Soils and Geology Procedures for Foundation Design of Buildings and Other Structures

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CHAPTER 1

INTRODUCTION

1-1. Purpose. This course presents guidance for selecting and designing foundations and associated features for buildings, retaining structures, and machinery. Foundations for hydraulic structures are not included. Foundation design differs considerably from design of other elements of a structure because of the interaction between the structure and the supporting medium (soil and/or rock).

1-2. Scope. Information contained herein is directed toward construction usually undertaken on military reservations, although it is sufficiently general to permit its use on a wide variety of construction projects.

a. This course includes-

(1) A brief summary of fundamental volumetric - gravimetric relationships.

(2) Summaries of physical and engineering properties of soil and rock.

(3) General descriptions of field and laboratory investigations useful for foundation selection and design.

(4) Design procedures for construction aspects, such as excavated slopes and shoring.

(5) Empirical design equations and simplified methods of analysis, including design charts, soil property-index correlations, and tabulated data.

(6) Selected design examples to illustrate use of the analytical methods.

b. Since the user is assumed to have some familiarity with geotechnical engineering, design equations and procedures are presented with a minimum of theoretical background and no derivations. The topics of dewatering and groundwater control, pile foundations, and foundations on expansive soils are covered in greater depth in separate technical manuals and are only treated briefly in this course.

1-3. Objectives of foundation investigations. The objectives of foundation investigations are to determine the stratigraphy and nature of subsurface materials and their expected behavior under structure loadings and to permit savings in design and construction costs. The investigation is expected to re- veal adverse subsurface conditions that could lead to construction difficulties, excessive maintenance, or possible failure of the structure. The scope of investigations depends on the nature and complexity of sub-surface materials and the size, requirements for, and cost of the structure.

1-4. Report of subsurface and design investigations. The report should contain sufficient description of field and laboratory investigation, sub-surface conditions, typical test data, basic assumptions, and analytical procedures to permit detailed re- view of the conclusions, recommendations, and final design. The amount and type of information to be presented shall be consistent with the scope of the investigation. For some structures, a cursory review of foundation conditions may be adequate. For major structures, the following outline shall be used as a guide:

a. A general description of the site, indicating principal topographic features in the vicinity. A plan map that shows the surface contours, the location of the proposed structure, and the location of all borings should be included.

b. A description of the general and local geology of the site, including the results of the geological studies.

c. The results of field investigations, including graphic logs of all foundation and borrow borings, locations of and pertinent data from piezometers, and a general description of subsurface materials, based on the borings. The information shall be presented in accordance with Government standards. The boring logs should indicate how the borings were made, type of sampler used, split-spoon penetration resistance, and other field measurement data.

d. Groundwater conditions, including data on seasonal variations in groundwater level and results of field pumping tests, if performed.

e. A general description of laboratory tests performed, range of test values, and detailed test data on representative samples. Atterberg limits should be plotted on a plasticity chart, and typical grain-size curves on a grain-size distribution plot. Laboratory test data should be summarized in tables and figures as appropriate. If laboratory tests were not performed, the basis for determining soil or rock properties should be presented, such as correlations or reference to pertinent publications.

f. A generalized geologic profile used for design, showing properties of subsurface materials and design values of shear strength for each critical stratum. The profile may be described or shown graphically.

g. Where alternative foundation designs are prepared, types of foundations considered, together with evaluation and cost data for each.

h. A table or sketch showing the final size and depth of footings or mats and lengths and types of piles, if used.

I. Basic assumptions for loadings and the computed factors of safety for bearing-capacity calculations, as outlined in chapter 6.

j. Basic assumptions, loadings, and results of settlement analyses, as outlined in chapters 5, 6, and 10; also, estimated swelling of subgrade soils. The effects of computed differential settlements, and also the effects of swell, on the structure should be discussed.

k. Basic assumptions and results of other analyses.

I. An estimate of dewatering requirements, if necessary. The maximum anticipated pumping rate and flow per foot of drawdown should be presented.

m. Special precautions and recommendations for construction. Possible sources for fill and backfill should also be given. Compaction requirements should be described.

CHAPTER 2

IDENTIFICATION AND CLASSIFICATION OF SOIL AND ROCK

2-1. Natural soil deposits.

a. The character of natural soil deposits is influenced primarily by parent material and climate. The parent material is generally rock but may include partially indurated materials intermediate between soil and rock. Soils are the results of weathering, mechanical disintegration, and chemical decomposition of the parent material. The products of weathering may have the same composition as the parent material, or they may be new minerals that have resulted from the action of water, carbon dioxide, and organic acids with minerals comprising the parent material.

b. The products of weathering that remain in place are termed residual soils. In relatively flat regions, large and deep deposits of residual soils may accumulate; however, in most cases gravity and erosion by ice, wind, and water move these soils to form new deposits, termed transported soils. During transportation, weathered material may be mixed with others of different origin. They may be ground up or decomposed still further and are usually sorted according to grain size before finally being deposited. The newly formed soil deposit may be again subject to weathering, especially when the soil particles find themselves in a completely different environment from that in which they were formed. In humid and tropical climates, weathering may significantly affect the character of the soil to great depths, while in temperate climates it produces a soil profile that primarily affects the character of surface soils.

c. The character of natural soil deposits usually is complex. A simplified classification of natural soil deposits based on methods of deposition is given in table 2-1, together with pertinent engineering characteristics of each type. More complete descriptions of natural soil deposits are given in geology textbooks. The highly generalized map in figure 2-1 shows the distribution of the more important natural soil deposits in the United States.

2-2. Identification of soils.

a. It is essential to identify accurately materials comprising foundation strata. Soils are identified by visual examination and by means of their index properties (grain-size distribution, Atterberg limits, water content, specific gravity, and void ratio). A description based on visual examination should include color, odor when present, size and shape of grains, gradation, and density and consistency characteristics.- Coarse-grained soils have more than 50 percent by weight retained on the No. 200 sieve and are described primarily on the basis of grain size and density. With regard to grain-size distribution, these soils should be described as uniform, or well-graded; and, if in their natural state, as loose, medium, or dense. The *shape* of the grains and the presence of foreign materials, such as mica or organic matter, should be noted.

b. Fine-grained soils have more than 50 percent by weight finer than the No. 200 sieve. Descriptions of these soils should state the color, texture, stratification, and odor, and whether the soils are soft, firm, or stiff, intact or fissured. The visual examination should be accompanied by estimated or laboratory-determined index properties. A summary of *expedient tests* for identifying fine-grained soils is given in table 2-2. The important index properties are summarized in the following paragraphs. Laboratory tests for determining index properties should be made in accordance with standard procedures.

2-3. Index properties.

a. Grain-size distribution. The grain-size distribution of soils is determined by means of sieves and/or a hydrometer analysis, and the results are expressed in the form of a cumulative semi-log plot of percentage finer versus grain diameter. Typical grain-size distribution curves are shown in figure 2-2. The knowledge of particle-size distribution is of particular importance when coarse-grained soils are involved. Useful values are the effective size, which is defined as the grain diameter corresponding to the 10 percent finer ordinate on the grain-size curve; the coefficient of uniformity, which is defined as the ratio of the D_{60} size to the D, , size (fig 2-2); the coefficient of curvature, which is defined as the ratio of the square of the D_{o3} size to the product of the D_{1o} and D_{60} sizes (table 2-3); and the 15 and 85 percent sizes, which are used in filter design.

b. Atterberg limits. The Atterberg limits indicate the range of water content over which a cohesive soil behaves plastically. The upper limit of this range is known as the liquid limit (LL); the lower, as the plastic limit (PL). The LL is the water content at which a soil will just begin to flow when slightly jarred in a pre

Table 2-1. A Simplified Classification of Natural Soil Deposits

	Major Divisions		Principal Soil Type	Pertinent Engineering Characteristics
Residual Soils	Mineral	Material formed by distintegration of underlying parent rock or partially indurated materials	Residual sands and rock fragments of various sizes formed by solution and leaching of cementing material, leaving the more resistant particles; commonly quartz	Generally favorable foundation conditions.
			Residual clay, extremely finely divided clay material formed in place by the weathering of rock, derived either by the chemical decay of feldspar and other rock minerals or by the removal of nonclay-mineral constituents by solution from a clay-bearing rock.	Variable properties requiring investigation to determine depth and conditon of weathering.
	Organic	Accumulations of highly organic material formed in place by the growth and subsequent decay of plant life	Peat. A somewhat fibrous aggregate of decayed and decaying vegetable matter having a dark color and odor of decay	Very compressible. Entirely unsuitable for supporting building foundations
			Muck. Finely divided, well-decomposed organic material intermixed with a high percentage (20-50%) of mineral matter	
Transported Soils	Alluvial	Material transported and deposited by running water	Floodplain deposits. Unconsolidated soils deposited by a stream within that portion of its valley subject to inundation by floodwater	
			Natural levees. Long, broad, low ridges of sand, silt, or silty clay deposited by a stream on its floodplain and along both banks of its channel during overbank flow.	Generally favorable foundation conditions.
			Point bar. Alternating deposits of arcuate ridges and swales (lows) formed on the inside or convex bank of migrating river bends. Ridge deposits consist primarily of silt and sand, swales are clay-filled	Generally favorable foundation conditions; however, detailed investigations are necessary to locate discontinuities. Flow slides may be a problem along riverbanks.
			Channel fill. Deposits laid down in abandoned meander loops isolated when rivers shorten their courses. Composed primarily of clay; however, silty and sandy soils are found at the upstream and downstream ends	Fine-grained soils are usually compressible. Portions may be very heterogeneous. Silty soils generally present favorable foundation conditions
			Backswamp. The prolonged accumulation of floodwater sediments in flood basins behind the natural levees of a river. Materials are generally clays but tend to become more silty near riverbank	Relatively uniform in a horizontal direction. Clays are usually subjected to seasonal volume changes
			Terrace deposits. Unconsolidated alluvium (including gravel) produced by renewed downcutting of the valley flood by a rejuvenated stream	Generally favorable conditions. Usually not subject to flooding.
			Fan Deposits. Alluvial deposits at foot of hills or mountains. Extensive plains or alluvial fans	Generally favorable foundation conditions
			Deltaic deposits. Deposits formed at the mouths of rivers which result in extension of the shoreline	Generally fine-grained and compressible. Many local variations in soil condition
	Lacustrine	Material deposited in a lake	Lacustrine deposits. Material deposited within lakes (other than those associated with glaciation) by waves, currents, and and organo-chemical processes. Deposits consist of unstratified organic clay or clay in central portions of the lake and typically grade to stratified silts and sands in peripheral zones	Usually very uniform in horizontal direction. Fine-grained soils generally compressible
	Estuarine	Material deposited in an estuary	Estuarine deposits. Fine-grained sediment (usually silt and clay) of marine and fluvial origin mixed with decomposed organic matter laid down in brackish water of an estuary	Generally compressible. Many local varations
	Aeolian	Material transported and deposited by wind	Loess. An unstratified calcarous deposit consisting predominantly of silt with subordinate grain sizes ranging from sand to clay. Often contains fossils and is traversed by a network of small, narrow, vertical tubes frequently filled with calcium carbonate conceptions formed by root fibers now decayed.	Relatively uniform deposits characterized by ability to stand in vertical cuts. Collapsible structure. Deep weathering or saturation can modify characteristics
			Dune sands. Mounds, ridges, and hills of uniform fine sand characteristically exhibiting rounded grains	Very iniform grain-size; may exist in relatively loose condition
	Glacial	Material transported and deposited by glaciers, or by melt water from the glacier	Glacial till. An accumulation of debris, deposited beneath, at the side (lateral moraines), or at the lower limit of a glacier (terminal moraine). Material lowered to ground surface in an irregular sheet by a melting glacier is known as a ground moraine	Consists of material of all sizes in various proportions from boulders and gravel to clay. Deposits are unstratified. Generally present favorable foundation conditions; but, rapid changws in conditions are common
			Glacio-Fluvial deposits. Coarse and fine-grained material deposited by streams of melt water from glaciers. Material deposited on ground surface beyond terminal of glacier is known as an outwash plain. Gravel ridges known as kames and eskers	Many local variations. Generally present favorable foundation conditions
			Glacio-Lacustrine deposits. Material deposited within lakes by melt water from glaciers. Consisting of clay in central portions of lake and alternate layers of silty clay or silt and clay (varved clay) in peripheral zones	Very uniform in a horizontal direction

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