Engineering Description of Wetland Soils

PURPOSE: This technical note provides guidance for describing soils as part of the site evaluation and soil survey as an aid to identify wetland soils, to delineate wetland areas, and to determine construction properties required for wetland engineering. It provides guidance on how to describe wetland soils by field expedient and laboratory procedures. A field expedient description is useful to obtain a preliminary identification of soils and to determine preliminary engineering properties. Laboratory procedures accurately identify the soils and provide the best evaluation of engineering properties from soil description data. Evaluation of engineering properties is not within the scope of this technical note. The information supplements the design sequence contained in WRP Technical Note WG-RS-3.1.

BACKGROUND: Wetland soils typically include hydric sediments with an organic component of decomposed plant material (peats and mucks). A hydric soil contains abundant moisture and under wetland conditions will periodically be in a reduced state containing limited oxygen and a high water table. Sediments are materials that are deposited or settle to the soil surface from an overlying body of water. The organic material can influence soil parameters. Organic soils are readily identified by their color, odor, spongy feel and frequently by a fibrous texture.

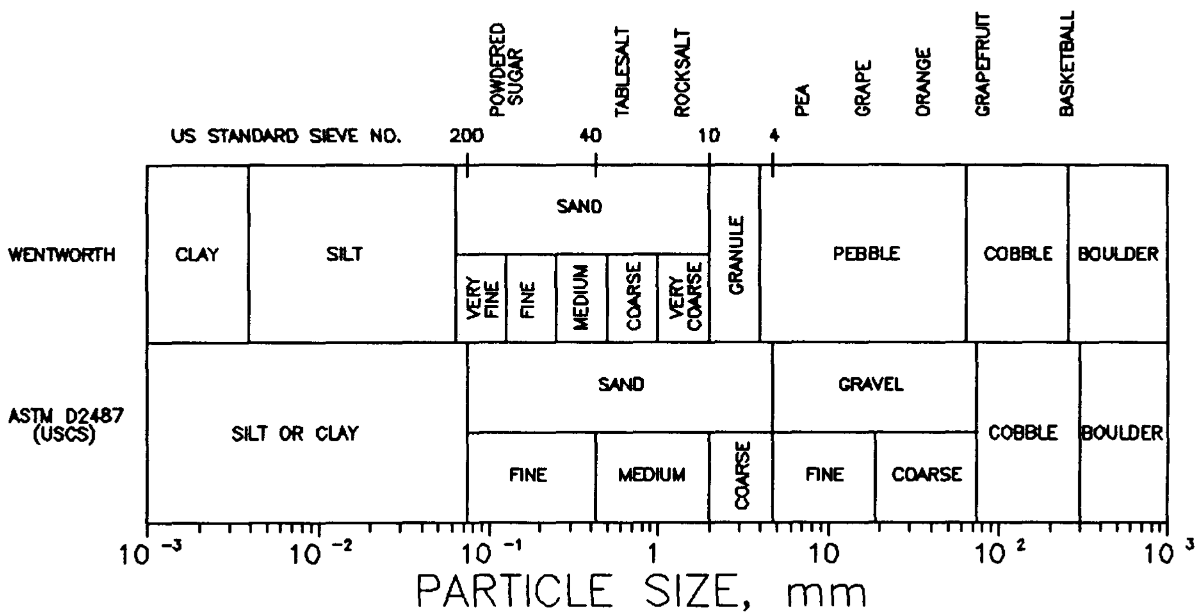
Diagnostic horizons of wetland soils include primitive entisols (E1), young inceptisols (I2), and mollisols (M1). Entisols (E1) are weakly developed wet soils with only A (exposed soil surface) and C (underlying parent material) horizons. The A horizon is young because of material deposited by water or some other agent. The A horizon will probably be a black, thick, fertile (mollic) or less fertile (umbric) soil. Inceptisols (I2) are usually moist immature soils commonly found in depressions where soil development is slowed by lack of periodic drying. Mollisols (M1) are found under wet grasslands with dense, fibrous root systems leading to a thick, dark, humus-enriched A horizon.

The thrust of the engineering description should be to identify soil from the texture; i.e., relative size, shape, and hardness of soil particles. The soil description with some information on mass (density, void ratio, water content) properties is sufficient to estimate a typical range of in situ or compacted soil properties for engineering applications.

Wetland soils are often sands with silts and clays. Particle sizes will typically be less than 4.75 mm (No. 4 US Sieve), according to the Wentworth (Müller 1967) or ASTM D 2487 (Unified Soil Classification System, USCS), Table 1. Table 2 identifies soil in terms of group symbols and typical group names by a field expedient procedure that uses the USCS. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, a GW-GC soil is a well-graded gravel-sand mixture with clay binder. A wetland soil may contain some sands with group symbols SW, SP, SM, and SC and may also contain silts and clays with group symbols ML, CL, OL, MH, CH, OL, and even may contain PT. A wetland soil will usually not contain any gravels.

Soft, compressible, fine-grained soil such as organic silt (OL), organic clay (OH), normally consolidated plastic clay (CH), peat (PT) or muck are undesirable for supporting embankments, roads, or other structures. Lean clays (CL) with plasticity index PI $\leq$ 12 and liquid limit LL $\leq$ 35, sands

Table 1. Grain Size Classification of Soils



(SC, SM-SC, SM, SP, SW), and gravels (GW, GP, GM, GC) usually provide the best soils for construction. Disturbed soil samples are required for an engineering description. Surface soils may be readily obtained by digging a small test pit with a pick and shovel or excavating a large test pit or trench with a backhoe, scoop, clamshell bucket or other mechanical equipment. Subsurface soil samples may be obtained by hand or machine-operated augers, piston, and other samplers (EM 1110-2-1907).

FIELD EXPEDIENT DESCRIPTION: An approximate description of wetland soils may be made in the field by observation and tests with portable equipment to determine the parameters given below. Equipment required to complete a field expedient description of soils is given in Table 3.

- Acid test. This test can determine the presence of calcium carbonate in the soil. Calcium carbonate is normally desirable because of the cementing action it provides and the soil strength that can be added to compacted soil over time. This test permits a better understanding of abnormally high strength values of fine-grained soils that are tested in-place. The test is conducted by placing a few drops of hydrochloric acid on a piece of the soil. A fizzing reaction (effervescence) indicates the presence of calcium carbonate.

- Bite test. This test is useful for identifying sand, silt, or clay. Sands grate harshly between the teeth, while silts feel gritty. Clays are not gritty, but feel smooth and powdery like flour.

- Breaking test. A pat of minus No. 40 sieve fraction is molded to 13 mm (1/2 in.) thickness by 32 mm (1-1/4 in.) diameter in the wet plastic state and allowed to dry completely. An attempt to break the thoroughly dried pat is made by using the thumb and forefingers of both hands. Avoid breaks along shrinkage cracks because these will not indicate the true breaking strength. The soil is roughly described as follows:

Table 2. Field Expedient Soil Classification (Data from Table 2-1 of FM 5-541, "Military Soils Engineering)

Major Divisions	Minor Divisions	Group Symbol	Typical Group Names and Description
Coarse-grained: Particles less than 75 mm (3 in.) and more than half larger than No. 200 sieve	Gravels: More than half larger than No. 4 sieve	GW	Well-graded gravels, gravel-sand mixtures; wide range of sizes with few or no particles less than No. 200 sieve
		GP	Poorly graded gravels or gravel-sand mixtures; predominantly one size with few or no particles less than No. 200 sieve
		GM	Silty gravels, gravel-sand-silt mixtures; nonplastic particles less than No. 200 sieve (see ML below)
		GC	Clayey gravels, gravel-sand-clay mixtures; plastic particles less than No. 200 sieve (see CL below)
	Sands: More than half smaller than No. 4 sieve	SW	Well-graded sands, gravelly sands; wide range of sizes with few or no particles less than No. 200 sieve
		SP	Poorly graded sands or gravelly sands; predominantly one size with few or no particles less than No. 200 sieve
		SM	Silty sands, sand-silt mixtures; nonplastic particles less than No. 200 sieve (see ML below)
		SC	Clayey sands, sand-clay mixtures; plastic particles less than No. 200 sieve (see CL below)
Fine-grained: Particles less than No. 40 sieve and more than half smaller than No. 200 sieve	Silts and Clays: liquid limit less than 50 percent	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity; none to slight dry strength; quick to slow dilatancy, no toughness
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays; medium to high dry strength, none to very slow dilatancy, medium toughness
		OL	Organic silts and organic silty clays of low plasticity; slight to medium dry strength, slow dilatancy, slight toughness
	Silts and Clays: liquid limit less than 50 percent	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts; slight to medium dry strength, slow to no dilatancy, slight toughness
		CH	Inorganic clays of high plasticity, fat clays; high to very high dry strength, no dilatancy, high toughness
		OH	Organic clays of medium to high plasticity, organic silts; medium to high dry strength, none to very slow dilatancy, slight to medium toughness
Highly Organic		PT	Peat and other highly organic soils; readily identified by color, odor, spongy feel and frequently by a fibrous texture

* See text for definitions of dry strength, dilatancy, and toughness.

Table 3. Equipment for Field Expedient Soil Classification

Equipment	Remarks
No. 40 U.S. standard sieve and, if available, No. 4 and No. 200 sieves	The breaking, dilatancy, dry strength, ribbon, roll, and toughness tests are performed on material passing the No 40. U.S. standard sieve. Any screen with about 40 openings per lineal inch is useful. A No. 4 sieve is useful for separating gravel and a No. 200 sieve is useful for separating fines.
Pick and shovel	Entrenching tools are required for obtaining soil samples. A hand auger should be available for obtaining samples from depths more than a few feet below the surface.
Spoon	The spoon is used to mix water with cohesive soil and to obtain a desired consistency. The consistency desired is often like that of putty. If too dry, water must be added and if sticky, the soil should be spread out in a thin layer and allowed to lose some moisture by evaporation.
Pocket knife	A pocket knife is required for obtaining samples and trimming them to the desired size.
Small mixing bowl	Cup or other small container with a rubber-faced or wood pestle are required for pulverizing fine-grained portions of the soil.
Heavy paper	Several sheets of heavy paper are required for rolling samples.
Pan and heating element	A pan and heating element are required to dry samples for sieve analysis and to determine water content. Drying by sunlight is adequate for performing the field expedient tests and classification.
Balances or scales	Scales are required for weighing samples.

CH - Soil cannot be broken or powdered or broken with great effort, but not powdered
CL - Soil can be broken and powdered with some effort
ML, MH, or CL - Soil easily broken and readily powdered
ML or MH - Soil crumbles and powdered when picked up in the hands

- Color. The color distinguishes between different strata and assists the identification of the type of soil. Color classes are chroma and achroma with brilliance, hue, and saturation attributes. Chroma colors are reds, greens, purples, browns, and pinks. Achroma colors are black, white, and grays intermediate between black and white. Brilliance measures the difference between dark (low brilliance) and light (high brilliance) colors or grays. Hue measures the difference between separate colors. Saturation measures the degree of vividness of the hue or the difference from gray. High brilliance light gray, olive green, brown, red, yellow, and white are generally associated with inorganic soils. Red, yellow, and yellowish brown colors may be caused by iron oxides. White to pinkish colors may indicate silica, calcium carbonate, or aluminum compounds. Gray, brown, and black colors indicate organic, fine-grained colloidal (OL, OH) soils. Grayish blue, gray, and yellow mottled colors indicate poor drainage. Wetland soils in a reduced state typically have a dark, gray, mottled appearance with 2 or less chroma colors.

- Dilatancy. A pat of the minus No. 40 sieve fraction of moist soil is prepared with a volume of about 8.2 cc or 1/2 cu in. Add enough water, if necessary, to make the consistency of the soil soft or like a putty, but not sticky. Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of the appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in the soil. Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

- Geophysical tests. Geophysical exploration by seismic, electrical, magnetic, and gravity methods is useful during the site evaluation to assist with identification of the soil profile and the location and thickness of the various strata. These tests allow rapid coverage of large areas at a much smaller cost than conventional equipment. Electrical and magnetic methods are influenced by salinity of the water and could reduce their usefulness in coastal wetlands. Definite interpretation of the results is often uncertain and should be applied only with other subsurface exploration (Das 1984, Telford, et al 1988).

- Grain shape. The grain shape influences soil stability. Irregular, angular particles increase frictional resistance to displacements from applied loads compared with rounded particles. Irregular particles also cause interlocking between grains to increase frictional resistance and strength.

- Odor. Sense of smell or fragrance. The odor may be increased by heating the soil sample over an open flame. Organic OH and OL soils have a distinctive, musty, slightly offensive odor. A rotten egg odor is an indicator of a hydric soil and a wetland.

- Ribbon test. A pat of the minus No. 40 sieve fraction of soil is molded to the consistency of putty without being sticky, adding water or drying if necessary. The soil is rolled by hand on the heavy paper to about 13 to 19 mm (1/2 to 3/4 in.) diameter and about 8 to 13 cm (3 to 5 in.) long. The material is placed in the palm of the hand and starting with one end, the roll is flattened to form a ribbon 6 to 13 mm (1/4 to 1/2 in.) thick by squeezing it between the thumb and forefinger. The soil should be handled carefully to form the maximum length of ribbon that can be supported by the cohesive properties of the soil. If the soil holds together for a length of 20 to 25 cm (8 to 10 in.) without breaking, the material is of high plasticity (CH).

- Roll test. A pat of the minus No. 40 sieve fraction of soil is molded to the consistency of putty without being sticky, adding water or drying if necessary. The sample is rolled rapidly into a thread 3 mm (1/8 in.) in diameter. Materials which cannot be rolled into this thread at any water content are nonplastic or of low plasticity (ML or MH). If the soil can be rolled into a thread, then the degree of plasticity is determined as follows:

  CH - Soil may be remolded into a ball and the ball deforms under extreme pressure by the fingers without cracking or crumbling.
  CL - Soil may be remolded into a ball, but the ball will crack and easily crumble under finger pressure.
  CL, ML, or MH - Soil cannot be lumped together into a ball without completely breaking up.
  OL or OH - Soils containing organic materials or mica particles will form soft spongy threads or balls when remolded.

- Slaking test. This test assists in determining the quality of shales and other soft rocklike materials. The material is placed in the sun or in an oven to dry, and then allowed to soak in water for at least 24 hours. Materials that slake appreciably are undesirable for construction.

- Toughness test. A pat of the minus No. 40 sieve fraction of soil is prepared with a volume of about 13 mm (1/2 in.) on a side and molded to the consistency of putty without being sticky, adding water or drying if necessary. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about 3 mm (1/8 in.) diameter. The thread is then folded and rerolled repeatedly. During this manipulation the water content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached. After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles. The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line of the plasticity chart (see FM 5-541 or ASTM D 2487). Highly organic clays have a very weak and spongy feel at the plastic limit.

LABORATORY DESCRIPTION: A precise description of wetland soils may be accomplished by the USCS. USCS is a precise system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of Atterberg limits and particle-size distribution. The ASTM version of the USCS is given as standard test method D 2487. Knowledge-based computer systems such as CLASS-92 (Bakeer 1992) expedite an efficient engineering description by the USCS. CLASS (Morse and Bakeer 1990) may be used to convert between Visual, USCS, ASTM, and AASHTO systems. Liquid limit, plasticity index, and the particle size distribution are sufficient to describe soil by the USCS.

- Atterberg limits. Indices expressed in terms of the water content (w) of soil in percent that are useful for general characterization of soil, particularly to evaluate the degree of plasticity and compressibility:

  Liquid limit LL, percent - water content between the liquid and plastic state. LL may be determined by ASTM D 4318.

  Plastic limit PL, percent - water content between the plastic and semisolid state. PL may be determined by ASTM D 4318.

  Plasticity index PI, percent - difference in water content between the liquid limit and plastic limit, PI = LL - PL.

- Particle size distribution - determines the proportions by mass of a soil or fragmented rock in specified ranges of particle sizes. D_n is the diameter of soil particles that is (n) percent finer by weight; e.g., D_{10} is the particle diameter at which 10 percent of the material is finer by weight. Particle size distribution may be determined by standard test method ASTM D 422. Refer to ASTM D 2487 for other methods of gradation analysis. The following gradation ratios are also applied by the USCS to classify soil:

  Coefficient of curvature C_c - $(D_{30})^2/(D_{10} \cdot D_{60})$.

  Coefficient of uniformity C_u - D_{60}/D_{10}.

Soils with C_c between 1 and 3 and C_u greater than 4 are well-graded clean gravels, GW, provided that the fines smaller than No. 200 mesh are less than 5 percent by weight. Soils with C_c between 1 and 3 and C_u greater than 6 are well-graded clean sands, SW, provided that fines smaller than No. 200 mesh are less than 5 percent by weight.

- Liquidity index LI, percent. Ratio of water content (w) minus PL to PI, (w - PL)/PI. LI close to and exceeding unity indicate normally consolidated soils, recently deposited sediments, and a potential of being wetland soils. LI exceeding unity indicates soil on the verge of being a viscous liquid. LI close to or less than zero indicates overconsolidated, desiccated soil and soil with high foundation strength.

- Shrinkage limit SL, percent. Component of Atterberg limits that is the water content between the solid and semisolid state; least water content at which the degree of saturation is 100 percent. SL may be determined by Appendix IIIB of EM 1110-2-1906. Water content near or less than SL indicates an overconsolidated, desiccated soil.

- Specific gravity of solids G_s. Ratio of mass (grams or g) in air of a given volume of solids at a stated temperature to the mass in air of an equal volume of distilled water at the same temperature. $G_s = \gamma_s/\gamma_w$, where γ_s = ratio of the solid mass to the volume of the solid mass, g/cc, γ_w = unit mass of water at 4°C, 1 g/cc. G_s may be determined by standard test method ASTM D 854. Estimates of G_s are given in Table 4. Typical G_s is 2.67 for sands and 2.70 for clays. Smaller G_s indicates soils with more organic material.

Table 4. Specific Gravities of Some Soils (After Bowles 1988)

Soil Type	Specific Gravity G_s
Sand	2.65 - 2.68
Silty sand	2.67 - 2.70
Inorganic clay	2.68 - 2.75
Inorganic silt	2.62 - 2.68
Soils with micas and iron	2.75 - 3.00
Organic clay	2.58 - 2.65

The specific gravity is used to determine mass properties such as the density, void ratio, and degree of saturation.

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POINT OF CONTACT FOR ADDITIONAL INFORMATION: Mr. Roy Leach, U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-GS-S, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, phone: (601) 634-2727, co-author.

Dr. Lawrence D. Johnson, U.S. Army Engineer Waterways Experiment Station, author.