PDHonline Course C650 (2 PDH)

Soil Identification by Visual-Manual Methods

Instructor: John Huang, Ph.D., PE and John Poullain, PE

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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Appendix F-3 (of EM 1110-1-1906)
Visual Identification of Soil Samples

E-1. Field Identification Techniques

Visual identification techniques reported herein generally yield results which are consistent with the Unified Soil Classification System (ASTM D 2487, 1993; ASTM D 2488, 1993; U.S. Army Engineer Waterways Experiment Station, 1960).[1] Because these techniques are primarily visual, subtle discrepancies may exist between the identifications obtained in the field and the classifications determined in the laboratory. However, the results are meaningful provided the inspector makes careful and consistent identifications. See Chapter 13 for details on handling and storage of samples and maintaining sampling records. The inspector's equipment required to conduct these tests is limited to a pocket knife, scale, magnifying glass, and a small container of diluted hydrochloric acid. Table E-1 can be used as a checklist for conducting a systematic visual identification of a soil sample; it is also useful for locating the appropriate table and/or figure which describe(s) a test procedure for visually identifying the soil.

E-2. Grain Size

The inspector must first determine whether the material is coarse grained or fine grained. To make this determination, spread a representative sample on a flat surface. Determine whether or not the predominant size fraction is discernible with the naked eye. Coarse-grained soils vary from particles in excess of 75 mm (3 in.) in diameter to particles just discernible with the unaided eye, such as table salt or sugar, whereas fine-grained soils are microscopic and submicroscopic. The predominant material of peat or muck is decaying vegetation matter. Table E-2 and Figure E-1 may aid in determining the grain size of the soil in question. If the predominant material is coarse grained, follow the procedures outlined in paragraph E-2*a*; if the soil is fine grained, follow the procedures outlined in paragraph E-2*b*.

a. Coarse-grained soils.

(1) *Coarse fraction*. Once the soil has been determined to be coarse grained, further examination is required to determine the grain size distribution, the grain shape, and the density of the in situ deposit (if applicable). The gradation of coarse-grained soils can be described as well graded, poorly graded, or gap graded.

Table E-3 and Figure E-2 can be used in selecting the appropriate descriptive terms. Soil particles can also be described according to a characteristic shape. Particle shape may vary from angular to rounded to flat or elongated. Appropriate descriptive terms are listed in Table E-4; particle shapes are illustrated in Figure E-3. The density of an in situ deposit of a coarse-grained soil is also valuable information. Results obtained by pushing a reinforcing rod into a surface deposit or from the Standard Penetration Test may indicate the density of an in situ deposit. Appropriate descriptive terms may be selected from Table E-5.

(2) *Fine fraction*. The plasticity characteristics of the fine fraction of a coarse-grained material also need to be determined. The tests for fine-grained soils (paragraph E-2*b*) which are described in

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[1] References cited in this appendix are included in Appendix A.

Table E-6 and illustrated in Figures E-4 through E-10 can be used to characterize the fine fraction of the soil sample in question.

b. Fine-grained soils.

(1) *Coarse fraction*. The coarse-grained fraction, where applicable, should be described in terms of the size of the predominate grain size, i.e., sand or gravel. Paragraph E-2*a*, Table E-2, and Figure E-1 may aid in selecting appropriate descriptive terms.

(2) *Fine fraction.* Several tests may be useful in determining the plasticity characteristics of fine-grained soils or
fractions thereof; these tests include the dilatancy or reaction to shaking test, the dry strength test, and the toughness and plasticity tests. For each test, the fraction which passes the No. 40 U.S. Standard Sieve (0.42 mm) is used; this fraction corresponds to the fraction which is required for determination of Atterberg limits. For the purpose of the visual tests, however, screening is not important; the removal of coarse particles is adequate. Tests to determine the plasticity characteristics of the fine fraction are described in Table E-6, the dilatancy test is illustrated in Figures E-4 through E-7, the dry strength test is presented in Figure E-8, and toughness and plasticity tests are given in Figures E-9 and E-10, respectively.

c. Other tests. The dispersion (settlement in water) test and the bite test can be used to determine the presence of and relative amounts of sand, silt, and clay fractions (see Table E-6). Several other tests, such as the odor and the peat tests for determining the presence of organic matter, the acid test for determining the presence of a calcium carbonate cementing agent, and the slaking test for determining whether the "rocklike" material is shale, are listed in Table E-6. Strength descriptors of a clay sample are listed in Table E-7.

E-3. Soil Moisture and Color

Soil moisture and color are important indicators of soil conditions. For example, visible or free water from a soil sample can infer the proximity of a water table. The color of a moist soil sample tells much about the minerals and chemicals present in the soil, the drainage conditions, and the presence of organic matter. Soil color charts prepared for the U.S. Department of Agriculture (USDA) by the Munsell Color Company, New Windsor, NY 12553, are helpful for describing the color of soil samples. Soil moisture conditions or water contents can be described following the criteria presented in Table E-8. The importance of color for identifying and classifying moist fine- grained soils is shown in Table E-9.

E-4. Mass Structure and Mass Defects of Soil Formations

Mass structure and mass defects yield data about the geotechnical engineering behavior of a soil formation in question. For example, a varved clay would most likely have different engineering properties from an homogeneous deposit of one of the constituent soils. Likewise, slickensides indicate a clay deposit has been overconsolidated because of desiccation, surcharge loading, or both; an overconsolidated clay would have different engineering properties from a normally consolidated deposit of the same material. Descriptive terms for mass structure and mass defects of a soil formation are presented in Tables E-10 and E-11, respectively.

E-5. Description of Soils

As presented in the footnote in Table E-1, the description of a soil sample should contain appropriate terms to characterize the soil type and grain size, its moisture content and color, and mass structure and defects. Commonly used names and descriptions for selected soils are presented in Table E-12.

Table E-1
Order of Description for Soils

Criteria	Table No.	Figure No.
Soil types and particle sizes	E-2	E-1
Coarse-grained soils		
Description of gradation of coarse-grained soils	E-3	E-2
Description of grain shape of coarse-grained soils	E-4	E-3
Density of coarse-grained soils	E-5	
Fine-grained soils		
Field identification procedures for fine-grained soils	E-6	E-4/E-10
Strength or consistency of clays	E-7	
Moisture content	E-8	
Role of color for identification of moist fine-grained soils	E-9	
Terms for describing mass structure of soils	E-10	
Terms for describing mass defects in soil structure	E-11	
Commonly used descriptive soil names	E-12	

Example: Sand, fine, silty, tan, poorly-graded, dense, wet, subrounded, very friable with occasional clay lenses.

Table E-2
Soil Types and Particle Sizes

Principal Soil Type	Descriptive Term	Size	U.S. Standard Sieve	Familiar Example
Coarse-grained Soils	Cobble	76 mm or larger	Greater than 3 in.	Grapefruit or orange
	Coarse gravel	76 mm to 19 mm	3 in. to 3/4 in.	Walnut or grape
	Fine gravel	19 mm to 5 mm	3/4 in. to #4	Pea
	Coarse sand	5 mm to 2 mm	#4 to #10	Rock salt
	Medium sand	2 mm to 0.4 mm	#10 to #40	Openings of a window screen
	Fine sand	0.4 mm to 0.074 mm	#40 to #200	Table salt or sugar
Fine-grained Soils	Silt or clay	Microscopic and submicroscopic		
Organic	Peat or muck			Decaying vegetable matter

Note: Particles which are retained on the No. 200 U.S. Standard Sieve (0.074 mm) can just be discerned with the naked eye at a distance of about 25 cm (10 in.).

Table E-3
Description of Gradation of Coarse-Grained Soils

Descriptive Term	Meaning
Well graded	A good representation of all grain sizes is present
Uniformly or poorly graded	All grains are approximately the same size
Gap graded	Intermediate grain sizes are absent

Table E-4
Description of Grain Shape of Coarse-Grained Soils

Descriptive Term	Example
Angular	Irregular with sharp edges such as freshly broken rock
Subangular	Irregular with smooth edges
Subrounded	Irregular but smooth as a lump of molding clay
Rounded	Marble or egg shaped, very smooth
Flaky	Sheet of paper or flake of mica
Flat	Ratio of width to thickness greater than 3
Elongated	Ratio of length to width greater than 3

Table E-5
Density of Coarse-Grained Soils

Descriptive Term	Blows per Foot[1,2]	Field Test
Very loose	Less than 4	----------
Loose	4-10	Easily penetrated with a 13-mm- (1/2-in.-) diam reinforcing rod pushed by hand
Medium dense	10-30	Easily penetrated with a 13-mm- (1/2-in.-) diam reinforcing rod driven with a 2.3-kg (5-lb) hammer
Dense	30-50	Penetrated 0.3 m (1 ft) with a 13-mm- (1/2-in.-) diam reinforcing rod driven with a 2.3-kg (5-lb) hammer
Very dense	Greater than 50	Penetrated only a few centimeters with a 13-mm- (1/2-in.-) diam reinforcing rod driven with a 2.3-kg (5-lb) hammer

[1] From SPT (Appendix B, Table B-1).
[2] 1 ft = 0.3048 m.

Table E-6
Field Identification Procedures for Fine-Grained Soils[1]

Test	Test Procedures and Interpretation of Results
Dilatancy	Prepare a pat of moist soil with a volume equivalent to a 25-mm (1-in.) cube (Figure E-4). Add water, if necessary, to make the soil soft but not sticky, i.e., (reaction to the "sticky limit"). Place the pat of soil in the open palm of one hand and shake horizontally; strike vigorously against the other hand several times. If the reaction is positive, water appears on the surface of the pat; the consistency of the pat then becomes livery; and the surface of the pat becomes glossy (Figure E-5). Next, squeeze the sample between the fingers (Figure E-6). The water and gloss should disappear from the surface of the pat; the soil will stiffen and crack or crumble (Figure E-7). The rapidity of the appearance of water on the surface of the soil during shaking and its disappearance during squeezing help to identify the character of the fines in the soil. Very fine clean sands give the quickest and most distinct reaction, inorganic silts give a moderately quick reaction, and plastic clays have no reaction.
Dry strength	Mold a pat of soil to the consistency of putty. If the soil is too dry, add water; if it is too sticky, the specimen should be allowed to dry by evaporation. After the consistency of the pat is correct, allow the pat to dry (by oven, sun, or air). Test its strength by breaking and crumbling between the fingers (Figure E-8). The dry strength increases with increasing plasticity. High dry strength is characteristic of high plasticity clays. Silty sand and silts have only slight dry strengths, but can be distinguished by feel when powdered; fine sands feel gritty whereas silts feel smooth like flour. It should also be noted that shrinkage cracks may occur in high plasticity clays. Therefore, precautions should be taken to distinguish between a break which may occur along a shrinkage crack or a fresh break which is the true dry strength of the soil.
Toughness and plasticity	A specimen of soil which is about the size of a 25-mm (1-in.) cube should be molded to the consistency of putty; add water or allow to dry as necessary. At the proper moisture content, roll the soil by hand on a smooth surface or between the palms into a thread about 3-mm (1/8-in.) diam (Figure E-9). Fold the thread of soil and repeat the procedure a number of times. During this procedure, the water content of the soil is gradually reduced. As drying occurs, the soil begins to stiffen and finally loses its plasticity and crumbles at the plastic limit. After the thread has crumbled, the pieces should be lumped together and a kneading action should be applied until the lump crumbles. For higher clay contents, threads are stiffer and lumps are tougher at the plastic limit than for lower plasticity clays. A complementary test is the ribbon test. A roll of soil about 13-to 19-mm (1/2-to 3/4-in.) diam by 75 to 125 mm (3 to 5 in.) long should be prepared at a moisture content just below the "sticky limit". Flatten the roll of soil to thickness of 3 to 6 mm (1/8 to 1/4 in.) between the thumb and forefinger (Figure E-10). For high plasticity clays, a ribbon 20 to 25 cm (8 to 10 in.) long can be formed; shorter lengths correspond to lower plasticity clays whereas a ribbon cannot be formed when using non-plastic soils.
Dispersion test	Place a few hundred grams of soil in a jar containing water. Shake the jar containing the mixture of soil and water and then allow the soil to settle. The rate of settling can be used to judge the (settlement predominate soil type(s) whereas the thicknesses of the various soils can be used to judge the gradation of the soil. Sands settle in 30 to 60 seconds, silts settle in 30 to 60 minutes, and clays may in water) remain in suspension overnight. The interface between fine sands and silts occurs where individual grains can not be discerned with the unaided eye. The cloudiness of the water indicates the relative clay content.
Bite test	Place a pinch of soil between the teeth and grind lightly. Fine sands grate harshly between the teeth; silts have a gritty feeling but do not stick to the teeth; clays tend to stick to the teeth, but do not have a gritty feeling.
Odor	Organic soils have a musty odor which diminishes upon exposure to air. The odor can be revived by heating a moist sample or by exposing a fresh sample.
Peat	Peat has a fibrous texture and is characterized by partially decayed sticks, leaves, grass, and other vegetation. A distinct organic odor is characteristic of peat. Its color generally ranges from dull brown to black.
Shine	A moist, highly plastic clay will shine when rubbed with a fingernail or pocketknife blade: a lean clay will have a dull surface.
Acid test	The presence of calcium carbonate in a soil can be determined by adding a few drops of dilute (3:1 ratio of water to acid) hydrochloric acid to the soil. The relative amount of calcium chloride in the soil can be determined by the effervescence (fizzing reaction) which occurs. Degrees of reaction range from none to strong. For some very dry non-calcareous soils, the illusion of effervescence as the acid is absorbed by the soil can be eliminated by moistening the soil before the acid is applied.
Slaking test	Certain shales and other soft "rocklike" materials disintegrate upon drying or soaking. The test is performed by placing the soil in the sun or oven to dry completely. After the sample has been dried, it should then be soaked in water. The degree of slaking should be reported.

[1] These tests must be performed on the minus No. 40 sieve size (0.42 mm) particles, which is the division between medium and fine sand. For field classification purposes, screening is not intended; simply remove the coarse particles that interfere with the tests.

Table E-7
Strength or Consistency of Clays

Descriptive Term	Blows[1] per Foot[2]	Unconfined Compressive Strength kPa	(tsf)	Field Test
Very soft	< 2	<25	(< 0.25)	Core (height twice diameter) sags under its own weight while standing on end; squeezes between fingers when fist is closed
Soft	2-4	25-50	(0.25-0.5)	Easily molded by fingers
Medium	4-8	50-100	(0.5-1.0)	Molded by strong pressure of fingers
Firm	8-15	100-190	(1.0-2.0)	Imprinted very slightly by finger pressure
Very firm	15-30	190-380	(2.0-4.0)	Cannot be imprinted with finger pressure; can be penetrated with a pencil
Hard	> 30	> 380	(> 4.0)	Imprinted only slightly by pencil point

[1] From SPT (Appendix B, Table B-1).
[2] 1 ft = 0.3048 m.

Table E-8
Moisture Content

Condition	Estimated Water Content, percent	Example
Dry	0 - 10	Absence of moisture; well below optimum water content for fine-grained soils
Moist	10 - 30	Fine-grained - damp, near optimum water content Coarse-grained - no visible water
Wet	30 - 70	Fine-grained - well above optimum water content Coarse-grained - visible water
Water bearing	-------	Water drains freely, below water table

Table E-9
Role of Color for Identification of Moist Fine-Grained Soils

General:

Detect different soil strata
Detect soil type based upon experience in local area
Colors become lighter as water content decreases

Soil Type:

Inorganic soils have clean, bright colors: light gray, olive green, brown, red, yellow, or white
Organic soils have dark or drab shades: dark gray, dark brown, or almost black

Presence of Chemicals:

Iron oxides: red, yellow, or yellowish brown
Silica, calcium carbonate, or aluminum compounds: white or pinkish

Drainage Conditions:

Poor: grayish blue and gray or yellow mottled colors

Table E-10
Terms for Describing Mass Structure of Soils

Descriptive Term	Definition
Homogeneous	Uniform properties
Heterogeneous	Mixtures of soil types not in layers or lenses
Stratified	Alternate layers of different soils or colors
Laminated	Repeating alternate layers of different soils or colors 3 to 6 mm (1/8 to 1/4 in.) thick
Banded	Alternate layers in residual soils
Lensed	Inclusions of small pockets of different soils

Table E-11
Terms for Describing Mass Defects in Soil Structure

Descriptive Term	Definition
Slickensides	Fracture of failure planes (polished surfaces) seen in stiff clays
Root holes	Holes remaining after roots have decayed
Fissures	Cracks from shrinkage, frost, etc.; specimen breaks along a definite plane of fracture
Weathered, oxidized	Irregular discolorations
Concretions	Accumulations of carbonates or iron compounds
Blocky	Cohesive soil broken into small angular lumps which resist further breakdown

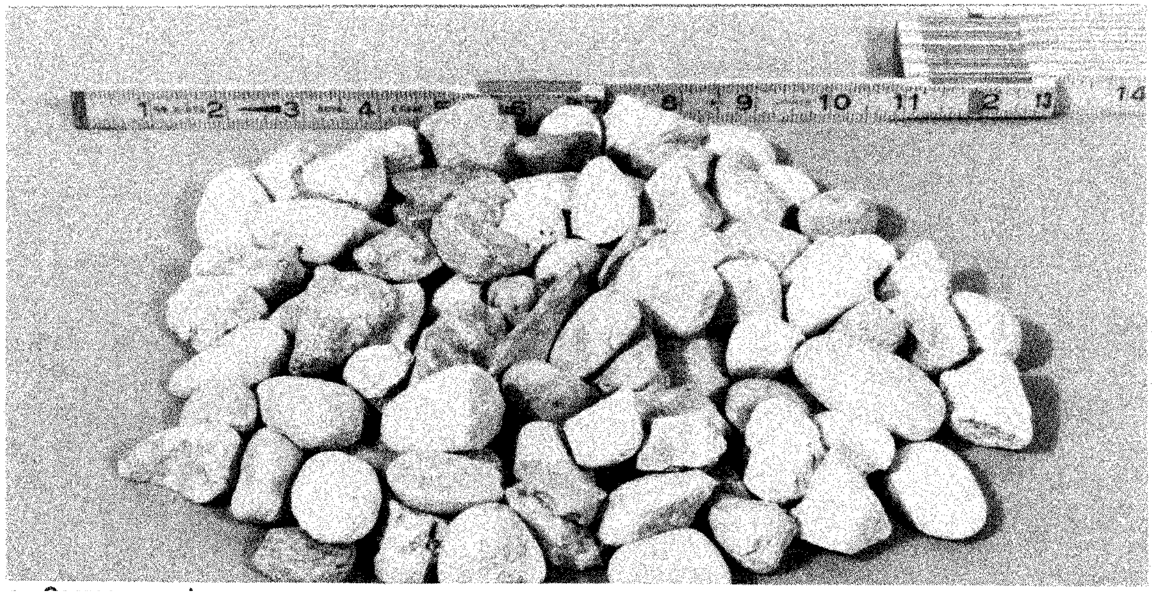
Table E-12
Commonly Used Descriptive Soil Names (Continued)

Common Name	Description
Adobe	Soils such as calcareous silts and sandy-silty clays which are found in semiarid regions of southwestern United States and North Africa.
Alluvium	Deposits of mud, silt, and other material commonly found on the flat lands along the lower courses of streams.
Argillaceous	Soils which abound in clays or clay-like materials.
Bentonite	A clay of high plasticity formed by the decomposition of volcanic ash.
Boulder clay (L)[1]	A name, used in Canada and England, for glacial till.
Buckshot (L)	Clays of southern and southwestern United States which crack into small, hard lumps of more or less uniform size upon drying.
Bull's liver (L)	The term name used in some sections of the United States to describe an inorganic silt of slight plasticity, which, when saturated, quakes like jelly from vibration or shock.
Calcareous	Soils which contain an appreciable amount of calcium carbonate, usually from limestone.
Caliche	The term which describes deposits of silt, clay, and sand cemented by calcium carbonate deposited by evaporation of groundwater; this material is found in France, North Africa, and southwestern United States.
Coquina (L)	Marine shells which are held together by a small amount of calcium carbonate to form a fairly hard rock.
Coral	Calcareous, rock-like material formed by secretions of corals and coralline algae.
Diatomaceous earth	A white or light gray, extremely porous, friable, siliceous material derived chiefly from diatom remains.
Dirty sand (L)	A slightly silty or clayey sand.
Disintegrated granite	Granular soil derived from decomposition and weathering of granite rock.
Fat clay (L)	Fine colloidal clay of high plasticity.
Fuller's earth	Highly plastic white to brown clays of sedimentary origin which are used commercially to absorb fats and dyes.
Gumbo (L)	Highly plastic silty and clayey soils which become impervious, sticky, and soapy or waxy when saturated.
Hardpan	A general term used to describe a hard, cemented soil layer which does not soften when wet.
Lateritic soils	Residual soils, usually red in color, which are found in tropical regions. In their natural state, these soils have a granular structure with low plasticity and exhibit good drainage characteristics; when remolded in the presence of water, they often become plastic and clayey.
Lean clay	Silty clays and clayey silts of low to medium plasticity.

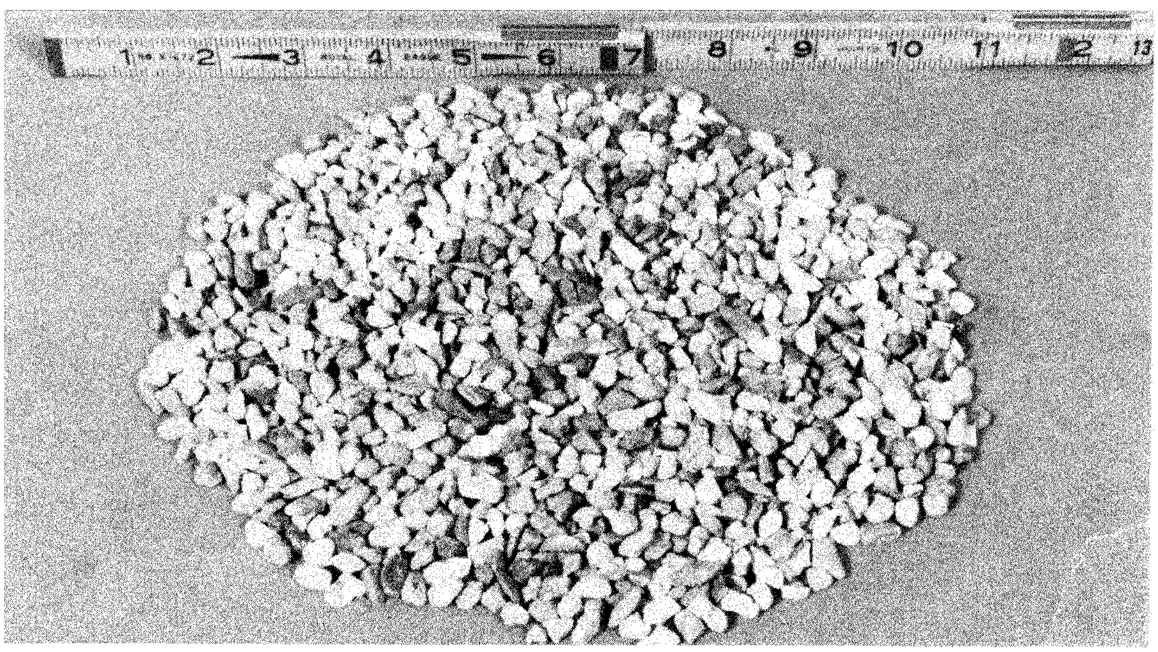
[1] (L) refers to a name which is used in local areas, only.

Table E-12 (Concluded)

Common Name	Description
Limerock (L)	A soft, friable, creamy white limestone found in the southeastern United States; it consists of marine remains which have disintegrated by weathering.
Loam	An agricultural term used to describe sandy-silty topsoils which contain a trace of clay, are easily worked, and are productive of plant life.
Loess	A silty soil of eolian origin characterized by a loose, porous structure, and a natural vertical slope; it covers extensive areas in North America, Europe, and Asia.
Marl	A soft, calcareous deposit mixed with clays, silts, and sands, and often contains shells or organic remains; it is common in the Gulf Coast area of the United States.
Micaceous soils	Soil which contains a sufficient amount of mica to give it distinctive appearance and characteristics.
Muck (mud)	Very soft, slimy silt which is found on lake or river bottoms.
Muskeg	Peat deposits found in northwestern Canada and Alaska.
Peat	Fibrous, partially decayed organic matter or a soil which contains a large proportion of such materials; it is extremely compressible and is found in many areas of the world.
Red dog (L)	The residue from burned coal dumps.
Rock flour	A low plasticity, sedimentary soil composed of silt-sized particles which may become quick at high moisture contents.
Shale	A thinly laminated rock-like material which has resulted from consolidation of clay under extreme pressure; some shales revert to clay on exposure to air and moisture.
Talus	A fan-shaped accumulation of fragments of rock that have fallen near the base of a cliff or steep mountainside as a result of weathering.
Topsoil	The top few inches of soil which contains considerable organic matter and is productive of plant life.
Tufa	A loose, porous deposit of calcium carbonate which usually contains organic remains.
Tuff	Stratified, compacted deposits of fine materials, such as cemented dust and cinders, ejected from volcanoes. Tuffs are prevalent in the Mediterranean area.
Varved clay	A sedimentary deposit which consists of alternate thin (less than 13 mm) layers of silt and clay.
Volcanic ash	Uncemented volcanic debris which consists of particles less than 3 mm diameter; upon weathering, a clay of high compressibility is formed.



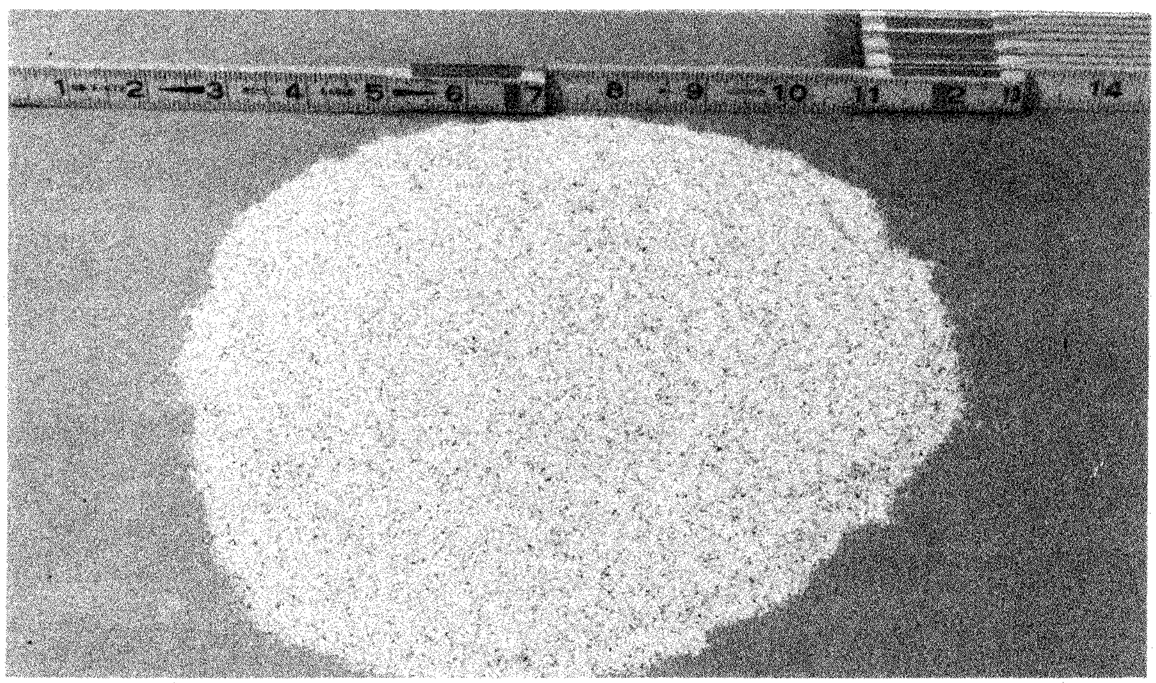
a. Coarse gravel



b. Fine gravel

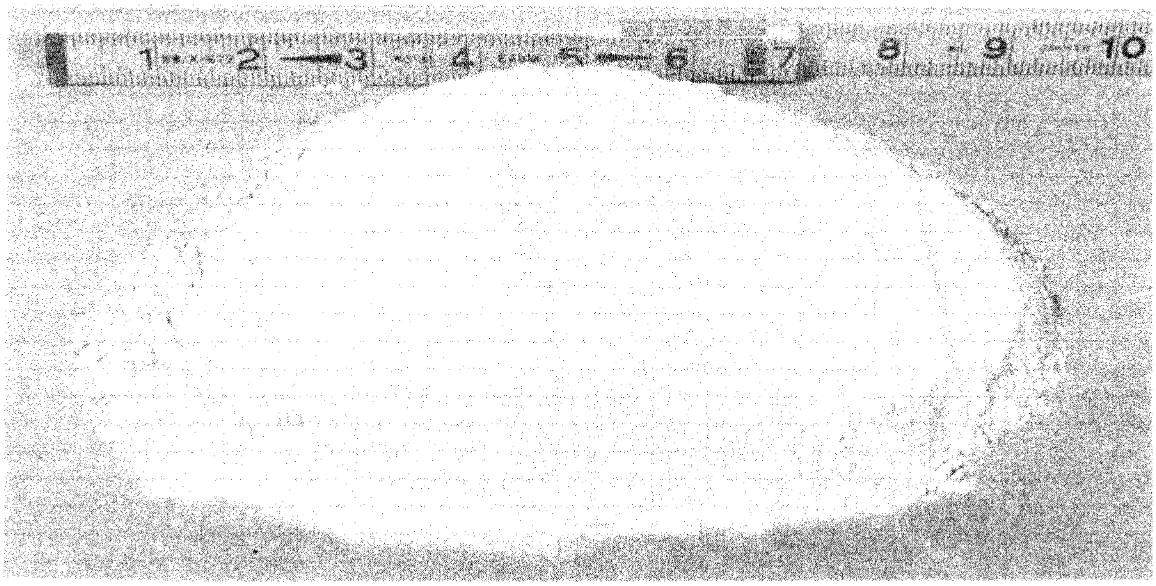
Figure E-1. Photographs of several soils to aid in selecting terms for describing the grain size of soil (Sheet 1 of 3)

c. Coarse sand



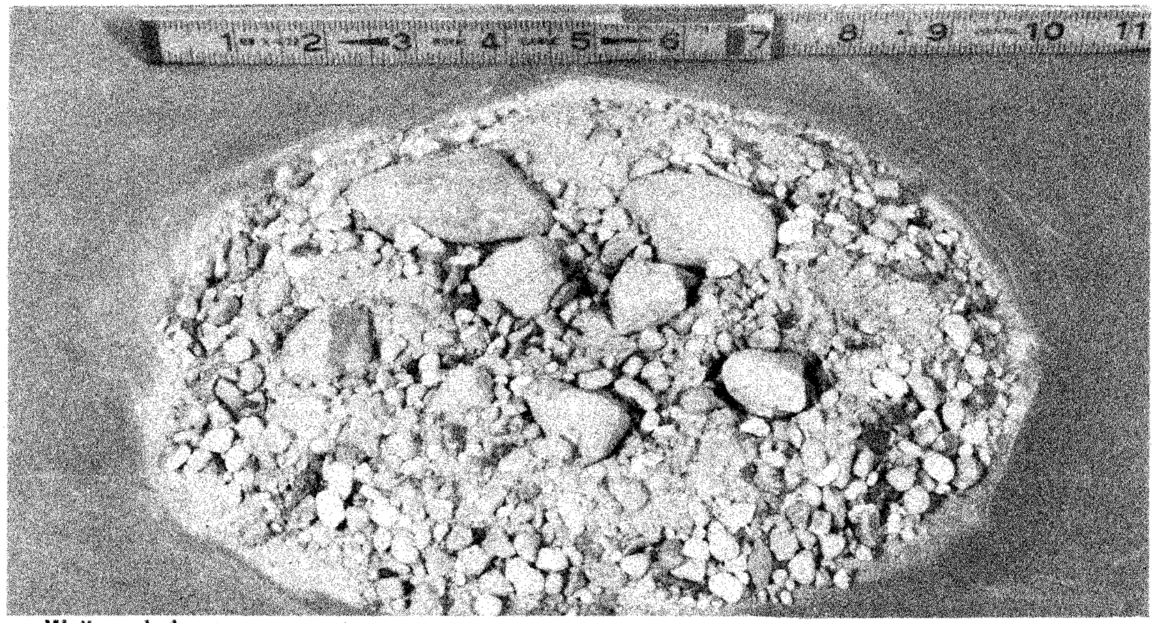
d. Fine sand

Figure E-1. (Sheet 2 of 3)



e. Silt or clay

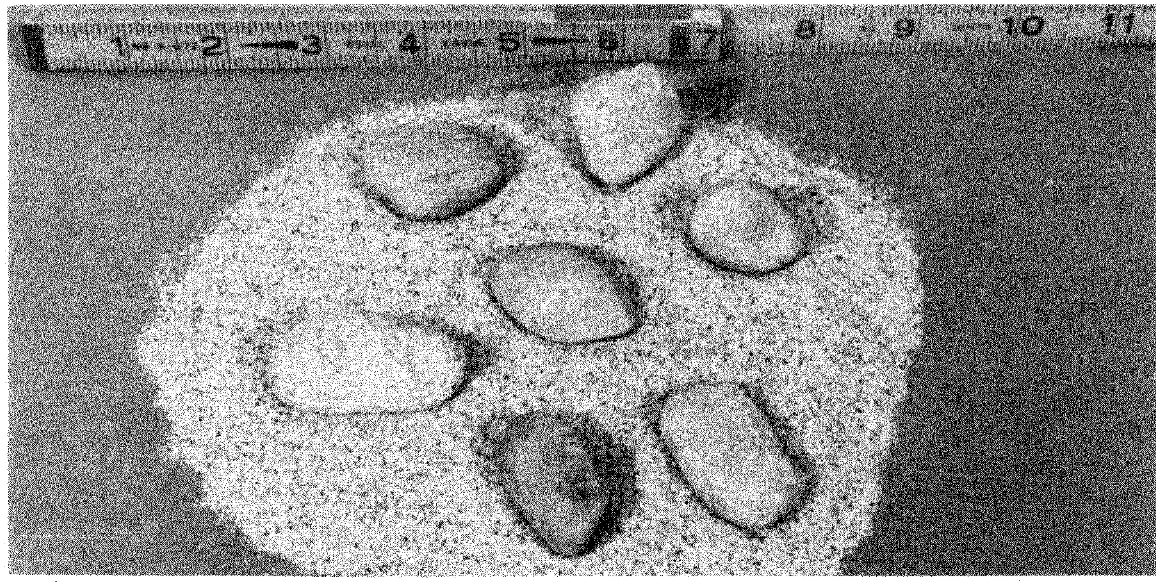
Figure E-2. Sheet 2 of 3)



a. Well graded

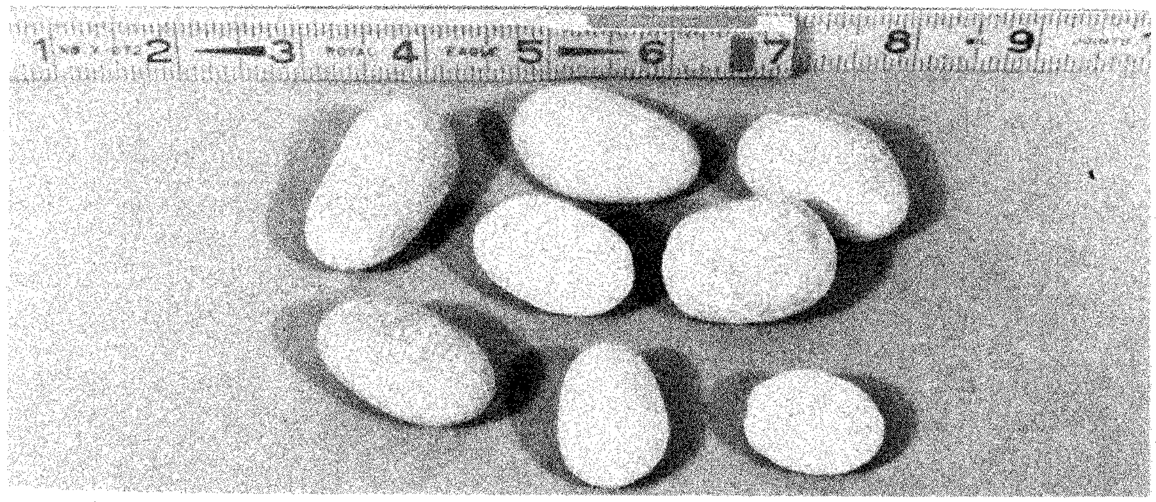
b. Uniformly or poorly graded

Figure E-2. Photographs of several soils to aid in selecting terms for describing the gradations of coarse-grained soils (Continued)

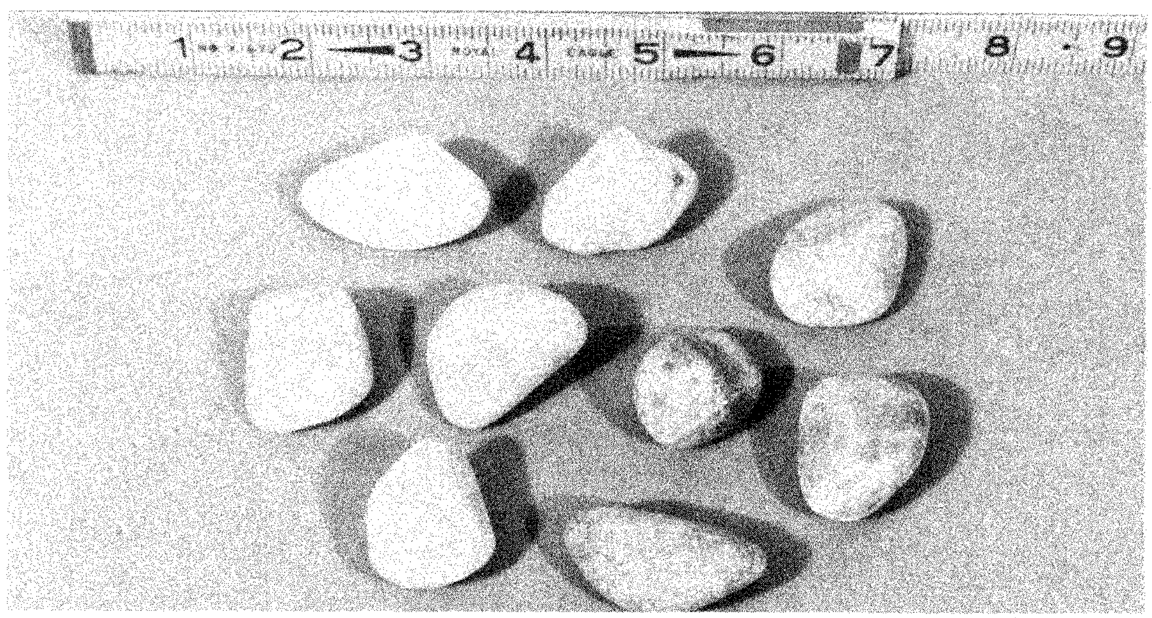


c. Gap graded

Figure E-2. (Concluded)

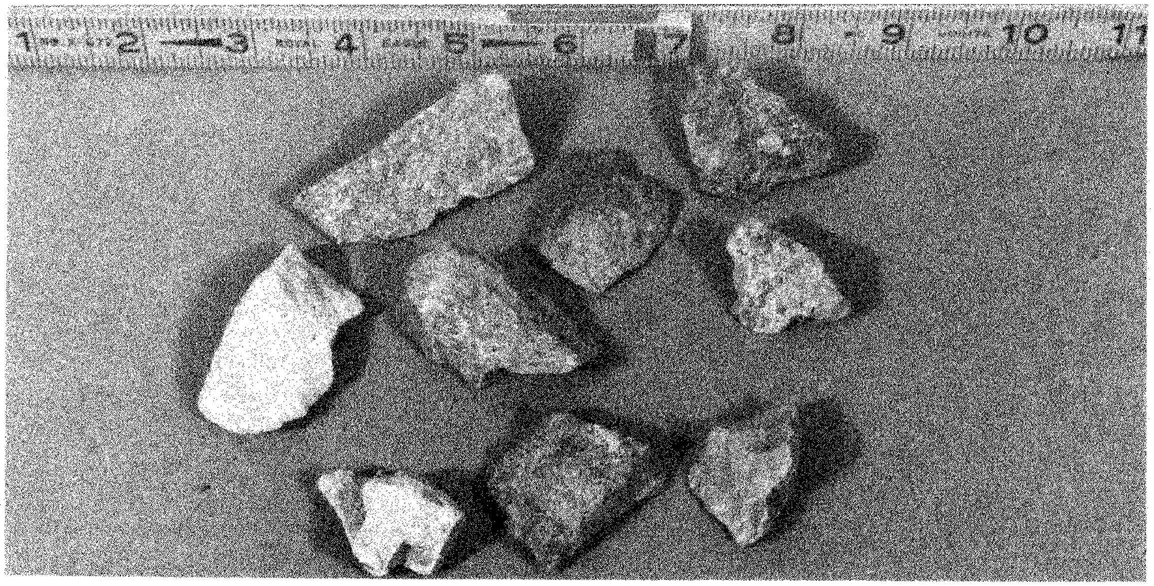


a. Rounded

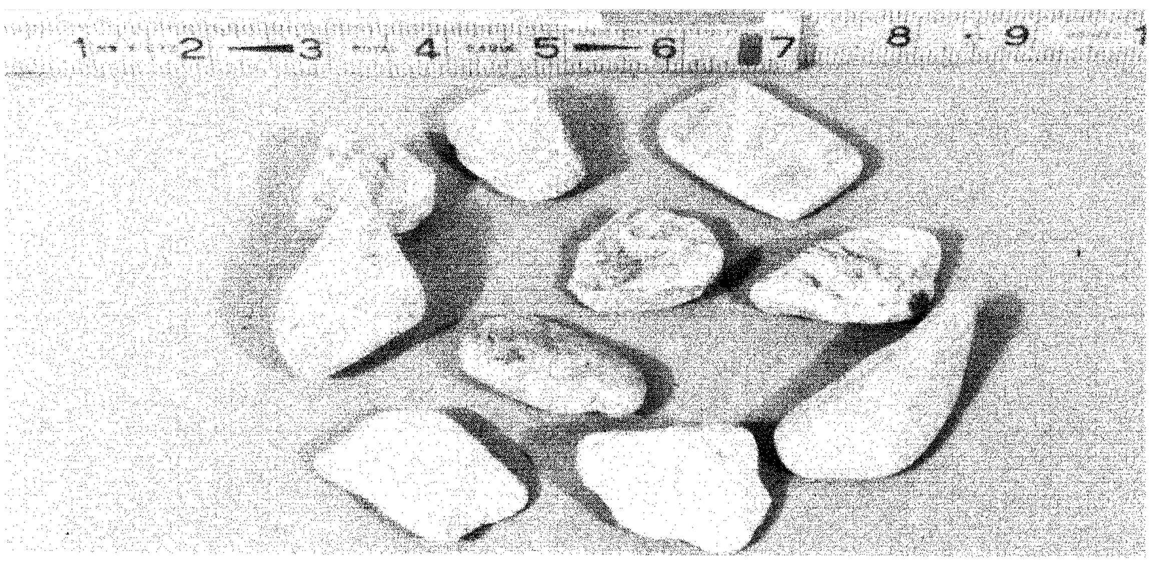


b. Subrounded

Figure E-3. Photographs of several soils to aid in selecting terms for describing the grain shape of coarse-grained soils (Continued)



c. Subangular



d. Angular

Figure E-3.   (Concluded)

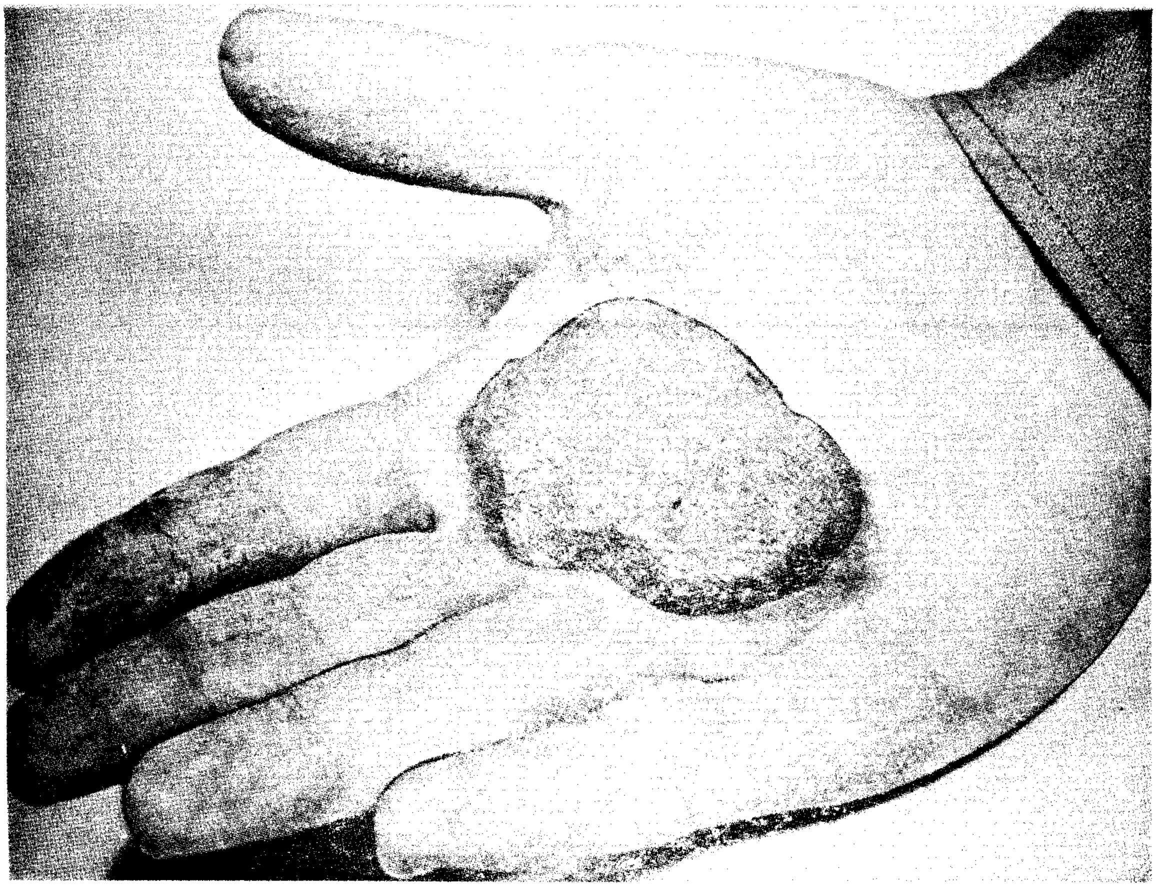


Figure E-4. Appearance of sample of moist, fine-grained soil prior to conducting the dilatancy test

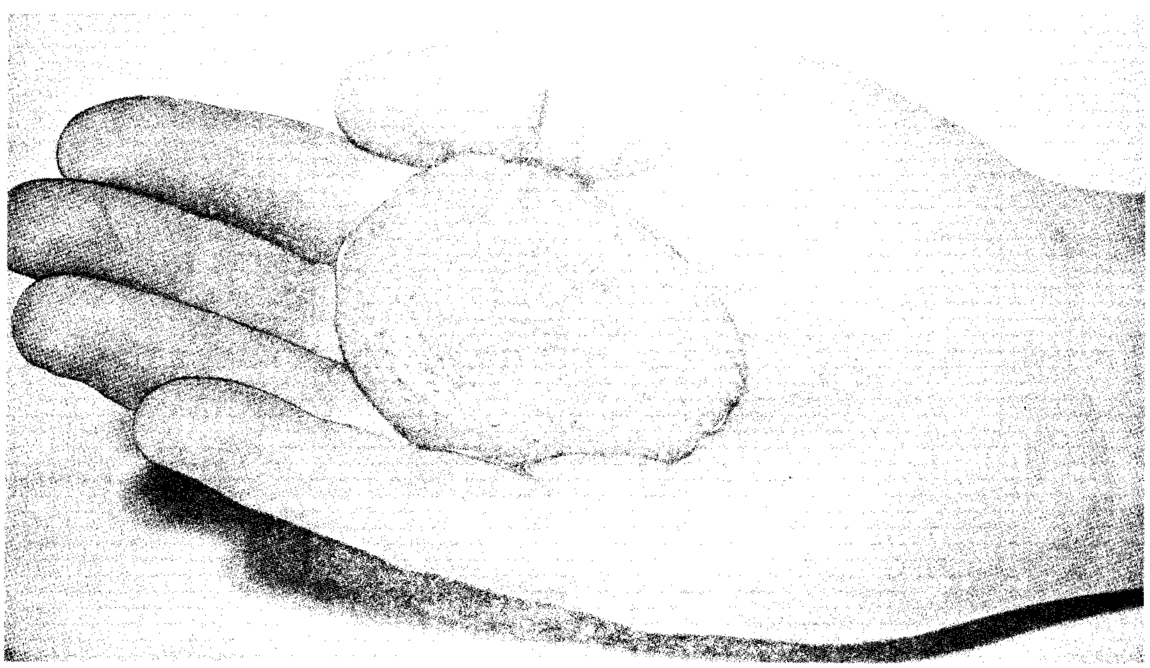


Figure E-5. Livery appearance of a sample of moist, fine-grained soil which occurred as a result of shaking during the dilatancy test

Figure E-6. Photograph of a sample of a moist, fine-grained soil being squeezed during the dilatancy test

Figure E-7. A sample of a moist, fine-grained soil cracking and crumbling during the dilatancy test

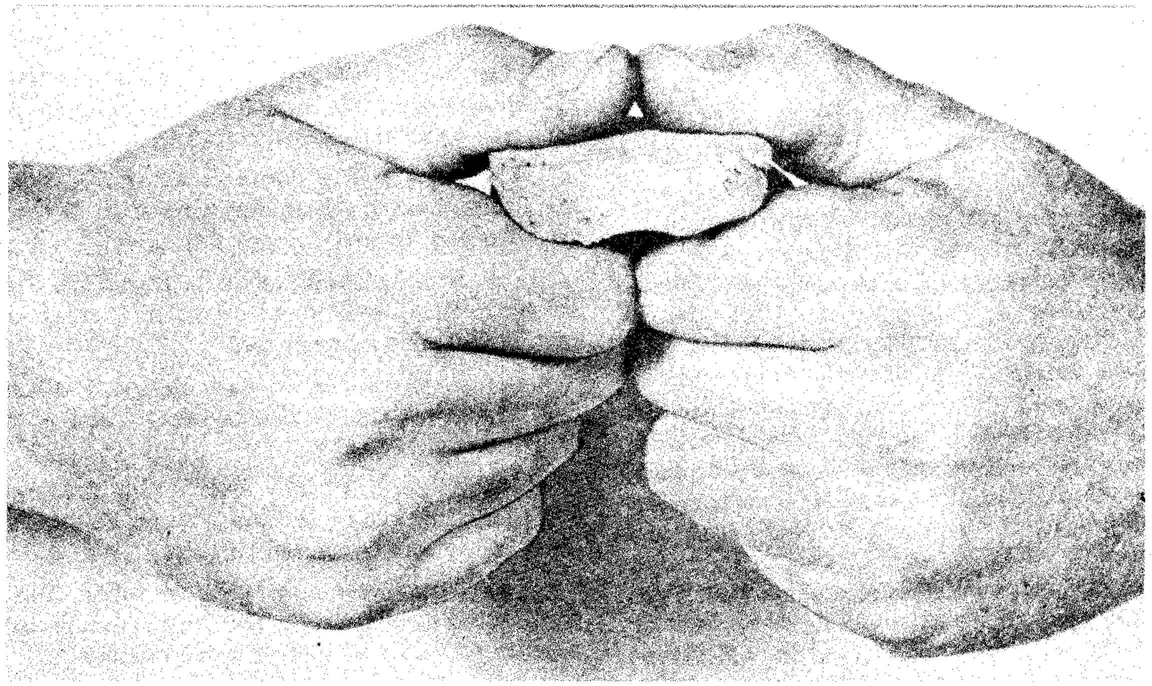


Figure E-8. A sample of a dry, fine-grained soil being broken to determine its dry strength

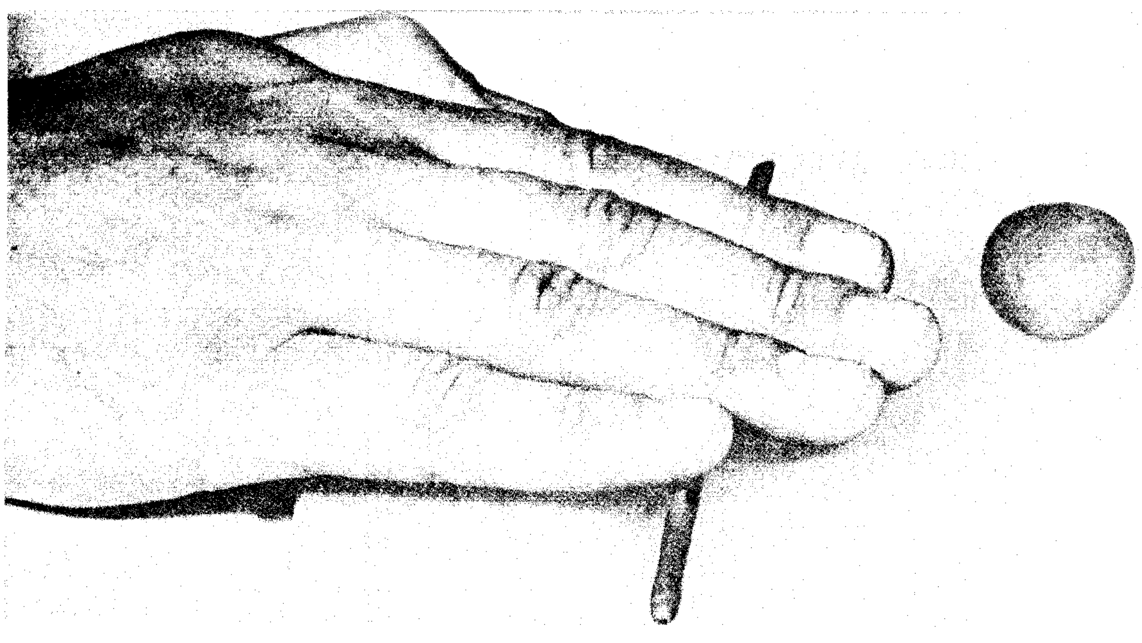


Figure E-9. A sample of a moist, fine-grained soil being rolled to a 3-mm- (1/8-in.-) diam thread to determine its toughness and plasticity

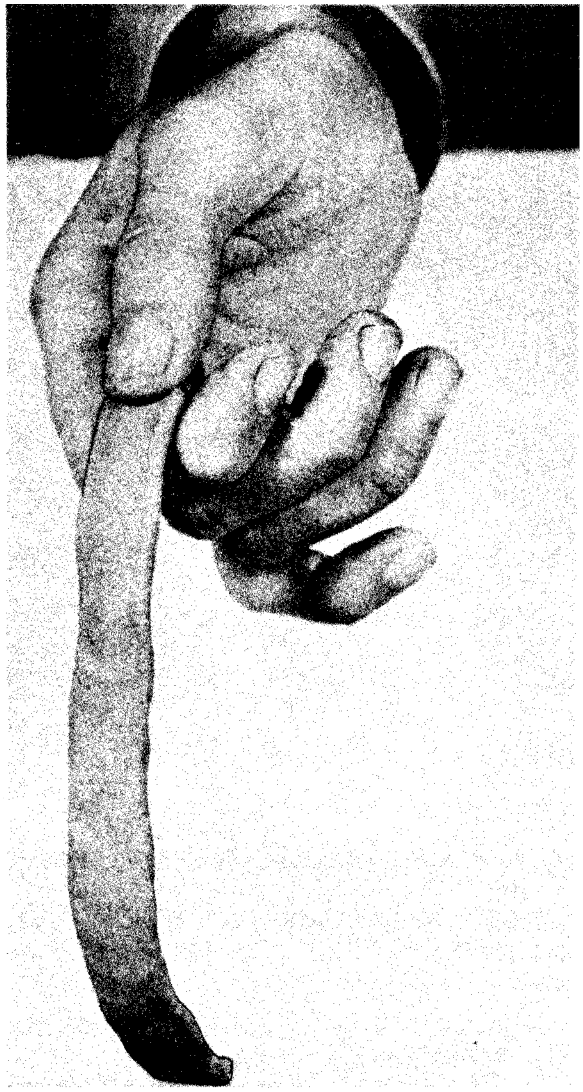


Figure E-10. Photograph of a sample of a moist, fine-grained soil being flattened to a ribbon about 3 to 6 mm (1/8 to 1/4 in.) thick to determine its toughness and plasticity