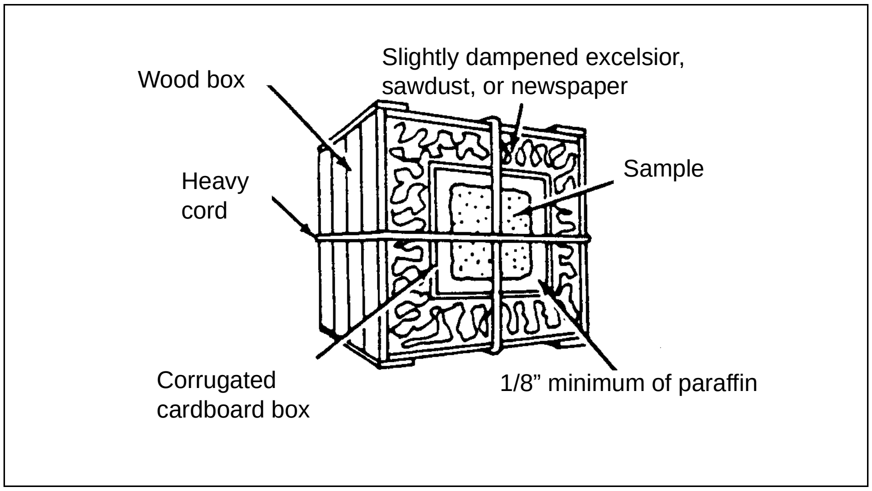


Figure 2-18. Packing a chunk sample for transportation or shipment to laboratory

CYLINDER SAMPLES

Obtain cylinder samples by using a cylindrical sampler or the CBR mold equipped with a sampling cutter. Expedient methods of obtaining cylinder samples are also used.

Soil-Trafficability Sampler

The soil-trafficability sampler consists of a cylindrical sample tube and an assembly to force the tube into the soil (see *Figure 2-19*). It is forced by hand pressure, not by blows from a hammer. A movable piston is fitted within the cylinder and attached to a rod that extends through the center of the drive tube and terminates in a flat dish or baseplate at the upper end. The outer drive tube is attached to the sample cylinder at the bottom and has two handles at the top. One of the handles is knurled and can be turned to lock the inner rod when the piston is in position. A long and a short spacer bar are bolted to the outer tube and used to establish the size of the sample core. The sampler should not be used for other than extremely soft and yielding soils. The walls of the cylinder are very thin and can be deformed if they come in contact with a hard object. Even hard or dry soil can damage the sampler. Its primary use is for samples to test the remolding characteristics in soils having initially low or very low supporting value. Additional information on the soil-trafficability sampler and soil-trafficability test set can be found in FM 5-430-00-1.

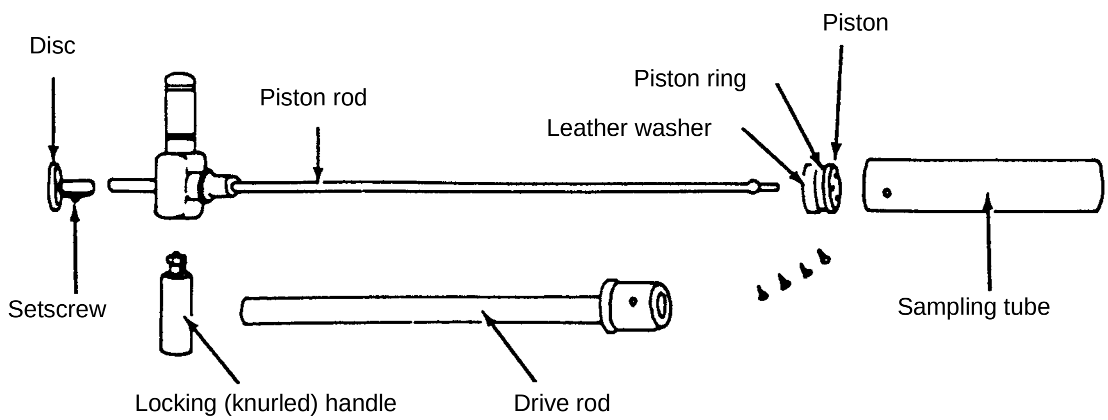


Figure 2-19. Soil-trafficability sampler

Perform the following steps for taking cylinder samples using a soil-trafficability sampler:

Step 1. Adjust the piston so it is flush with the sampler cylinder's cutting edge. Lock the knurled handle.

Step 2. Place the sampler firmly in contact with the soil to be sampled.

Step 3. Hold the disk at the top to prevent vertical movement, unlock the knurled handle, and force the sampler cylinder into the soil.

Step 4. Ensure that the cylinder is fully in the soil; then lock the knurled handle to clamp the piston, and keep the soil sample from slipping out due to the vacuum created.

Step 5. Rotate the entire sampler a half turn to shear the soil at the base of the cylinder; then carefully withdraw it from the hole and invert it so that the dish becomes a baseplate. There is a spud on the side of the sampler for releasing the side friction and the vacuum caused by withdrawing the sampler from the ground.

Step 6. Swing the longer spacer bar into position to act as a stop while the piston ejects the sample.

Step 7. Release the knurled handle, and push the drive tube until the spacer bar hits the baseplate and a portion of the sample is pushed up out of the cylinder.

Step 8. Cut and discard the portion of the sample flush with the cutting edge of the sampler. This amount of soil discard offsets any uneven shearing at the bottom of the hole and gives the soil sample a true cylindrical shape.

Step 9. Swing the short spacer bar into position and move the long bar out of the way.

Step 10. Eject the soil sample until the short bar stops the action. A portion of the soil sample will still be in the cylinder.

Step 11. Cut off the soil sample flush with the sampler's cutting edge into a preformed plate made to fit around the cutter. Use the sample cutter (piano wire) for this operation. The sample is now exactly 1.87 inches in diameter and 3.45 inches long.

Step 12. Discard the remaining soil in the sampler.

This sampler can be used with a hand auger to obtain cores at depths up to 48 inches below the surface. The cores are sealed.

The soil-trafficability sampler requires proper maintenance and adjustment to produce consistent results. Keep the inside of the sampling tube, the piston tube, the piston ring, and the leather washer reasonably clean. After 5 to 25 samplings (depending on the type of soil), immerse the tube, first in water and then in fuel oil, and work the piston up and down five or six times in each liquid. After wiping off the excess fuel oil, squirt light machine oil into the tube. If the instrument becomes stiff and hard to work, remove the tube, disassemble and thoroughly clean the piston, and oil the leather washer. Take care in removing the tube to prevent its slipping from the head suddenly and bending the piston rod. The tube walls and cutting edges are relatively soft and should be handled with care.

Adjust the effective piston-rod length to keep the face of the piston flush with the tube's cutting edge when the piston-rod handle (disk) is fully depressed. Do this by loosening the setscrew on the handle, screwing the handle up or down to the correct position, and retightening the setscrew.

CBR Mold

In soft, fine-grained soils, cylinder samples for undisturbed CBR or density tests may be taken directly in the CBR compaction cylinder by using the sampling collar (cutter) (see *Figure 2-20*). Perform the following steps using a CBR mold:

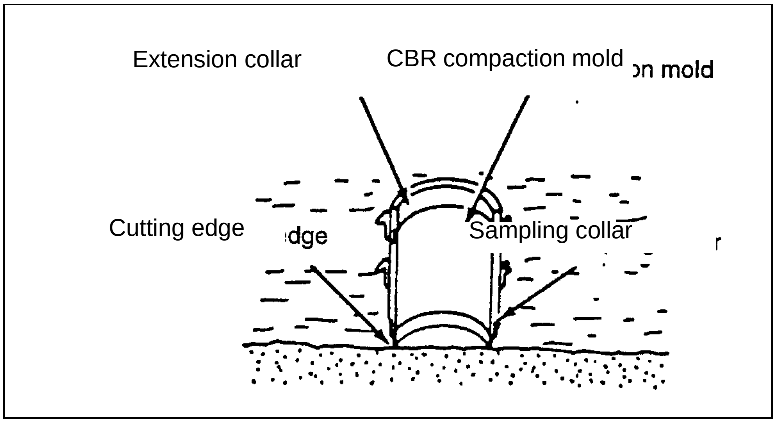


Figure 2-20. Section through CBR mold

Step 1. Smooth the surface of the ground and press the sampling collar and mold into the soil with moderate pressure.

Step 2. Excavate a trench around the cylinder (see *Figure 2-21*).

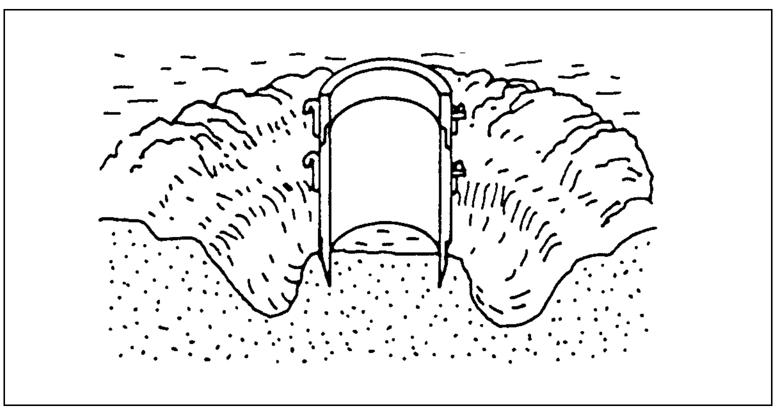


Figure 2-21. Trench excavated around cylinder

Step 3. Press the mold down firmly over the soil again, using the hand driver or loading bar if necessary (see *Figure 2-22*, *page 2-46*). A loading bar may be improvised from any piece of timber of suitable size.

Step 4. Trim the soil away from the sampling collar with a knife, cutting downward and outward to avoid cutting into the sample. The actual cutting to size is done with the sampling collar. The sampler may be forced down with the truck jack, if available. In either case, do not force the sampler down ahead of the trimming on the outside of the cylinder.

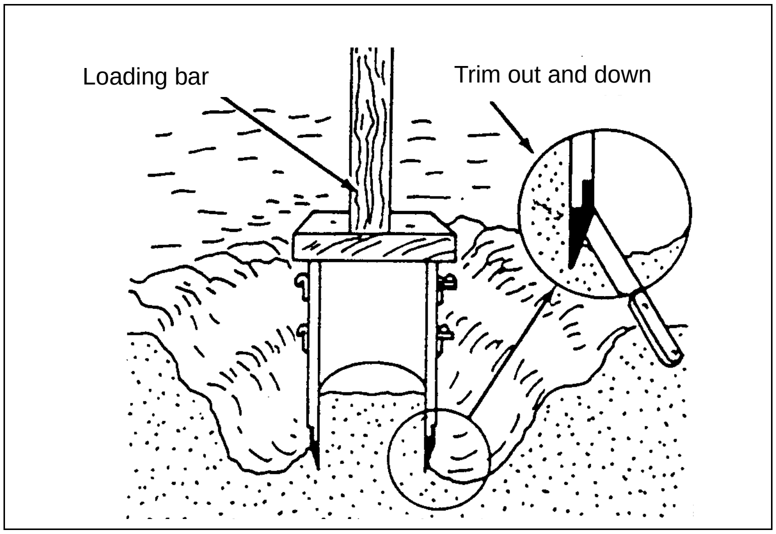


Figure 2-22. Using load bar to drive cylinder

Step 5. Excavate the trench deeper and repeat the process until the soil penetrates well into the extension collar (see *Figure 2-23*). If stones interfere, pick them out carefully and fill the space with soil. Record this fact in the log of the sample where it is pertinent.

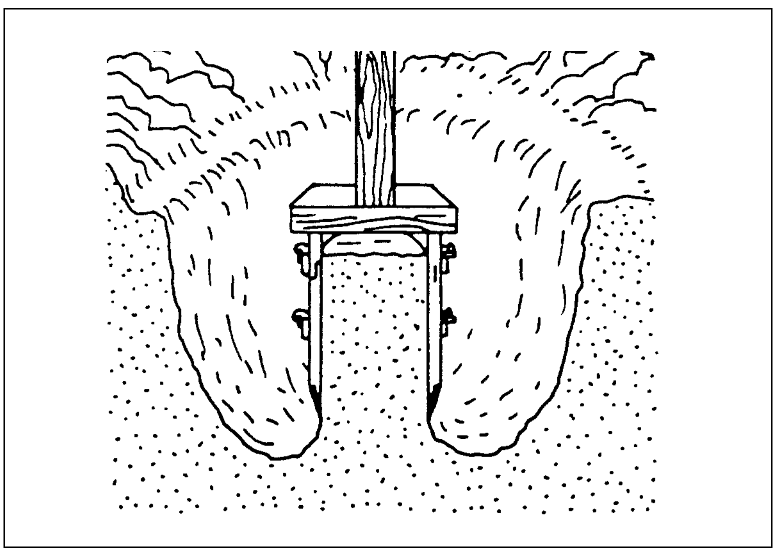


Figure 2-23. Cylinder in position before cutting sample

Step 6. Cut the sample off at the bottom of the mold using a shovel, knife, or wire saw (see *Figure 2-24*).

Step 7. Remove the mold and sample from the hole.

Step 8. Remove the upper collar, and trim the top surface of the sample about 1/2 inch down into the mold. Fill this recess with paraffin to seal the end of the sample (see *Figure 2-25*).

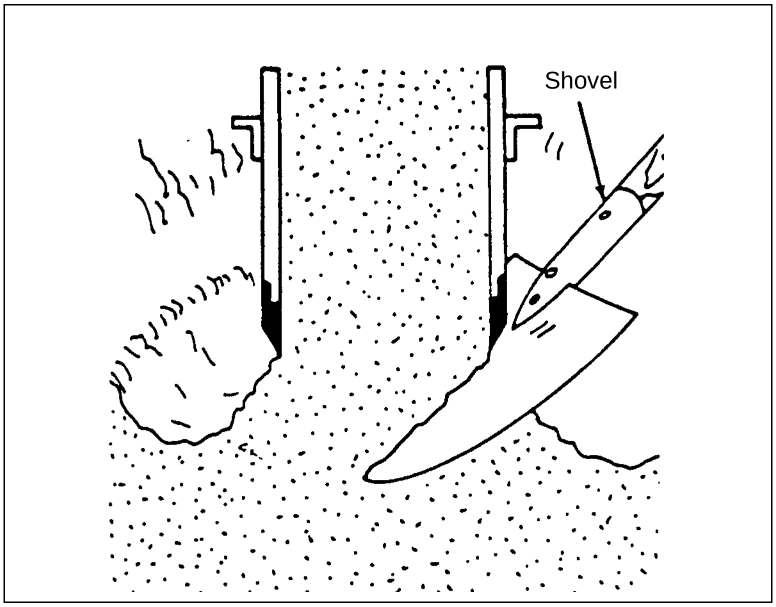


Figure 2-24. Cutting off cylindrical sample

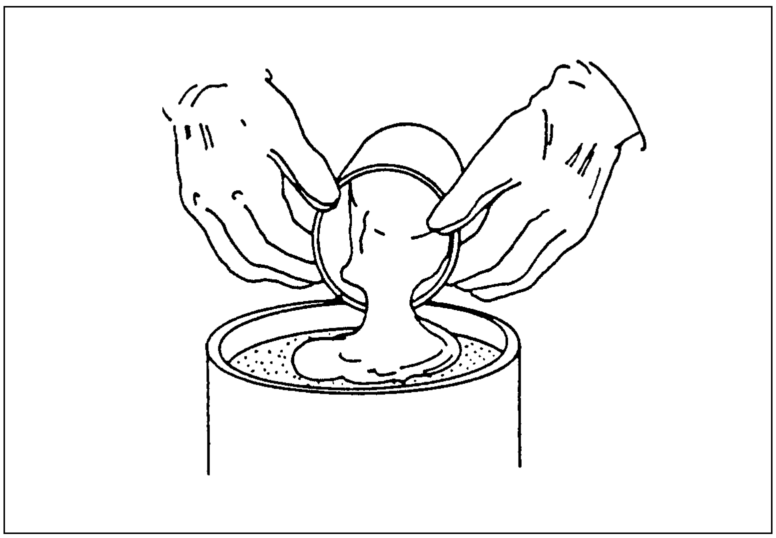


Figure 2-25. Cylinder in position before cutting sample

Step 9. Turn the mold over and remove the cutting edge. Trim this end down into the mold about 1/2 inch, as before, and fill the resulting space with paraffin. If the sample is to be handled very much before testing, overfill the ends with paraffin and then trim it exactly flush with a straightedge.

Step 10. Place boards over each end, and clamp them in place using bolts, wire, or string (see *Figure 2-26, page 2-48*).

Step 11. Wrap the samples in cloth, and soak them in paraffin layers if they must be transported some distance or if they have to be handled quite a bit before testing.

Figure 2-26. Protecting a sample in a CBR mold

QUARTERING SAMPLES

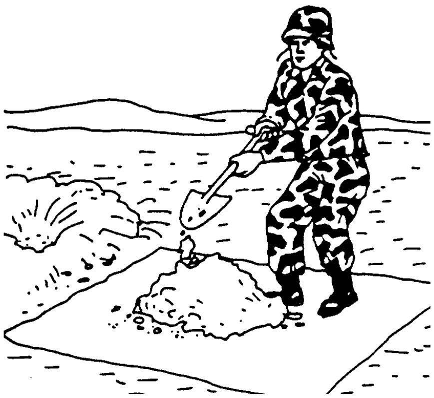
The process of reducing a representative sample to a convenient size, or of dividing a sample into two or more smaller samples for testing, is called quartering. The procedure to be used varies somewhat, depending on the size of the sample.

SAMPLES WEIGHING OVER 100 POUNDS

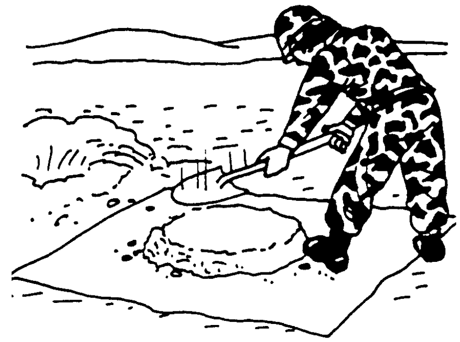
Quartering a sample in excess of 100 pounds is shown in *Figure 2-27*. First, mix the sample and pile it on the quartering canvas (see *Figure 2-27a*). Place each shovelful in the center of the cone so that the soil runs down evenly in all directions to mix the sample. Flatten the cone with the shovel, spreading the material to a circular layer of uniform thickness (see *Figure 2-27b*). Insert a stick or pipe under the center of the pile (under the canvas) and lift both ends of the stick, thus dividing the sample into two parts (see *Figure 2-27c*). Remove the stick, leaving a fold in the canvas. Insert the stick under the pile (this time at right angles to the first division) and lift again, dividing the sample into four parts (see *Figure 2-27d*). Discard the two diagonally opposite quarters and carefully clean the fines from the canvas. Remix the remaining material by taking alternate shovelfuls from each quarter. Repeat the quartering process as necessary to reduce the sample to the desired size.

SAMPLES WEIGHING 25 TO 100 POUNDS

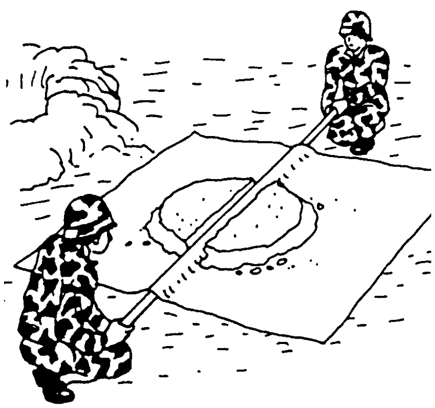
To quarter samples weighing 25 to 100 pounds, pile the soil on the canvas and mix it by alternately lifting the corners of the canvas and pulling over the samples as if preparing to fold the canvas diagonally, as illustrated in *Figure 2-28, page 2-50*. Then flatten and quarter the sample.



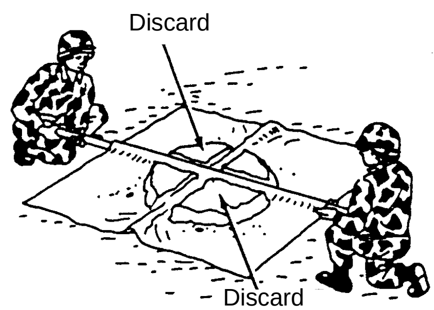
a. Mixing and piling a sample weighing more than 100 pounds



b. Flattening sample to uniform thickness



c. Halving the sample



d. Quartering the sample

Figure 2-27. Samples weighing more than 100 pounds

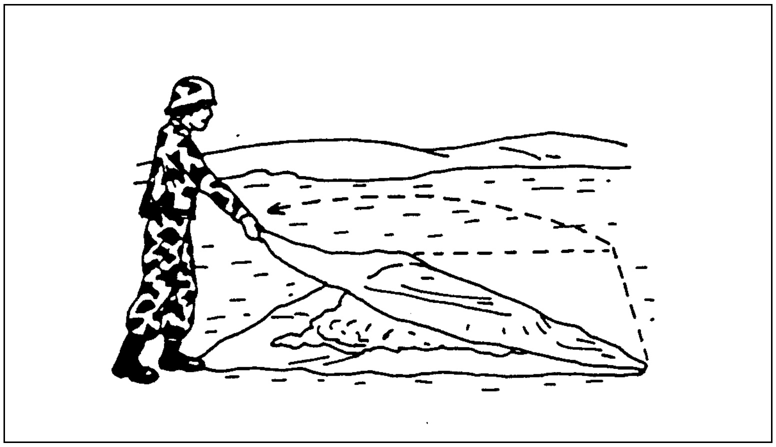


Figure 2-28. Mixing a sample weighing 25 to 100 pounds

SAMPLES WEIGHING LESS THAN 25 POUNDS

The process of quartering samples less than 25 pounds is similar to the process for 100 pounds and more. Place the sample on the canvas or a clean sheet of paper. Mix it thoroughly with a trowel and form it into a conical pile (see *Figure 2-29a)*. Flatten the cone by pressing downward with the trowel (see *Figure 2-29b*). Use the trowel to divide the sample into quarters. Discard diagonally opposite quarters (see *Figure 2-29c*). Repeat the process as necessary to reduce the size of the sample for testing.

THE SOIL PROFILE

Keep a detailed field log of each auger boring or test pit made during the soil survey. After completing the survey, consolidate the information contained in the separate logs. In addition to the classification and depth of soil layers recorded in each log, show the natural water contents of fine-grained soils along the side of each log. Also note the elevation of the groundwater table. Determine the elevation during the soil survey by observing the level at which free water stands in the borings. To get an accurate determination, cover holes and inspect them 24 hours after being dug. This allows the water to reach its maximum level. The soil profile is a graph of a vertical cross section of the soil layers from the surface of the earth downward (see *Figure 2-30, page 2-52*).

PURPOSE

The soil profile has many practical uses in locating, designing, and constructing roads, airfields, and structures. It has a great influence in the location of the grade line, which should be placed to take full advantage of the best soils available at the site. The profile shows whether soils to be excavated are suitable for use in embankments or if borrow soils are required. It may show the existence of undesirable conditions, such as peat or organic matter or bedrock close to the surface, which will require special construction measures. It aids in planning drainage facilities to take advantage of the presence of well-draining soils. It may indicate that special drainage installations will be needed with soils that are difficult to drain, particularly in areas where the

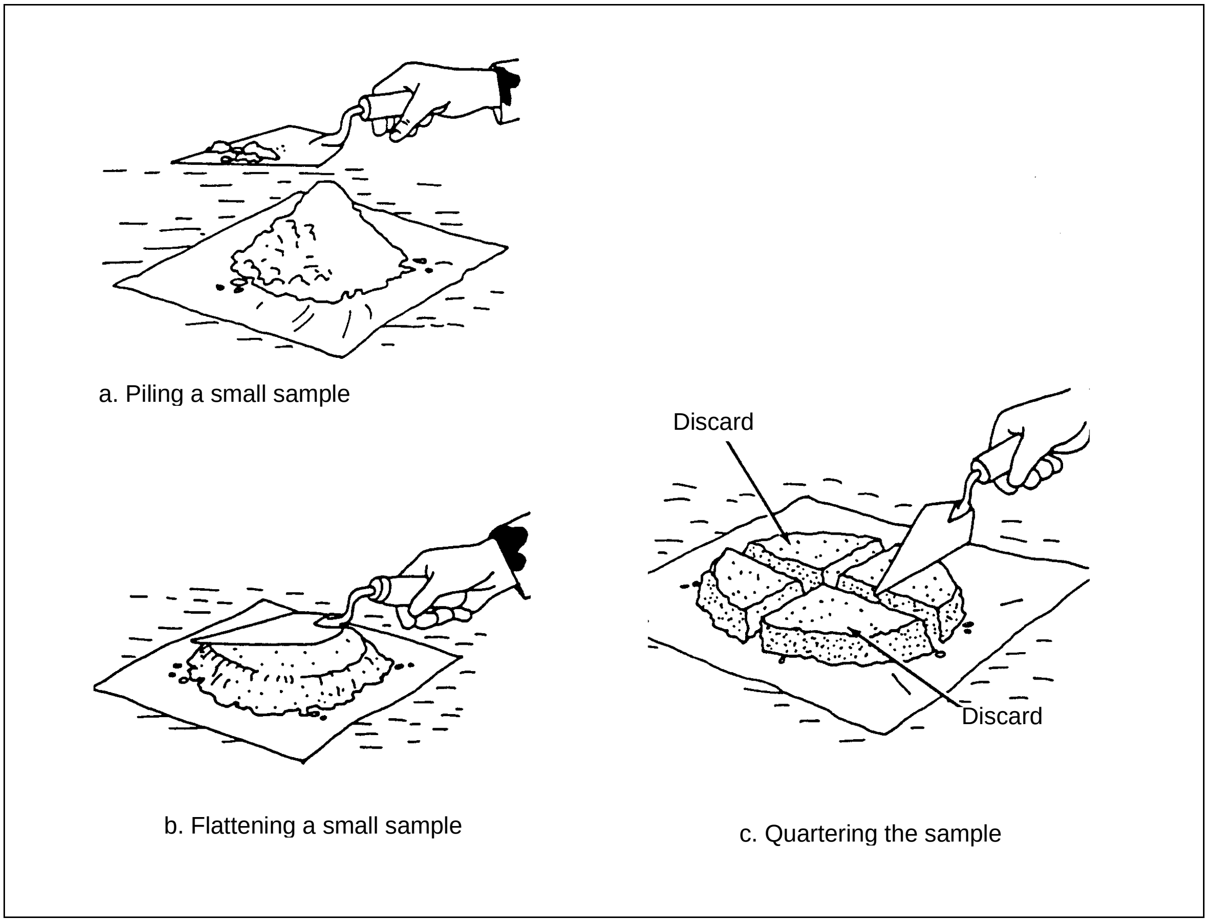


Figure 2-29. Mixing a sample weighing less than 25 pounds

water table is high. Considerations for capillary and frost action may be particularly important when frost-susceptible soils are shown on the profile.

The soil profile, including the legend, will show each soil layer, water table, and the relative elevation to within ± 1 foot. Locate the holes horizontally to within one half of the smallest dimension of the scale used. The boreholes will be sketched in with appropriate soil symbol hatchings for each layer.

EQUIPMENT

Use the following items in a laboratory environment to obtain a soil profile:

- Boring logs.
- Graph paper.
- Pencils.
- A straightedge.
- FM 5-430-00-1.

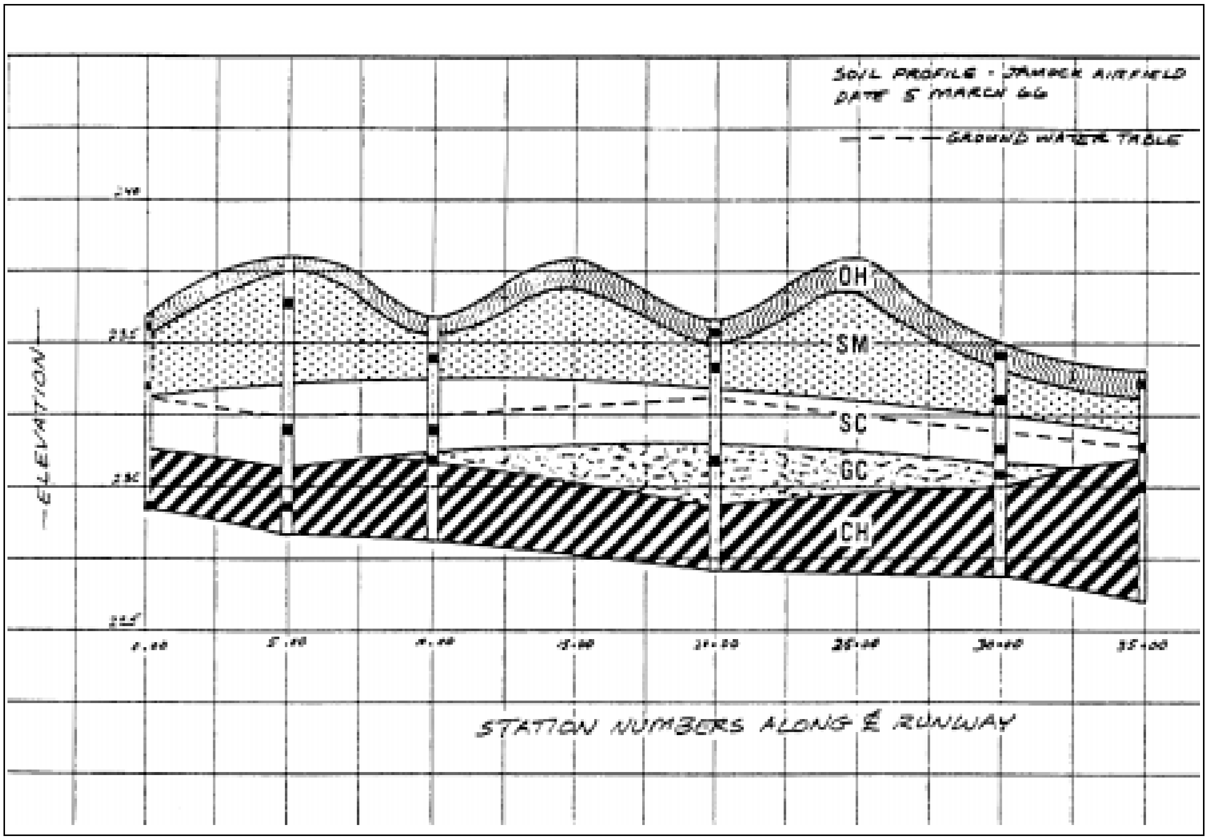


Figure 2-30. Typical soil profile

STEPS

Perform the following steps to obtain a soil profile:

Step 1. Determine the scales to be used (see *Figure 2-31).*

a. Determine and label (along the left side of the graph paper) the vertical scale representing the highest and lowest elevations found in the bore logs.

b. Determine and label (along the bottom of the graph paper) the horizontal scale representing the stations that cover the area where borings have been made.

Step 2. Plot the boreholes and mark the depth for each soil layer of each borehole.

Step 3. Draw the representing soil hatching symbol for each soil layer. The symbols taken from bore logs are located in FM 5-430-00-1.

Step 4. Connect the soil layers from borehole to borehole with a solid line. Connect the bottoms of the boreholes with a dashed line.

Step 5. Label each soil layer with a soil-group symbol in the USCS and a color (use the symbols from *Table B-2, pages B-6 and B-7,* or *Table B-3, pages B-16 and B-17*).

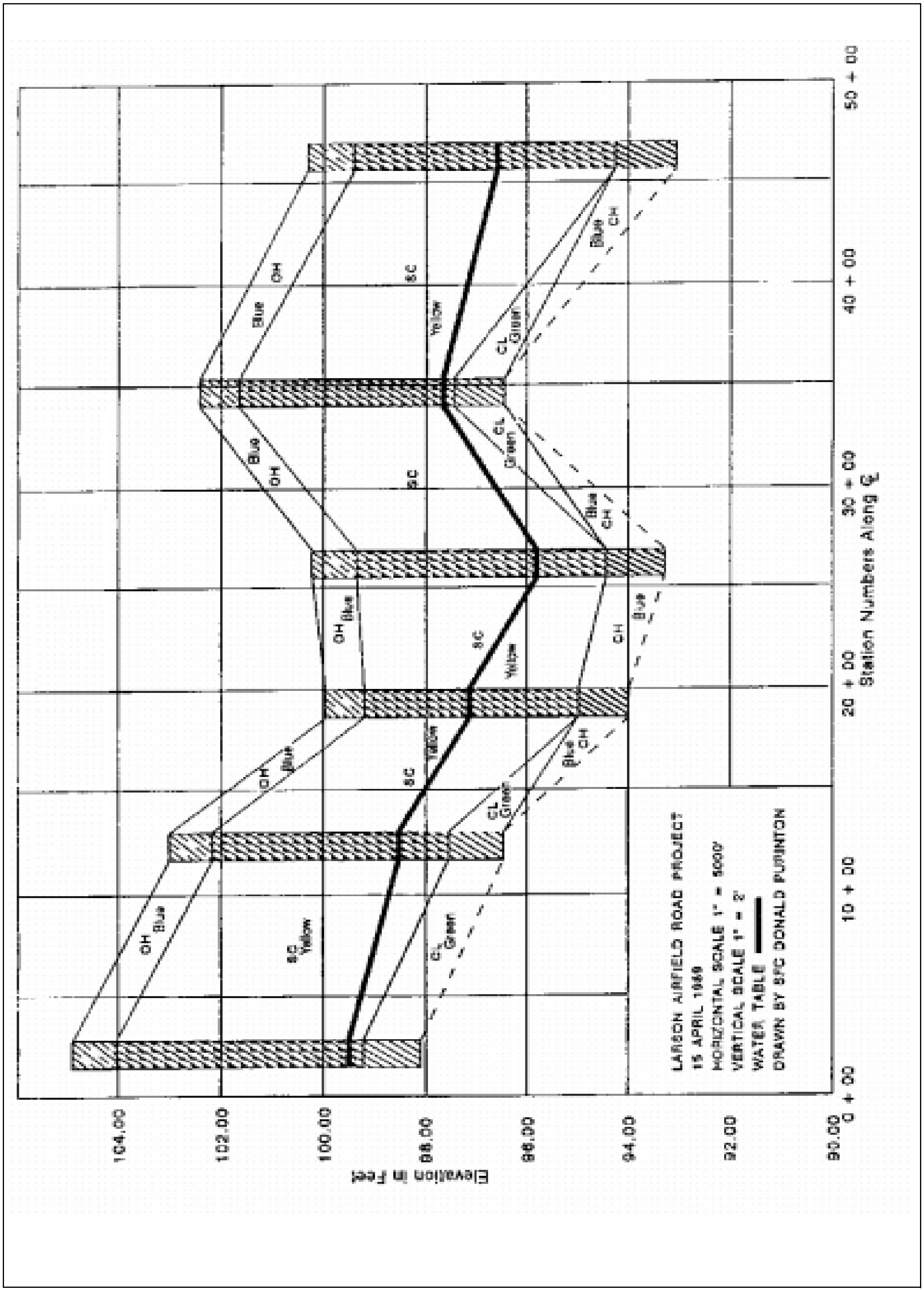


Figure 2-31. Soil-profile scales

Step 6. Plot the depth of water at each borehole and connect the points (with a solid, heavy line) together showing the water-table profile.

Step 7. Place the legend in a corner of the graph paper, including the following:

a. The horizontal and vertical scales.

b. The line symbol for the water table.

c. The project title and location.

d. The name of the preparer and the date prepared.

SECTION III. MOISTURE-CONTENT DETERMINATION

The soil's moisture content (also referred to as water content) is an indicator of the amount of water present in a soil. By definition, moisture content is the ratio of the weight of water in a sample to the weight of solids (oven-dried) in the sample, expressed as a percentage (w).

$$w = \frac{W_W}{W_S} \times 100$$

where—

w = moisture content of the soil (expressed as a percentage)

Ww = weight of water in the soil sample

Ws = weight of oven-dried-soil solids in the sample

With many soils, close control of moisture content during field compaction by rolling is necessary to develop a required density and strength in the soil mass. The amount of compaction effort that must be exerted to obtain a specified density depends on having the moisture content at or very close to optimum. Because the specified density is in terms of dry unit weight, the moisture content must be determined with the wet unit weight to determine whether moisture must be added or removed from the in-place soil to achieve the optimum moisture content (OMC). This is a necessary field procedure in constructing embankments and compacting highway subgrades, since moisture-content adjustments are known promptly and oven-drying time is not always afforded.

There are several methods of determining the moisture content of soils, including the–

- Oven-dry method (ASTM D 2216-90).
- Microwave-oven method (ASTM D 4643-87).
- Calcium-carbide-gas pressure method (American Association of State Highway and Transportation Officials [AASHTO] T 217-1986).
- Nuclear-moisture-and-density-gauge method (ASTM D 2922-96 and ASTM D 3017-96).

OVEN-DRY METHOD (ASTM D 2216-90)

The most accurate method of determining moisture content is the oven-dry method. This method uses an oven with a temperature or thermostatic control. For expedient determinations, soils are sometimes dried in a frying pan or container heated by an external source, either a stove or an exhaust manifold. However, heating most soils to excessive temperatures results in chemical changes that may lead to errors in moisture-content results. Hence, drying soils by an uncontrolled heat source is usually less accurate than drying them in a thermostatically controlled oven.

PURPOSE

Perform this test to determine the moisture content of a soil sample to within a desired percentage.

EQUIPMENT

The following items are necessary for this test method:

- A laboratory oven.
- Heat-resistant gloves.
- A calculator.
- Moisture-determination tares.
- A grease pencil.
- A balance scale sensitive to 0.01 gram.
- DD Form 1205.
- A pencil.

STEPS

Perform the following steps to determine the moisture content:

Step 1. Record all identifying information of the sample in blocks 1 through 5 of DD Form 1205 (see *Figure 2-32, page 2-56*).

Step 2. Label and weigh the clean, dry moisture-determination tares, and record the weights on the form as the weight of the tare (line D).

Step 3. Obtain the required soil sample. Place it in the tare and cover it with the lid.

- When conducting this test as part of another test method, use the specimen mass stated in that test method.
- When conducting this test with no minimum specimen mass provided, use the values provided in *Table 2-5*, *page 2-57*, depending on the degree of accuracy of the reported water content.

Step 4. Weigh the soil sample and the tare to the nearest 0.01 gram. Record the weight on the form as the weight of the tare and the wet soil (line A).

Step 5. Oven-dry the sample, with the moisture-determination tare lid removed, at 110°C ± 5° until the sample weight becomes constant. Oven-drying

SOIL MOISTURE-CONTENT DETERMINATION

1. PROJECT		2. DATE
ENGINEER CENTER EXPANSION		1 DEC 99
3. JOB NUMBER	**4. TEST SITE**	**5. SAMPLE NUMBER**
16-P-T	NORTH CORNER	5-C-1

TEST BAG 1 AVERAGE 3.6 %						
RUN NUMBER	1	2	3	4		
TARE NUMBER	1-1	1-2	1-3	1-4		
a. WEIGHT OF TARE + WET SOIL	33.92	37.82	32.46	32.26		
b. WEIGHT OF TARE + DRY SOIL	33.31	37.18	31.84	31.68		
c. WEIGHT OF WATER, W_w *(a - b)*	0.61	0.64	0.62	0.58		
d. WEIGHT OF TARE	16.48	18.82	15.02	15.13		
e. WEIGHT OF DRY SOIL, W_s *(b - d)*	16.83	18.36	16.82	16.55		
WATER CONTENT, w *(c/e x 100)*	3.6 %	3.5 %	3.7 %	3.5 %	%	%

TEST BAG 2 AVERAGE 8.9 %						
RUN NUMBER	1	~~2~~	3	4		
TARE NUMBER	2-1	~~2-2~~	2-3	2-4		
a. WEIGHT OF TARE + WET SOIL	41.32	~~45.93~~	39.94	43.64		
b. WEIGHT OF TARE + DRY SOIL	39.22	~~42.82~~	38.06	41.36		
c. WEIGHT OF WATER, W_w *(a - b)*	2.10	~~3.11~~	1.88	2.28		
d. WEIGHT OF TARE	16.31	~~18.56~~	15.93	15.81		
e. WEIGHT OF DRY SOIL, W_s *(b - d)*	22.91	~~24.26~~	22.13	25.55		
WATER CONTENT, w *(c/e x 100)*	9.2 %	~~12.8 %~~	8.5 %	8.9 %	%	%

TEST AVERAGE %						
RUN NUMBER						
TARE NUMBER						
a. WEIGHT OF TARE + WET SOIL						
b. WEIGHT OF TARE + DRY SOIL						
c. WEIGHT OF WATER, W_w *(a - b)*						
d. WEIGHT OF TARE						
e. WEIGHT OF DRY SOIL, W_s *(b - d)*						
WATER CONTENT, w *(c/e x 100)*	%	%	%	%	%	%

SAMPLE

TEST AVERAGE %						
RUN NUMBER						
TARE NUMBER						
a. WEIGHT OF TARE + WET SOIL						
b. WEIGHT OF TARE + DRY SOIL						
d. WEIGHT OF WATER, W_w *(a - b)*						
d. WEIGHT OF TARE						
e. WEIGHT OF DRY SOIL, W_s *(b - d)*						
WATER CONTENT, w *(c/e x 100)*	%	%	%	%	%	%

6. REMARKS

WATER CONTENT $w = \frac{Ww}{Ws} \times 100$

7. TECHNICIAN *(Signature)*	8. COMPUTED BY *(Signature)*	9. CHECKED BY *(Signature)*
SPC Hoffman	SPC Hoffman	SSG Dobbs WD

DD FORM 1205, DEC 1999 PREVIOUS EDITION IS OBSOLETE.

Figure 2-32. Sample DD Form 1205

Table 2-5. Recommended minimum test specimen for reporting water content

Maximum Particle Size (100% Passing)	Standard Sieve Size	Minimum Moist Mass for Reporting to ± 0.1%	Minimum Moist Mass for Reporting to ± 1%
2.0 mm or less	No. 10	20.0 g	20 g*
4.75 mm	No. 4	100.0 g	20 g*
9.50 mm	3/8 in	500.0 g	50 g
19.00 mm	3/4 in	2.5 kg	250 g
37.50 mm	1 1/2 in	10.0 kg	1 kg
75.00 mm	3 in	50.0 kg	5 kg
*** To be representative, not less than 20 grams shall be used.**			

time will vary depending on the type of soil, the size of the sample, and other factors. For routine water-content determination, oven-dry a sample consisting of clean sands and gravel for a minimum of 4 hours. For most other soils, a minimum drying time of 16 hours is adequate.

Step 6. Remove the sample from the oven and replace the moisture-determination tare lid. Allow the sample to cool until the tare can be handled comfortably with bare hands.

Step 7. Weigh the dried soil sample and the tare. Record the weight as the weight of the tare and dry soil (line B).

Step 8. Determine the weight of the water (W_w) by subtracting the weight of the tare and dry soil (line B) from the weight of the tare and wet soil (line a). Record the weight on the form (line C).

Step 9. Determine the weight of the dry soil (W_s) by subtracting the weight of the tare (line D) from the weight of the tare and dry soil (line B). Record the weight on the form (line E).

Step 10. Determine the water content (w), in percent, and record it using the following formula:

$$w = \frac{W_W}{W_S} \times 100$$

When determining the average water content, the individual tests must be within ± 1 percent. Any individual tests that do not meet this requirement will not be used (see *Figure 2-32*). If none of the individual tests meet this requirement, then additional testing is required.

CALCIUM-CARBIDE-GAS PRESSURE METHOD (AASHTO T 217-1986)

CAUTION

The chemical reaction of calcium carbide with water produces acetylene gas which is extremely flammable. Exercise extreme caution to avoid open flame when releasing the gas from the speedy moisture tester. Perform the test in a well-ventilated area, as asphyxiation could occur if performed in a confined area.

Use the calcium-carbide-gas pressure method to determine the moisture content of a soil sample using the 26-gram speedy moisture tester to within ± 0.5 percent. If another tester is to be used, consult the user's manual for the tester before conducting the moisture-content determination.

PURPOSE

Perform this test to determine the moisture content of a soil sample to within ± 0.5 percent.

EQUIPMENT

Use the following items for the calcium-carbide-gas pressure test:

- A calcium-carbide-pressure (speedy) moisture tester to hold a 26-gram soil specimen.
- A balance (readable to 0.1 gram).
- Two 1 1/4-inch steel balls.
- A cleaning brush and cloth.
- A scoop (for measuring calcium-carbide reagent).
- Calcium-carbide reagent.

STEPS

Perform the following steps to determine the soil's moisture content:

Step 1. Weigh the soil sample to be tested, ensuring that it weighs exactly 26 grams. Place the soil sample in the tester's body and add the two 1 1/4-inch steel balls.

Step 2. Place three scoops (about 24 grams) of calcium carbide into the cap of the tester and, with the pressure vessel in a horizontal position, insert the cap into the pressure vessel. Seal the unit by tightening the clamp, taking care that no carbide comes in contact with the soil until a complete seal is achieved.

Step 3. Raise the moisture tester to a vertical position so that the reagent in the cap will fall into the pressure vessel.

Step 4. Shake the instrument vigorously in a rotating motion so that all lumps are broken up to permit the calcium carbide to react with all available free moisture. Shake the instrument in a rotating motion so that the steel balls will not damage the instrument or cause soil particles to become embedded in the orifice leading to the pressure diaphragm. Continue shaking at least 1 minute for granular soils and up to 3 minutes for other soils to permit complete reaction between the calcium carbide and the free moisture. Allow time for the dissipation of the heat generated by the chemical reaction.

Step 5. Hold the instrument in a horizontal position at eye level. Read the dial when the needle stops moving. Record the dial reading as the percent of moisture by wet mass.

Step 6. Point the cap of the instrument away from the operator and release the gas pressure slowly. Empty the pressure vessel and examine the material for lumps. If the sample is not completely pulverized, repeat the test using a new sample. Clean the cap thoroughly of all carbide and soil before running another test.

The limit of the tester is 12 percent moisture for aggregate or 20 percent moisture for soil. If the limit is exceeded, then the test must be run again using a half-sized sample (13 grams) and the dial reading must be multiplied by 2.

CALCULATIONS

Determine the percentage of moisture by dry mass of the soil from the calibration curve (see *Figure 2-33, page 2-60*) or from the conversion chart (see *Figure 2-34, page 2-61*) as explained below. The calibration curves, moisture-content determination by the calcium-carbide-gas pressure method, are used for materials that need the pulverizing steel balls (see *Figure 2-33*). Using the highest reading obtained during the test (direct reading), read over to the curve and then down to the oven-dry moisture percentage. The curve to be used will depend on the test time.

Use the conversion chart (see *Figure 2-34*) to determine oven-dry moisture contents of materials that do not need the steel balls. If direct readings are not on the conversion chart, interpolate the difference between the two known direct readings.

EXAMPLE

A speedy test is performed on a sand. The highest reading obtained is 3.5 percent (wet weight). The difference between 3.0 percent (which has a known dry weight of 3.2 percent) and 4.0 percent (which has a known dry weight of 4.3 percent) must be interpolated for 3.5 percent.

Using *Figure 2-34*, the values in *Table 2-6* are known. To find the value of x, place the differences in the table values into a ratio. The ratio of differences is—

$$\frac{3.5-3.0}{4.0-3.0} = \frac{x-3.2}{4.3-3.2} \qquad or \qquad \frac{0.5}{1.0} = \frac{x-3.2}{1.1}$$

then—

cross multiplied, x - 3.2 = 0.55;

therefore, leaving x = 3.2 + 0.55 = 3.75.

So, at 3.5 percent wet weight, x = 3.2 + 0.55 = 3.75 percent comparable oven-dry weight.

Table 2-6. Determining the soil's moisture content

Percent Wet Weight	Percent Dry Weight
3.0	3.2
3.5	x
4.0	4.3

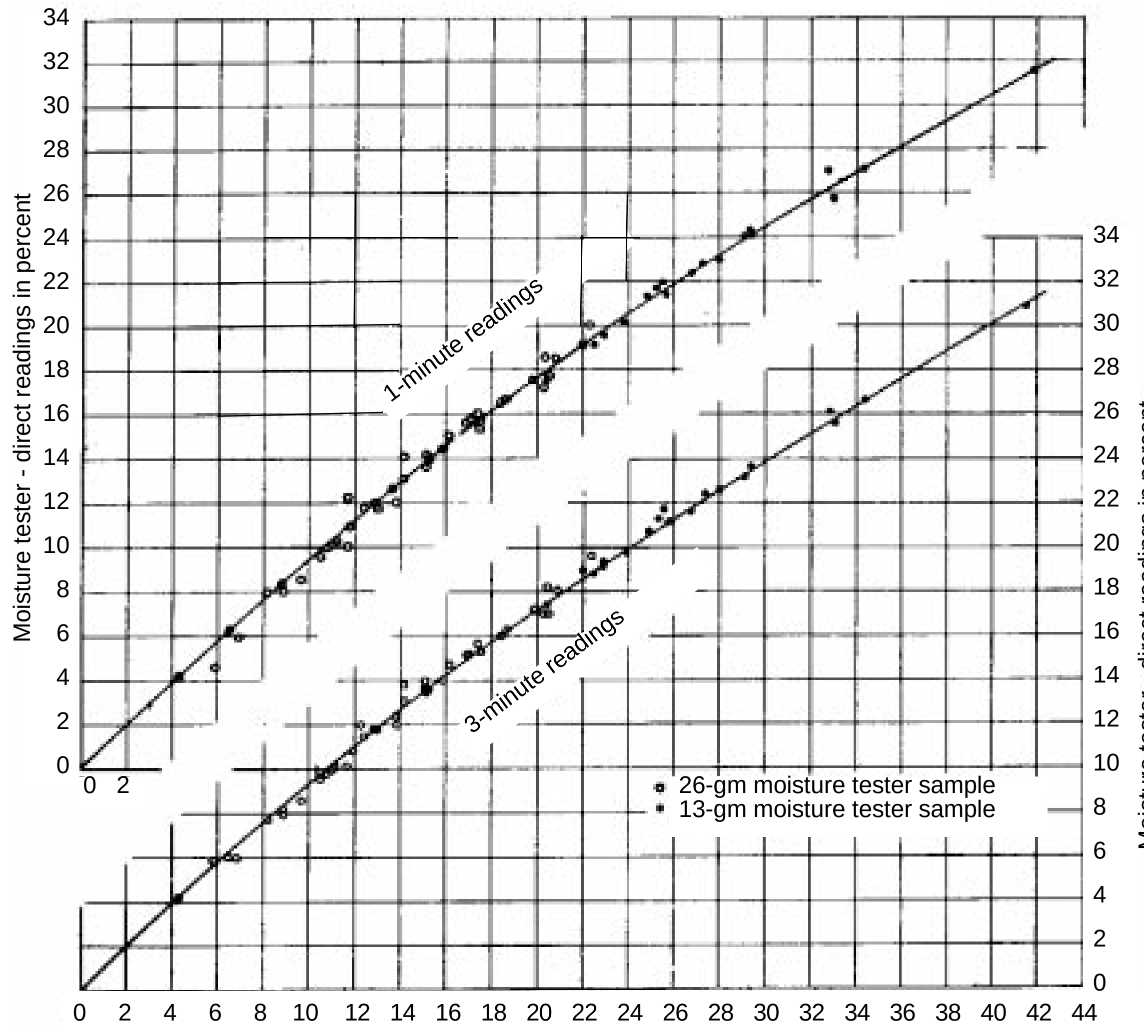


Figure 2-33. Speedy-moisture tester calibration chart, for use with the 1 1/4-inch steel balls

The curves and charts are usually supplied with the moisture tester. However, check each moisture tester for the accuracy of its gauge and the accuracy of the conversion curve. Check the accuracy of the tester gauge by using a calibration kit (obtained from the tester's manufacturer) equipped with a standard gauge. In case of discrepancy, adjust the gauge on the tester to conform with the standard gauge. For checking the accuracy of the conversion curve, make a calibration for meter readings versus oven-dry moisture contents using local soils. Also, additional testing may be necessary

Speedy Reading Wet Weight %	Dry Weight %	Speedy Reading Wet Weight %	Dry Weight %	Speedy Reading Wet Weight %	Dry Weight %
1.0	1.0	20.5	25.8	35.5	55.0
2.0	2.1	21.0	26.5	36.0	56.2
3.0	3.2	21.5	27.4	36.5	57.4
4.0	4.3	22.0	28.2	37.0	58.7
5.0	5.4	22.5	29.0	37.5	60.0
6.0	6.5	23.0	29.8	38.0	61.2
7.0	7.6	23.5	30.7	38.5	62.6
8.0	8.7	24.0	31.5	39.0	63.9
9.0	9.8	24.5	32.4	39.5	65.2
10.0	11.0	25.0	33.3	40.0	66.6
10.5	11.7	25.5	34.2	40.5	68.0
11.0	12.3	26.0	35.3	41.0	69.4
11.5	13.0	26.5	36.0	41.5	70.9
12.0	13.6	27.0	36.9	42.0	72.4
12.5	14.2	27.5	37.9	42.5	73.8
13.0	14.9	28.0	38.8	43.0	75.4
13.5	15.6	28.5	39.8	43.5	76.9
14.0	16.3	29.0	40.8	44.0	78.5
14.5	16.9	29.5	41.8	44.5	80.1
15.0	17.6	30.0	42.8	45.0	81.8
15.5	18.3	30.5	43.9	45.5	83.4
16.0	19.0	31.0	44.9	46.0	85.1
16.5	19.7	31.5	45.9	46.5	86.9
17.0	20.4	32.0	47.0	47.0	88.6
17.5	21.2	32.5	48.1	47.5	90.6
18.0	21.9	33.0	49.2	48.0	92.3
18.5	22.7	33.5	50.3	48.5	94.1
19.0	23.4	34.0	51.5	49.0	96.0
19.5	24.2	34.5	52.6	49.5	98.0
20.0	25.0	35.0	53.8	50.0	100.0

Figure 2-34. Speedy-moisture tester conversion chart, for use when not using the 1 1/4-inch steel balls

to extend the conversion curve beyond 44 percent moisture content (see *Figure 2-33*).

It may be more convenient for field use of the equipment to prepare a table of moisture-tester readings versus oven-dry moisture content.

RETURN TO TOC

GO TO CHAPTER 2, PART 2