SCS NATIONAL ENGINEERING HANDBOOK

SECTION 8 -- ENGINEERING GEOLOGY

CHAPTER 3. SAMPLES

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CHAPTER 3. SAMPLES

Samples are obtained for soil mechanics testing to determine the physical properties of materials and how they behave under specific conditions. The results of these tests provide a basis for predicting the behavior of the materials during construction and operation of a structure. Such data furnish a basis for developing certain aspects of the design to provide a safe, economical, and practical structure.

To serve the intended purpose adequately, samples must be representative of the horizon sampled. They must be of suitable size and character so that the desired tests can be performed. The kind of samples to be taken at a particular site depends on the nature of the materials and on the size and purpose of the structure. The number of samples needed depends on the variability of the materials. The minimum requirements for sampling are outlined by group classification in chapter 5.

Determining Sampling Needs

After completing phase 1 of a detailed site investigation (chapter 6), the geologist and engineer must determine what materials should be sampled and what tests are needed. The character of the material and the tests to be performed govern the size and kind of sample required. The selection of equipment and the method of obtaining samples are controlled by site conditions, character of the material, depth of sampling, and the size and kind of samples needed. The kinds of samples to be taken for different locations and tests are outlined in the following pages.

Foundation

Take undisturbed samples of questionable materials at the intersection of the centerline of the dam with the centerline of the principal spillway. Take undisturbed samples at other points along the centerline of the dam if materials of questionable bearing strength, compressibility, or permeability are encountered that cannot be correlated with strata at the intersection of the centerlines of the dam and principal spillway. Always consider taking additional undisturbed samples if the proposed dam is to be more than 35 feet high.

Take 25-pound disturbed samples from each distinct horizon in a proposed cutoff-trench area for compaction analysis if the material that might be excavated is suitable for use in the embankment. Take 4-pound disturbed samples of all other soil horizons and of the same horizons from different holes if they are needed to verify correlation.

Take cores of compaction-type shales for slaking (wetting-drying) and freezing-thawing tests. Foundations of these materials may require special treatment, such as spraying with asphalt or immediate backfilling of the cutoff trench on exposure. Rebound following unloading may also

be a problem in some types of shale. The geologist and engineer should jointly decide what laboratory tests are needed for both soil and rock samples.

Principal Spillway

In addition to samples from the intersection of the centerlines of the dam and principal spillway, take additional undisturbed samples of any other materials of questionable bearing capacity that are beneath the centerline of the proposed principal spillway.

If rock is to be excavated, take undisturbed cores of rock materials. To protect them from weathering, the samples of some rock cores must be dipped in paraffin and stored indoors.

Emergency Spillway

Take large disturbed samples of any material proposed for use in the embankment. If rock is to be excavated, take cores of the rock material.

Although soft shales may be classified as common excavation, it is desirable to obtain cores for later inspection by prospective contractors. If there is any question about the suitability of the rock materials for use in the dam, send cores or samples to the laboratory for freezing-thawing, wetting-drying, rattler, and other tests that will help to determine their physical characteristics.

Borrow Areas

Take large disturbed samples of each kind of unconsolidated material that can be worked as a separate zone or horizon. For classification, collect small samples of materials that are of such limited extent or so distributed that they cannot be worked separately or placed selectively in the fill. Although these less abundant materials generally are mixed with adjoining materials during borrowing operations, their inclusion in samples from the more abundant materials or more extensive borrow zones may result in erroneous evaluation. Laboratory identification of the index properties of these less abundant materials results in better evaluation of the effect and use of various mixtures.

Materials with the same Unified soil classification and from the same horizon and zone can be composited by taking approximately equal amounts of material from each hole that is to be included in the composite. But like materials from significantly different topographic elevations or from different stratigraphic elevations should not be composited.

Do not take composite samples in areas where high salt content, montmorillonitic clay, or dispersion are suspected. In these areas, collect small individual samples from each hole. Samples with like characteristics are composited in the laboratory or testing section after the index properties have been evaluated. The geologist and engineer should furnish guidance on laboratory compositing, based on field distribution of the materials.

On the soil sample list, form SCS-534, show from what holes and at what depth in each hole the materials in a composite sample were taken. Give estimates of the quantity of borrow material represented by each sample on form SCS-35 or in the geologic report.

It is not necessary to sample surface soil that is to be stripped from the site, stockpiled, and later placed on the completed embankment. Since this surface soil is not to be compacted to a required density, compaction tests are not needed.

For sites at which the borrow material is wet and is expected to remain wet during construction, place several samples in sealed pint jars or plastic bags. These samples are needed to determine the field moisture content.

In borrow areas where the water table is permanently high, the collection of borrow samples of cohesive materials below the water table serves no useful purpose unless the area can be drained.

In the geologic report and on form SCS-356, specify what tests other than compaction are needed.

Show the location of all samples on both the plan and the cross sections of the borrow area on the geologic investigation sheets.

Reservoir Basins

Take large disturbed samples that are representative of the bottoms and sides of farm ponds and storage reservoirs for sites where moderate or excessive leakage is suspected. If local materials are to be used for blanketing or sealing, obtain 25-pound samples of each kind. To determine the permeability of reservoirs or pond basins, collect samples from the surface 12 inches of the present or proposed bottom and sides. Where borrow is to be removed from the pond area, take samples from below the proposed borrow depth for permeability tests.

Relief Well and Foundation Drain Locations

If there are permeable strata that may require drainage, take undisturbed samples, if possible, for permeability determinations. If the geologist and the engineer conclude that relief wells or foundation drains are needed, the aquifer must be fully delineated and representative samples taken. Take undisturbed samples of all strata from the surface of the ground to 2 feet below the bottom of the permeable stratum.

It is impossible to obtain an undisturbed sample of some kinds of permeable material. It may therefore be necessary to determine the permeability or transmissibility (permeability times thickness) of an aquifer or aquifers in the field by field permeability tests. If field permeability tests are made, take representative samples for use in the design of the well and filter.

Where corrosion or incrustation of the relief-well screen is a problem take a sample (1 quart) of the ground water. Send it to the laboratory for such tests as alkalinity, chlorides, iron, total hardness, and pH value.

If investigations of the centerline of the dam indicate that foundation drains may be needed, take 4-pound disturbed samples for mechanical analysis of each horizon in which a drain may be placed. These samples usually are of permeable material, but where it is necessary to pass the drain through impermeable horizons, collect samples of this material also.

Stream Channel and Other Areas

If gravels and sands from channels or other nearby areas seem to be suitable for drains or filters, take samples for mechanical analysis.

For Soil Stabilization

Any samples needed for soil-stabilization measures should be representative of the area where the measures are to be installed. The number of samples to be taken depends on the areal extent of the treatment and on the kind or kinds of material. Tests for soil cement or other chemical soil-stabilization measures require very large (75 pound) samples.

Undisturbed Samples

Undisturbed samples are those taken in such a manner that the structure and moisture content of the original material are preserved to the maximum extent possible. Undisturbed samples are used to determine shear strength, consolidation, and permeability. Rock cores are used to determine strength, permeability, and weathering characteristics. Undisturbed samples are generally collected from foundation materials beneath embankments and appurtenant concrete structures when information on natural strength, consolidation, or permeability is needed.

The important considerations for undisturbed samples are that they be representative and that any disturbance of structure and moisture conditions of the sample be reduced to an absolute minimum. This requires close attention to sampling procedures, tools, packaging methods, and transportation.

Undisturbed samples from a depth of more than 15 feet usually must be obtained with drilling equipment. In the absence of drilling equipment, their collection involves the excavation of test pits from which cubes or cylinders of soil can be taken. Cubes, cylinders, or clods of soil can also be cut from the sides of open pits and cut banks, both natural and artificial. See chapter 2 for sampling equipment and methods.

Minimum Size Requirements

The Soil Mechanics Laboratory requirements for trimmed sample sizes and for trimming allowance vary with the homogeneity of the material, the maximum grain size, and the kind of test required.

To meet these requirements, the minimum diameter of undisturbed samples is 5 inches for triaxial shear and horizontal permeability tests and 3 inches for all other tests. In homogeneous material, however, where reliable test results can be obtained from specimens cut from succeeding vertical depths, the minimum diameter for triaxial shear tests is 3 inches.

These minimum diameters apply to material in which the maximum grain size is no more than 2 mm. In materials containing fragments larger than 2 mm., the minimum diameter for undisturbed samples may need to be larger.

The recommended minimum size for rock core samples is NX (2-1/8 inches), but to complete some holes, a smaller diameter may be necessary.

Field Notes

Take detailed field notes for each undisturbed sample. They should include the following items as appropriate.

1. Hole No. and location.
2. Complete log of hole above and below samples.
3. Method of drilling and size of hole.
4. Type and size of test pit.
5. Casing (type and size) or drilling mud mixture used.
6. Ground-water elevation and date and time measured.
7. Length of drive and length of sample recovered, or percent recovery.
8. Size of sample (diameter).
9. Elevations or depths between which sample was taken.
10. Method of cleaning hole before sampling.
11. Other items, such as difficulties in obtaining sample.

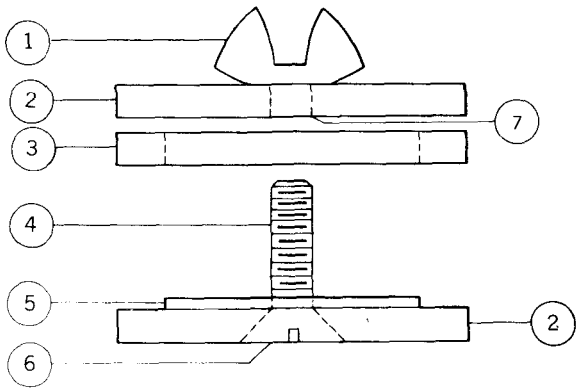
With a permanent marking device, label the sample container. Record the following information on the label.

1. Watershed, site No., and location.
2. Date.
3. Hole No. and sample No.
4. Elevations or depths between which sample was taken.
5. Top clearly identified.
6. Name of person who took the sample.

Packaging

Samples collected in a double-tube core barrel are encased in metal liners when they are removed from the barrel. Plug both ends of these containers with expanding packers or metal caps. Wooden plugs can also be used. If nails are used to fasten the plugs, be careful not to disturb the sample while nailing.

Expanding packers (fig. 3-1) are preferred for sealing the ends of thin-wall tubes, but metal caps, tape, and wax can also be used. Be careful that there is no air space between the sample and the seal. Place labels and all identification on the tube or the liner, not on the ends.



1. Brass wingnut.
2. Aluminum bar stock.
3. Gum rubber gasket.
4. Flathead brass machine screw.
5. Washer.
6. Head sealed with water-proof cement.
7. Drill.

Figure 3-1.--Expanding packer for sample tube.

If they are tightly confined, samples collected by hand excavation can be placed in tin cans, Denison tins, or similar containers.

Seal all undisturbed samples thoroughly with a high-melting-point wax. Beeswax or a mixture of beeswax and paraffin is recommended. These waxes do not shrink away from the container so much as paraffin alone, usually have a higher melting point, and thus deform less in hot weather. The wax seal should fill all spaces between the sample and the container, as well as cover both ends of the sample. Pack all undisturbed samples in excelsior, sawdust, or other shock-absorbent material and crate them. Two or more samples can be boxed together for shipment, but they should not touch each other.

Use reusable boxes. They are to be returned by the laboratory along with sample bags, thin-wall tubes, Denison liners, expanding packers, and the caps for tubes and liners. Mark the boxes with precautionary information, such as "Handle with Care," "This Side Up," "Do Not Drop," and "Protect from Freezing."

Disposition of Rock Cores

Store samples of easily weathered rock cores, such as shale, at the nearest SCS office. If they are left outdoors and allowed to weather, they may give prospective contractors an erroneous impression of their original hardness.

Handle rock cores carefully and store them in boxes of dressed lumber or other suitable materials. The storage boxes should be adequate for cores about 4 feet long. Usually no more than four cores should be stored in each box. The cores should be separated by longitudinal partitions. Use separation blocks wherever core is lost. Embossed metal tape or other

acceptable materials can be securely fastened in the box to indicate by elevation the beginning and end of each reach of core in proper sequence as taken from boring. Place cores first in the top compartment next to the hinged cover and proceed toward the front of the box in the order cores are taken from the drill hole, filling each compartment from left to right in turn (as one reads a book). Note the elevations on separation blocks for those sections in which a core could not be obtained. It is desirable to photograph the cores after they are boxed.

Storage boxes can be fitted with hinged or telescopic covers. On the inside of the cover stencil the box No., project name, site No., and hole No. Stencil the same information on the outside of one end of the box.

Disturbed Samples

To be adequate, disturbed samples must be representative of the stratum, material, or area being sampled. They are used to make qualitative estimates of the probable behavior of materials. This kind of sample is the easiest to obtain and is important for the classification of materials and for many soil mechanics tests. But if quantitative information on in-place strength, consolidation, or permeability is needed, disturbed samples are of little value. The important consideration for disturbed samples is that they be representative of the stratum from which they are taken.

Size

The amount of material needed for laboratory testing depends on two factors: (1) Number, kind, and purpose of tests to be performed and (2) particle-size characteristics of the material to be sampled.

The Soil Mechanics Laboratory has established three general size groups for disturbed samples that are to be sent to the laboratory for testing.

"S" (small) samples are used only for index and classification tests, such as particle-size distribution (mechanical analysis), dispersion, soluble salts, liquid limit, and plastic limit. "S" samples usually consist of 4 to 10 pounds of material collected for purposes of comparison and correlation of stratigraphy and other general soil characteristics of foundations or borrow areas.

"L" (large) samples are used for more comprehensive analyses including index and classification, moisture-density relationships (compaction), permeability, shear, consolidation, and filter-design tests. "L" samples usually consist of 25 to 50 pounds of borrow and spillway material proposed for use in embankments, of reservoir bottom material proposed for sealing, and of aquifer material to be relieved by wells or drains.

"XL" (extra-large) samples are used for special compaction tests, soil-cement tests, and tests for durability as riprap or drain materials.

"XL" samples consist of 75 to 150 pounds of sand or fine-grained materials proposed for soil-cement stabilization or of 40 pounds of rock materials proposed for use as riprap, rock toes or berms, and drainage blankets.

Table 3-1 shows the amount of material that is needed to perform the various soil mechanics tests. These amounts form the basis for the recommended minimum sizes of field samples (table 3-2).

Table 3-1.--Amount of material needed for various soil mechanics tests

Test	Particle size used in test	Amount of material needed
		Pounds
Index and classification tests:		
Sieve analysis (gravel)--------	Passing 3-inch sieve, retained on No. 4 sieve.	3
Hydrometer analysis, dispersion, salts, and Atterberg limits.	Passing No. 10 sieve----	3
Comprehensive tests:		
Compaction----------	Passing No. 4 sieve-----	8
Permeability----------	Passing 3/4-inch sieve--	7
Reservoir sealing----------	Passing 3/4-inch sieve--	25
Shear:		
For materials in which 90 percent passes No. 4 sieve, specimen size is 1.4 inches by 3 inches.	Passing No. 4 sieve-----	5
For materials in which less than 90 percent passes No. 4 sieve, specimen size is 2.8 inches by 6 inches.	Passing 1/2-inch sieve--	18
Consolidation----------	Passing No. 4 sieve-----	2
Specific gravity (coarse fraction).	Passing 3-inch sieve, retained on No. 4 sieve.	2
Special filter-design tests----	Passing 3-inch sieve----	20
Soil-cement tests----------	Passing 3/4-inch sieve--	70

To fulfill individual test requirements, the size of the sample to be sent to the laboratory varies with the gradation of the natural material. Most laboratory tests are performed on materials passing a No. 4 sieve. Larger samples are therefore needed of materials that contain significant amounts of larger particles. The minimum sizes of field samples for various gradations of materials are shown in table 3-2.

Table 3-2.--Minimum field-sample size for various gradations of material[1]

Gradation of material and sample size group	Maximum particle size	Minimum field sample size
		Pounds
Gradation No. 1, natural materials with 90 percent passing No. 4 sieve:		
"S" sample	3 inches	4
"L" sample	3 inches	25
"XL" sample	3 inches	75
Gradation No. 2, natural materials with 50 to 90 percent passing No. 4 sieve:		
"S" sample	3 inches	10
"L" sample--1 sample	No. 4 sieve	25
"L" sample--1 sample	3 inches	25
"XL" sample	6 inches	150
Gradation No. 3, gravel materials with less than 50 percent passing No. 4 sieve:		
"S" sample	3 inches	20
"L" sample	3 inches	40
"XL" sample	6 inches	150

[1] Note that the maximum particle size to be included in field samples ranges from 3 inches for "S" and "L" samples to 6 inches for "XL" samples. Estimate the percentage of over-size materials excluded from the field samples and record it along with descriptions of the samples on forms SCS-533 (Log of Test Holes) and SCS-534 (Soil Sample List). It is not necessary to screen samples to determine the exact amounts of the various particle sizes. Visual estimates of the particle sizes and the quantities involved are adequate.

Put disturbed samples that are to be sent to the laboratory for moisture determination in wide-mouth jars or evacuated plastic bags and seal immediately.

Methods of Obtaining

Representative disturbed samples are obtained by hand excavation or, at a greater depth, by bucket-type augers or drive samplers (table 2-8). Be careful not to contaminate the sample with materials from other strata. Continuous-flight augers and wash borings are unsatisfactory. Take proportionate volumes of all material between the selected elevations in the sample hole. If the sample so obtained is too large, it can be reduced by quartering after it is thoroughly mixed.

Sample Containers

Place disturbed samples in heavy canvas bags. Each State should maintain a supply of these bags.

Table 3-3 relates the size of sample bags to capacity. If it is necessary to retain the field moisture content for laboratory determination, such as in borrow material that is wet and is expected to remain wet, use polyethylene plastic liners inside the canvas sample bags. Suitable liner sizes are given in table 3-3.

Table 3-3.--Capacity of various sample bags

Sample-bag measurements	Plastic liner		Capacity
	Thickness	Size	
Inches	Inches	Inches	Pounds
9 x 15	0.0015	5 x 3-1/2 x 14	10
16 x 24	0.002	10 x 4 x 24	50
16 x 32	0.002	10 x 8 x 30	75

Labeling, Numbering, and Shipping

Tag bag samples of disturbed material with cloth (linen) shipping tags that show the following information: (1) Location of project (State and town or community), (2) site or project name and No., (3) fund classification of project (FP-2, WP-1, WP-2, CO-1), (4) location of sample on the site (centerline station, borrow grid, etc.), (5) test hole No., (6) field No. of sample, (7) depth of sample, and (8) date and name of collector. Number composite samples and show this number on the tag. Record the Nos. of the individual holes from which the composite sample was taken and the field Nos. of the samples on form SCS-534.

Since tags are often pulled off in transit, place a duplicate tag inside the bag.

To expedite the sorting, numbering, and handling of samples in the laboratory, the field No. of a sample should start with the test-hole No., followed by a decimal that indicates the No. of the sample from that hole. Examples are sample Nos. 1.1, 1.2, 1.3, which are three samples from test hole No. 1 (in the centerline of the dam), and sample Nos. 101.1 and 101.2, which are two samples from hole No. 101 (borrow area).

Under separate cover send the standard forms containing the descriptions of the samples and logs of the test holes to the laboratory along with copies of plans and profiles at the same time the samples are shipped.

Send a copy of the geologic report to the laboratory as soon as possible. A summary of the material to be sent to the laboratory follows.

1. Form SCS-533, Log of Test Holes.
2. Form SCS-534, Soil Sample List--Soil and Foundation Investigations. On this sample list show the individual holes, or the samples, included in composited samples if such mixtures are prepared in the field. Record the method of transportation and information concerning Government bills of lading. List the samples on form SCS-534 in this order: Foundation area, principal spillway, drainage and relief wells, channel, emergency spillway, and borrow area.
3. Forms SCS-35A, -35B, and -35C, Plan and Profiles for Geologic Investigations.
4. Copy of the geologic report, including the supplement on interpretations and conclusions.

At the time the samples are sent to the laboratory, send copies of the various forms and of the geologic report including the supplement to the State office. This information is needed to prepare form SCS-356, Request for Soil Mechanics Laboratory Test. Form SCS-356 is an administrative form used to commit funds to reimburse the laboratory for the cost of sample analyses. An alternate procedure is to supply the State office a copy of form SCS-356 that already contains the information that the geologist needs to supply.

Large bag samples are usually shipped by freight or express. Be sure that each bag is correctly labeled and addressed. Small bag samples can be packaged together and shipped by freight or express. Single small bag samples not exceeding 4 pounds in weight can be sent by franked mail. Get a Government bill of lading from the State office if samples are shipped by freight or express.