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Revision Memo

12/01	Page 7	Added cross-hole testing as a technique for determining soil shear modules.
	Pages 10, 11	Minor edits.
	Page 11	Replaced reference to sand drains with wick drains.



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SCOPE

Special investigations of subsurface conditions by qualified consulting firms are necessary to establish soils data for civil design. This section covers preparation of the memorandum of instructions typically issued to such firms for guidance in the conduct of these investigations and for control of the scope of work. This section also covers issues pertaining to the site preparation and earthwork often necessary for major new plant facilities.

REFERENCES

GLOBAL PRACTICES

GP 4-3-2	Additional Requirements for Blast Resistant Buildings and Structures
GP 4-6-2	Supporting Structures and Foundations for Heavy Machinery
GP 4-7-1	Piles
GP 4-7-2	Steel Sheet Piling
GP 4-8-2	Foundation Pads, Atmospheric Storage Tanks

OTHER LITERATURE

ASTM C33	Specification for Concrete Aggregates
ASTM C127	Specific Gravity and Absorption of Coarse Aggregate
ASTM C294	Descriptive Nomenclature for Constituents of Natural Mineral Aggregates
ASTM D420	Site Characterization for Engineering, Design, and Construction Purposes
ASTM D421	Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
ASTM D422	Particle-Size Analysis of Soils
ASTM D427	Shrinkage Factors of Soils by the Mercury Method
ASTM D653	Terminology Relating to Soil, Rock, and Contained Fluids
ASTM D698	Laboratory Compaction Characteristics of Soil Using Standard Effort
ASTM D854	Specific Gravity of Soils
ASTM D1140	Amount of Material in Soils Finer Than the No. 200 Sieve
ASTM D1143	Test Method for Piles Under Static Axial Compressive Load
ASTM D1452	Soils Investigation and Sampling by Auger Borings
ASTM D1556	Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D1557	Laboratory Compaction Characteristics of Soil Using Modified Effort
ASTM D1586	Penetration Test and Split-Barrel Sampling of Soils
ASTM D1587	Thin-Walled Tube Sampling of Soils
ASTM D1883	CBR (California Bearing Ratio) of Laboratory-Compacted Soils
ASTM D2113	Diamond Core Drilling for Site Investigation
ASTM D2166	Test for Unconfined Compressive Strength of Cohesive Soil and Rock
ASTM D2167	Density and Unit Weight of Soil in Place by the Rubber-Balloon Method
ASTM D2216	Laboratory Determination of Water (Moisture) Content of Soil
ASTM D2217	Wet Preparation of Soil Samples for Grain-Size Analysis and Determination of Soil Constants
ASTM D2399	Selection of Cutback Asphalts
ASTM D2434	Permeability of Granular Soil (Constant Head)
ASTM D2435	One-Dimensional Consolidation Properties of Soils
ASTM D2487	Classification of Soils for Engineering Purposes
ASTM D2488	Description and Identification of Soils (Visual-Manual Procedure)
ASTM D2573	Field Vane Shear Test in Cohesive Soil
ASTM D2728	Paving Uses and Application Temperatures for Road Tars

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ASTM D2850	Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression
ASTM D2922	Determining the Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
ASTM D2937	Density of Soil in Place by the Drive-Cylinder Method
ASTM D3017	Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)
ASTM D3441	Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests in Soil
ASTM D4253	Maximum Index Density and Unit Weight of Soils Using a Vibrating Table
ASTM D4254	Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
ASTM D4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4429	CBR (California Bearing Ratio) of Soils in Place
ASTM D4943	Shrinkage Factors of Soils by the Wax Method

BACKGROUND

Soils investigations are comprised of field exploration and testing, gathering of samples, laboratory testing, and engineering analysis. Because of the special equipment, techniques and interpretive knowledge required, geotechnical consulting firms specializing in the execution of these steps have evolved. Geotechnical consultants, however, often have little in-depth knowledge of the operational requirements, practices, and equipment peculiar to refineries and chemical plants. Also, equipment layouts often are not finalized when a soils investigation must start, and consultants near the project site may not be near the layout development effort or privy to last minute equipment location changes. Consequently, the Company typically issues a Soils Investigation Memorandum to define the requirements of an investigation and direct the efforts of the consulting firm toward the specific data needed. This memorandum is also valuable for obtaining a proposal for the work.

A large project may require more than one soils investigation as it evolves. The results of a soils investigation may be used to assist in selecting a site for the project, prepare soils and foundations-related input to cost estimates, define requirements for site preparation and earthwork, and determine foundation types and design parameters. Regarding site preparation, most sites require preparation in advance of the installation of new facilities. Such preparation can consist of:

- Dewatering, clearing and grubbing.
- Removal of existing structures, foundations, piping and utilities.
- Removal or improvement of weak soils present.
- Earthmoving to reshape the site to meet project needs.
- Development of a drainage system.
- Construction of access roads.
- Construction of earth retaining walls and protective seawalls.

Few sites require all of the above. Responsibility for determining which are necessary, from a civil engineering viewpoint, and development of specifications to ensure their successful execution by the contractor, rests primarily with the civil designer.

To carry out this responsibility, the civil designer must have a knowledge of existing site conditions, and also a knowledge of the requirements peculiar to the type of new facilities to be installed. For the first, he must rely generally on information gathered during site and engineering surveys and the soils investigations. For the latter, he must rely on the onsite and offsite designers who are directly involved in the design of the new facilities. Among their responsibilities is the development of layouts. Ultimately site preparation specifications must conform with the areas, elevations and equipment locations prescribed in the layouts.

DEFINITIONS

Backfill

Backfill is the common term for soil placed in excavations for the purpose of restoring ground levels to intended grades.

Borings

A boring is a hole drilled in the ground to obtain information on soil stratigraphy, to obtain samples for laboratory testing, to permit conduct of in-place tests, and to assess groundwater levels.

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DEFINITIONS (Cont)

California Bearing Ratio (CBR)

CBR is a dimensionless number which relates the wheel load bearing capacity of roadway materials to that of a standard material (crushed rock). CBR is usually determined in the laboratory, but a field test can be conducted also. CBR is used in combination with empirical design charts to determine design thickness of pavements, bases and other roadway layers (ASTM D1883 and D4429).

Casing

Casing is pipe used to maintain a boring open in unstable soils.

Clearing

Clearing is the removal of trees, brush, rubbish, structures, and buried facilities such as old foundations and piping.

Cohesionless Soils

Cohesionless soils are those which have little or no strength when unconfined, obtaining their strength through friction between soil grains. Sands and gravels are typical examples.

Cohesive Soils

Cohesive soils are those which possess an internal strength which permits them to resist shearing stresses even when unconfined. Fine-grained soils such as clays are typical cohesive soils.

Cone Penetration Tests

Cone penetration tests consist of pushing a rod equipped with a conical tip into the ground. These are sometimes conducted in lieu of borings in certain situations, and no soil sample is obtained. The device is instrumented to permit measurement of cone resistance to penetration, and friction on a sleeve section. Soil type, strength, and other information can be assessed by analysis of the penetration resistance and friction data (ASTM D3441).

Corings

Corings are samples, usually of rock, obtained by use of a hollow drill bit. Rock cores are typically obtained for the purposes of assessing the compressive strength of intact rock, or the overall quality of fractured and jointed rock.

Cut

Cut is the term commonly applied to soil excavated by earthmoving equipment in the course of site preparation.

Dewatering

Dewatering is the term applied to removal of excess water, either above or under ground, from a site. Above ground water can usually be removed by ditches, with diversion dikes perhaps used to prevent additional surface water from entering the site. Ground water can often be lowered somewhat by ditches, but may require use of well points, sump pumps, or deep wells.

Disturbed Sampling

Disturbed sampling involves obtaining a soil sample in such a way that the character of the soil is changed from its natural state. A common example of a disturbed sample is that obtained from the split spoon sampler used in conducting a Standard Penetration Test. Disturbed samples are useful in determination of soil type and index properties, but not for strength and compressibility.

Drillers Mud

Drillers mud is an aqueous solution, usually of bentonite, sometimes used in lieu of casing to maintain a boring open.

Fill

Fill is the term commonly applied to soil or rock placed by earthmoving equipment in the course of site preparation.

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DEFINITIONS (Cont)

Geophysical Surveys

Geophysical surveys are indirect methods for assessing site conditions. They can be quite valuable in filling in data gaps between borings. Numerous methods are available, all involving input of some type of signal or energy to the ground, or measurement of some property of the ground. Analysis of the data acquired can provide indications of soil type, stratigraphy, and other properties. Geophysical surveys should be used in combination with borings for calibration purposes. The most common types used in soil surveys are seismic refraction and electrical resistivity.

Grubbing

Grubbing is the removal of tree stumps, root structure, rubbish, etc., below natural grade.

Permeability Tests

Permeability tests involve measurement of the permeability of soil or rock strata. Permeability is most commonly used to design well point or deep well dewatering systems, and to assess the ability of the material to resist infiltration.

Preloading

Preloading is a soil improvement technique involving temporary application of load, usually through a pile of soil, for the purposes of removing settlement and increasing strength. Preloading is used to prepare the ground for the permanent structures.

Probes

A probe is a simple exploration method consisting of penetrating soft soil deposits with threaded rods, either by pushing or driving. Purposes are normally to determine the thickness of the soft soil, and the depth to firm soil or rock.

Proofrolling

Proofrolling is used to check for soft areas or unexpected soil behavior before the start of facility construction. Proofrolling involves traversing the area with a heavy piece of equipment, commonly a loaded dump truck or heavy compactor, using overlapping passes, and observing the soil behavior. Observation should be done by a person experienced with earthworks, and what would constitute normal and abnormal soil behavior. Commonly a geotechnical engineer is utilized for this.

Solution Cavity

This is a cavity sometimes found in rock composed of calcium carbonate (limestone, coral), which is caused by dissolution of the rock material by the movement of groundwater. Solution cavities can cause major foundation problems, and any site containing calcium carbonate rock should be specifically investigated for their existence.

Standard Penetration Test (SPT)

The Standard Penetration Test is a technique for measuring, within borings, the resistance of soils to penetration by a split spoon sampler of specific dimensions driven in a specific manner (ASTM D1586). The number of blows required to drive the sampler over successive 6 in. (150 mm) increments is recorded. These blow counts have been correlated to soil strength parameters. When the sampler is withdrawn and opened, a disturbed sample is obtained.

Test Pits

Test pits are excavations used on land for exploring soil conditions to a shallow depth. Their depth is often limited by water table level or the capabilities of the excavating equipment. They can be a quick and inexpensive method of exploration given the proper conditions, and both disturbed and undisturbed samples can be obtained.

Undisturbed Sampling

This sampling involves use of a sharpened, thin-walled steel tube which is either pushed (preferable) or driven into cohesive soil. The most common type is called a Shelby tube. Diameter of the tube should be a minimum of 2 in. (50 mm), with 3 in. (75 mm) preferred. Extracted tubes containing soils samples must be handled very carefully, and the samples should be removed from the tube only in the lab. When carefully done, such sampling yields a relatively undisturbed sample suitable for strength and compressibility testing. Undisturbed samples cannot be obtained in cohesionless soils as the sampling operation always results in significant disturbance.