



**US Army Corps
of Engineers
Afghanistan Engineer District**

AED Design Requirements: Geotechnical Investigations (Provisional)

**Various Locations,
Afghanistan**

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1.0 GENERAL

This design guide presents guidance for planning, performing, and reporting soil investigations. All information presented within this document is summarized from Unified Facilities Criteria (UFC) and Engineering Manuals (EM). It is not a comprehensive textbook on soil sampling; the treatment of this subject cannot be substituted for actual experience. Rather, it is a summary of commonly accepted soil sampling practices and procedures which are intended to assist geotechnical personnel performing actual field operations or those personnel functioning as contracting officers' representatives. Soils investigations for USACE-AED projects are intended to provide the design engineer various design parameters including:

- a. Revealing adverse subsurface conditions that could lead to construction difficulties, excessive maintenance, or failure of the structure
- b. Depth required for satisfactory bearing material for foundations
- c. Bearing capacity of soil for building or other structural foundations
- d. Potential range of settlements of buildings
- e. Allowable California Bearing Ratio (CBR) for road bed design
- f. Optimum moisture content at optimum compaction
- g. Depth of groundwater for dewatering and buoyancy design considerations
- h. Minimum embankment side slope and benching required for cuts and fills
- i. Erosion protection requirements
- j. Expected long term settlements of high embankments and placement and compaction procedures to minimize adverse impact to project functions
- k. Active and passive pressures for retaining walls and revetments
- l. Internal friction angles and cohesive strengths of soil for analyses
- m. Water-soluble sulfate in soil (ASTM C 1580). Percolation test results (U.S. Environmental Protection Agency guidance is available from AED).

Additional design parameters may be requested in the contract technical requirements.

This design guide is intended to provide contractors information on the expected investigations and methods required for geotechnical reports for USACE-AED projects. It should provide USACE-AED with standardized sets of information from which a reliable data base can be maintained for future use in project development. It is intended to eliminate submittal of information that USACE neither requests in the contract technical requirements nor uses in its evaluation of project designs; thereby also reducing costs for supplying this information from contractors. Insufficient geotechnical investigations, faulty interpretation of results, or failure to portray results in a clearly understandable manner may contribute to inappropriate designs, delays in construction schedules, costly construction modifications, use of substandard borrow material, environmental damage to the site, post construction remedial work, and even failure of a structure and subsequent litigation.

2.0 PLANNING OF SITE GEOTECHNICAL INVESTIGATION

In order to properly characterize the sub surface soils at any site for any project a geotechnical investigation plan is crucial to accommodate any situation that may arise once the investigation has started. Due to security issues here in Afghanistan, proper planning will reduce risks to life, limb and equipment by ensuring only one site visit is necessary to capture site specific information.

2.1 SITE SPECIFIC INFORMATION

The logical and necessary first step of any field investigation is the compilation of all pertinent information on geological and soil conditions at and in the vicinity of the site or sites under consideration, including previous excavations, material storage, and buildings. A geotechnical investigation plan also involves collection of information such as project type, location, and purpose of the structure or facility. The project type will control the depth and number of boreholes that are required. For instance, a road construction project will require numerous boreholes at a shallow depth where a vertical construction project will require boreholes that are drilled to depths sufficient to characterize the soils within the zone of influence and below.

2.2 DEPTH, LOCATION, AND SPACING OF EXPLORATION

Depths of explorations shall be determined by the type of structure to be constructed on site. Major structures shall have a minimum of 3 borings within the footprint and 5 for variable soil conditions and earthquake zone. The minimum depth shall be the greater of 6 meters or twice the height of the structure. Minor structures shall have 1 to 3 test pits, 1 test pit for every 225 square meters. The test pits shall be a minimum of 3 meters in depth. Major structures shall be defined as reinforced concrete structures greater than 1000 square meters, steel frame buildings greater than 3000 square meters, structures with a height greater than or equal to 1.5 stories, and steel or concrete water tanks greater than 350 square meters. Minor structures are defined as all smaller structures than Major structures.

2.3 MINIMUM SAMPLING AND TESTING

- a. Unified soil classification system (USCS) tests shall be performed for every sample including all accompanying tests to determine soil type. SPT blow counts and USCS shall be performed every 0.75 meters.
- b. Direct shears for ML, SC, SP, SW, and SC shall be conducted; 3 for each soil type encountered from samples taken at preferably 1 meter in depth.
- c. 3 unconfined compressive strength and consolidation tests shall be performed for each fine grained soil type encountered at the site, preferably at 1 meter of depth.
- d. 6 percolation tests distributed over the proposed absorption field at 0.5 meters.
- e. Minimum 1 soluble sulfate test to a maximum of 4 per site at 0.5 meters.

2.3.1 ROADS

In determining subgrade conditions, borings will be carried to the depth of frost penetration, but no less than 1.8 meters (6 feet) below the finished grade. In the design of some high fills, it may be necessary to consider settlement caused by the weight of the fill. This results in the need for borings deeper than 1.8 meters to determine soil characteristics where compressive soils may or are suspected to exist at greater depth. Specific needs for pavement design will be directed by the designer-of-record. For flexible pavement design, soaked California bearing ratio (ASTM D 1883) will likely need to be determined as a function of soil dry density for each subgrade soil type. For rigid pavement design, modulus of subgrade

reaction will likely need to be determined by plate bearing tests (ASTM D 1196). These values are correction for saturated soil conditions, in accordance with CRD-C 655 (USACE Standard Test Method).

3.0 GEOTECHNICAL SITE INVESTIGATION

There is no set standard for a geotechnical investigation as every site is different and every project is different. The site investigation for the most part should follow the geotechnical investigation plan unless conditions arise that require alteration of the plan in the field. All changes and the logic used to adjust the plan shall be reported in the final geotechnical report.

3.1 SAMPLING

Depending on the material expected to be encountered at the project site from the information gathered in the compilation of pertinent data the geotechnical investigation plan shall provide a minimum number of disturbed samples to be collected. If cohesive soils are expected to be encountered during the investigation then the minimum number of undisturbed samples shall be collected. Samples shall be taken at not more than 0.75 meter (2.5 feet) intervals. The number of samples shall be determined by taking the required amount of borings, multiplying the total depths of each boring, and dividing by 0.75 meters.

3.2 UNDISTURBED SAMPLES

Undisturbed samples have been subjected to relatively little disturbance and may be obtained from borings using push-type or rotary-core samplers. High-quality undisturbed samples may be obtained by hand trimming block samples from test pits and trenches. Undisturbed samples are useful for strength, compressibility, and permeability tests of the foundation materials. Undisturbed sampling should be conducted in a manner to minimize: (a) changes of void ratio and water content, (b) mechanical disturbance of the soil structure, and (c) changes of stress conditions. Efforts should also be undertaken to eliminate other causes of disturbance, such as freezing and chemical changes, caused by prolonged storage in metal containers. Any method of taking and removing a sample that results in a stress change, possible pore water change, and some structure alteration because of displacement effects of the sampler is not acceptable. Careful attention to details and use of proper equipment can reduce disturbance to a tolerable amount. Sample disturbance is related to the area ratio A_r , through which the sample passes (commonly the cutting edge is swedged to a lesser diameter than the inside tube wall thickness to reduce friction) defined as follows:

$$A_r = (D_o^2 - D_1^2 / D_1^2) \times 100 \text{ percent} \quad \text{Eq. 2}$$

Where:

D_o = outside diameter of sampler tube, mm

D_1 = internal diameter of the cutting shoe, mm

The area ratio should be less than 10 percent for undisturbed sampling. Undisturbed samples are commonly taken by thin-wall seamless steel tubing from 50 to 75 mm (2 to 3 inches) in diameter and lengths from 0.61 to 1.2 meters (2 to 4 feet). Undisturbed samples for shear, unconfined compression, and consolidation testing are commonly 75 mm (3 inches) in diameter, but 125 mm (5 inches) diameter samples are much preferred. An indication of sample quality is the recovery ratio, L_r , defined as follows:

$$L_r = \frac{\text{Length of recovered sample}}{\text{Length sample tube pushed}}$$

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A value for $L_r < 1$ indicates that the sample was compressed or lost during recovery, and $L_r > 1$ indicates that the sample expanded during recovery or the excess soil was forced into the sampler.

The following table shall be used to determine the minimum size of sample necessary for an undisturbed sample:

Table 1 Minimum sample sizes

Test Sample that is Collected for:	Minimum Sample Diameter, mm (in.)
Unit weight	75 (3)
Consolidation	125 (5)
Unconfined compression	75 (3)
Direct shear	125 (5)

Undisturbed samples must be handled and preserved in a manner to preserve stratification or structure, water content, and in situ stresses, to the greatest extent possible. Once the sample has been removed from the borehole, it must be either sealed within the sampling tube or extruded and sealed within another suitable container prior to shipment to the laboratory for testing. In general, carbon steel tubes should not be used if the samples are to be stored in the tubes for an extended period of time (i.e. more than 48 hours) because the tubes will rust or corrode and may contaminate the sample. If extended storage is required, containers made of alternative metals or wax-coated cardboard tubes should be considered. Samples for water content determination must be sealed to prevent changes of soil moisture. If glass jars are used, the gasket and the sealing edge of the container must be clean to ensure a good seal. Guidance for preservation and shipment of samples is given in ASTM Standard D 4220-83 (ASTM 1993). The most common test method for undisturbed samples in this country is the unconfined compression test (ASTM D 2166). Specimens shall have a minimum diameter of 30 mm (1.3 in.) and the largest particle contained within the test specimen shall be smaller than one tenth of the specimen diameter. For specimens having a diameter of 72 mm (2.8 in.) or larger, the largest particle size shall be smaller than one sixth of the specimen diameter.

For each building structure, samples should be obtained at 3 locations and at 2 to 3 depths for each location: 1 m below surface, 3 m below surface and at the depth of any different soil layer between 1 and 3 m.

3.2.1 ADVANCING THE BOREHOLE

Position the drill rig over the sampling location, chock (secure) the wheels on the drill rig, and adjust the mast to a vertical position. Place the drill rods and related equipment at a convenient location for use with respect to the drill rig. The drill rods, sampling equipment, casing, etc., may be placed about 5 m (15 ft) from the drill rig. The inspector's work station, areas for sample storage, power units, support vehicles, and other equipment can be located at greater distances, depending on the type of drilling and/or sampling operations, site topography, weather conditions, logistics, etc.

After a vertical pilot hole has been established, attach the drill bit or auger to the drill rod and lower the string into the borehole. Attach more drilling rods or auger flights, as necessary. The depth of the borehole is advanced to the desired depth by rotating the auger or bit and applying a downward pressure from the drill rig or by gravity feed as required to achieve a satisfactory penetration rate. After the hole has been advanced to the desired sampling depth, remove the excess cuttings from the bottom of the hole before the drill string is withdrawn. As the string is withdrawn, disconnect the sections of rod and lay aside. Repeat until the cutting head is retrieved.

When lowering the equipment into the borehole to a new sampling depth, repeat the above procedures in reverse order. Count the number of rods to determine the depth of the borehole. Carefully monitor and record the depth of the hole for use during the sampling operations. All trips up and down the borehole with the drill string should be made without rotation.

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In order to obtain an undisturbed soil sample, a clean, open borehole of sufficient diameter must be drilled to the desired sample depth. The sample should be taken as soon as possible after advancing the hole to minimize swelling and/or plastic deformation of the soil to be sampled.

3.2.2 DIAMETER OF THE BOREHOLE

The diameter of the borehole should be as small as practical. If casing is not used, a borehole 6 to 19 mm (1/4 to 3/4 in.) greater in diameter than the outside diameter of the sampler should be sufficient. In soils containing irregular hard and soft pockets that cause deviation of the drill bit. In soils that tend to squeeze, a slightly larger clearance, i.e., 12 to 19 mm (1/2 to 3/4 in.), may be required. When casing is used, the hole should be drilled 6 to 25 mm (1/4 to 1 in.) larger than the outside diameter (OD) of the casing.

3.2.3 METHODS OF ADVANCE

Boreholes for undisturbed samples may be advanced by rotary drilling methods or with augers. Augers are discussed in Chapters 3, 7, and 8 of EM 1110-1-1804 "GEOTECHNICAL INVESTIGATIONS".

Displacement and percussion methods for advancing boreholes are not acceptable for undisturbed sampling operations.

3.3 DISTURBED SAMPLES AND QUANTITIES

Boreholes for disturbed soil samples, obtained by split-barrel samplers, may be advanced in the same manner as those procedures used for boreholes for undisturbed soil samples. Other acceptable procedures for advancing boreholes are listed in ASTM D 1586. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the split-barrel sampler. Disturbed samples are primarily used for moisture content, Atterberg limits, specific gravity, sieve analysis or grain-size distribution, and compaction characteristics. The amount of sample material required is shown in Table 2. Strength and deformation tests may be conducted on reconstituted (remolded) specimens of the disturbed materials. Samples can be obtained by means of auger or drive-sampling methods. Thick-wall, solid, or split-barrel drive samplers can be used for all but gravelly soils. Samples taken with a drive sampler should be not less than 50 mm (2 inches), and preferably 75 mm (3 inches) or more in diameter. Where loose sands or soft silts are encountered, a special sampler with a flap valve or a plunger is usually required to hold the material in the barrel. A bailer can be used to obtain sands and gravel samples from below the water table. Split-spoon samples should be used to obtain representative samples in all cases where the density of cohesionless materials must be estimated.

Table 2 Minimum sample size for disturbed samples

Test	Minimum Sample Required for soils with all material passing the No. 4 sieve. kg (lb)	Minimum Sample Required for all other soils. kg (lb)
Water content	0.227 (0.5)	5 (11)
Atterberg limits	0.091 (0.2)	0.2 (0.44)
Specific gravity	0.091 (0.2)	0.2 (0.44)
Grain-size analysis	0.227 (0.5)	70 (154)
Standard compaction	13.61 (30)	29 (64)
Direct shear	0.907 (2)	8 (17.6)
4-in.-diam consolidation	0.907 (2)	

3.4 STANDARD PENETRATION TESTS

This test is performed in conjunction with split-barrel sampling. It provides a rough approximation of the relative density or consistency of foundation soils and should always be made when piles are to be driven. For a single test results, the split spoon is driven a total of 457 mm; the penetration resistance in blows per foot (or N-value) is based on the last 305 mm; the first 152 mm being to seat the sampler in undisturbed soil at the bottom of the boring. "Refusal" is usually taken at a blow count of 50 per 6 inches. This test must be performed in accordance with ASTM D 1586; that is, the split-barrel sampler must conform to specified dimensions and it must be driven by a 63.5-kg hammer, which drops 0.76 m to impose a "blow." On large projects, the SPT data should be used in conjunction with tests on undisturbed samples.

At least one SPT test should be recorded for each 0.75 m elevation change down to 4.5 m. Below 4.5 m depth, at least one SPT test is needed for every 1.5 m elevation change

3.5 TEST PITS AND TEST TRENCHES

Test pits and trenches may be excavated by hand or by conventional earth-moving equipment. Shallow pits dug to depths up to 1.2 m (4 ft) in stable soil usually require no shoring; for deeper excavations or pits in unstable soil, shoring must be used (EM 385-1-1). Excavations extending below the water table require control of the groundwater. In impervious or relatively impervious soils, groundwater can be controlled by pumping directly from a sump or drainage ditch in the pit. If the pit extends below the water table in sand or silt, dewatering by means of a well-point system may be necessary to ensure dryness and stability of the pit. If seepage forces are great, blowouts in the bottom or sides of the pit can result.

Test pits are commonly used for exposing and sampling foundation and construction materials. The test pit must be large enough to permit detailed examinations of the material in situ to be conducted or to obtain large, undisturbed samples as required by the investigation. Typically, the plan view of the pit will be square, rectangular, or circular. The minimum dimensions of the pit are on the order of 0.9 by 1.5 m (3 by 5 ft) or 1.2 by 1.8 m (4 by 6 ft); it should be noted that these dimensions are net dimensions at the bottom of the excavation and do not include the space required for shoring or sloping the walls of the excavation in unstable or soft materials or for deep excavations.

Test pits may be dug by hand or by machine. Power excavating equipment, such as backhoes may be used for rough excavation of test pits to a distance of about 0.6 m (2 ft) from the proposed sample. The final excavation of samples must be carefully made with hand tools, such as picks, shovels, trowels, and buckets. Deeper pits must be started with sufficient dimensions to allow for shoring or sloping of the sides to prevent caving. The depth of the pit and the type and condition of the soil generally dictate the type of support system, such as sheeting, sheet piling, bracing, shoring, or cribbing, which is needed. Shoring must be installed progressively as the pit is deepened. The space between the walls of the pit and the support system should be kept to a minimum.

Care must be exercised in excavating the area near the intended sample or test. The limits of the sample should be outlined with a pick and shovel. The material near the proposed sample should be excavated to a depth about 25 to 50 mm (1 to 2 in.) below the bottom of the intended sample. The excavated zone should be trimmed relatively level and be sufficiently large to allow adequate working space for obtaining the sample. A pedestal of soil, roughly the shape of the sample and about 25 mm (1 in.) larger in each dimension, should be left undisturbed for final trimming.

Excavated material should be placed at a horizontal distance from edge of the pit not less than the anticipated maximum depth of the pit. Excavated material should be placed in orderly fashion around the pit to facilitate logging of the material. Wooden stakes can be used to mark the depth of the excavated material. Samples for water content determination should be obtained in a timely manner to prevent drying of the material.

Test trenches can be used to perform the same function as test pits but offer one distinct advantage, i.e., trenches provide a continuous exposure of the continuity and character of the subsurface material along a given line or section. Test trenches can be excavated with ditching machines, backhoes, bulldozers, or pans, depending upon the required size and depth of the trench. The minimum bottom width of a trench is

about 0.6 to 0.9 m (2 to 3 ft), although this dimension is sometimes greater because of the use of power equipment, such as bulldozers and pans. As the trench is deepened, the sides must be sloped, step cut, or shored to prevent caving, similar to the procedures that must be used for excavating deep test pits. Final excavation in the vicinity of the intended sample must be performed carefully by hand.

3.5.1 DISTURBED SAMPLES

Disturbed samples may be obtained from test pits or trenches. Disturbed, representative samples of soil are satisfactory for certain laboratory tests including classification, water content determination, and physical properties tests. For certain soils such as very soft clays or gravelly soils, undisturbed samples may be impossible to obtain. Provided that the unit weight and moisture content of the soil in place can be estimated or are known, it may be permissible to perform certain laboratory tests on specimens remolded from samples of disturbed material.

To sample a particular stratum, remove all weathered and mixed soil from the exposed face of the excavation. Place a large tarpaulin or sheet of plastic on the bottom of the test pit or accessible boring. With a knife or shovel, trench a vertical cut of uniform cross section along the full length of the horizon or stratum to be sampled. The width and depth of the cut should be at least six times the diameter of the largest soil particle sampled. Collect the soil on the tarpaulin. All material excavated from the trench should be placed in a large noncorrosive container or bag and preserved as a representative sample for that stratum. An alternative sampling procedure consists of obtaining a composite sample of two or more soil strata; if samples from certain strata are omitted, an explanation must be reported under .Remarks. on the log form. Samples obtained for determination of water content may be placed in pint glass or plastic jars with airtight covers; the sample should fill the container. Take care to ensure that overburden or weathered material is not included as a portion of the sample.

3.5.2 UNDISTURBED SAMPLES

Undisturbed samples are taken to preserve as closely as possible the in-place density, stress, and fabric characteristics of the soil. Although excavating a column of soil may relieve in situ stresses to some degree, it has been demonstrated that hand sampling of certain soils, such as stiff and brittle soils, partially cemented soils, and soils containing coarse gravel and cobbles, is perhaps the best and sometimes the only method for obtaining any type of representative sample. Large block samples of these materials are suitable for certain laboratory tests, although smaller samples should be used whenever the size of the sample does not adversely affect the test results. During handling and shipping of undisturbed samples, it is important to minimize all sources of disturbance including vibration, excessive temperature changes, and changes of water content.

3.5.2.1 BLOCK OR CUBE SAMPLES

To obtain a cube or block sample, prepare the surface of the soil to be sampled. Excavate a pedestal of soil that is slightly larger than the dimensions of the box or container into which the sample is to be placed. A knife, shovel, trowel, or other suitable hand tools should be used to carefully trim the sample to about 25 mm (1 in.) smaller than the inside dimensions of the box. As the sample is trimmed to its final dimensions, cover the freshly exposed faces of the sample with cheesecloth and paint with melted wax to prevent drying and to support the column of soil. After the block of soil has been trimmed but before it has been cut from the underlying material, place additional layers of cheesecloth and wax to form a minimum of three layers, as presented in ASTM D 4220-83 (ASTM 1993). A 1:1 mixture of paraffin and microcrystalline wax is better than paraffin for sealing the sample. A sturdy box should be centered over the sample and seated. Loose soil may be lightly tamped around the outside of the bottom of the box to align the box with respect to the soil sample and to allow packing material such as styrofoam, sawdust, or similar material to be placed in the voids between the box and the soil sample. Hot wax should not be poured over the sample. After the packing material has been placed around and on top of the sample and the top cover for the box has been attached, cut or shear the base of the sample from the parent soil and turn the sample over. After the sample has been trimmed to about 12 mm (1/2 in.) inside the bottom of

the box, the bottom of the sample should be covered with three alternating layers of cheesecloth and wax. The space between the bottom of the sample and the bottom of the box should be filled with a suitable packing material before the bottom cover is attached. The top and bottom of the box should be attached to the sides of the box by placing screws in predrilled holes. The top and bottom should never be attached to the sides of the box with a hammer and nails because the vibrations caused by hammer blows may cause severe disturbance to the sample.

3.5.2.2 PUSH SAMPLERS

Several hand-operated open- or piston-samplers are available for obtaining undisturbed samples from the ground surface as well as from the walls and bottom of pits, trenches, or accessible borings. The hand-operated open sampler consists of a thin-wall sampling tube affixed to a push rod and handle. The piston sampler is similar to the open sampler except a piston is incorporated into the design of the device. The procedures for operating these samplers are similar to the procedures for open samplers or piston samplers in rotary drilling operations. Hand operated push samplers may be used to obtain samples in soft-to-medium clays, silts, and peat deposits at depths of 6 to 9 m (20 to 30 ft) or more.

3.6 BORING AND SAMPLING RECORDS

After the soil samples have been removed from the sampling apparatus, visually identified according to the procedures and methods which are presented in ASTM D 2488, and sealed in appropriate sample containers, the sample containers should be identified and labeled and the boring logs should be updated.

All tubes and samples should be labeled immediately to ensure correct orientation and to accurately identify the sample. The information on the sample identification tag should include project title and location, boring and sample number, depth and/or elevation interval, type of sample, recovery length, trimmed sample length, sample condition, visual soil classification (ASTM D 2488), date of sampling, and name of inspector. All markings should be made with waterproof, nonfading ink. Pertinent boring information and sample data, must be recorded in the boring log.

In addition to the aforementioned data which were placed on the sample identification tag, clear and accurate information which describes the soil profile and sample location should be documented in the boring logs. Record any information that may be forgotten or misplaced if not recorded immediately, such as observations which may aid in estimating the condition of the samples, the physical properties of the in situ soil, special drilling problems, weather conditions, and members of the field party.

3.7 SHIPMENT OF SAMPLES

The most satisfactory method of transporting soil samples is in a vehicle that can be loaded at the exploration site and driven directly to the testing laboratory. This method helps to minimize sample handling and allows the responsibility of the samples to be delegated to one person. In general, jar samples from the bottom of the tube samples can usually be packaged in containers furnished by the manufacturer, although special cartons may be required if considerable handling is anticipated. Undisturbed sample tubes should be packed in an upright orientation in prefabricated shipping containers or in moist sawdust or similar packing materials to reduce the disturbance due to handling and shipping. For certain cases, special packing and shipping considerations may be required. Regardless of the mode of transportation, the soil samples should be protected from temperature extremes and exposure to moisture. If transportation requires considerable handling, the samples should be placed in wooden boxes. Additional guidance is presented in ASTM D 4220-83, .Preserving and Transporting Soil Samples. (ASTM 1993).

3.8 BACKFILLING BOREHOLES AND EXCAVATIONS

All open boreholes, test pits or trenches, and accessible borings, including shafts or tunnels, must be covered or provided with suitable barricades, such as fences, covers, or warning lights, to protect pedestrians, livestock or wild animals, or vehicular traffic from accidents (EM 385-1-1). After the excavations have served their intended purposes, the sites should be restored to their original state as nearly as possible. Boreholes or excavations which are backfilled as a safety precaution may be filled with random soil. The quality of the backfill material should be sufficient to prevent hazards to persons or animals and should prevent water movement or collapse, particularly when drilling for deep excavations or tunnels. The soil should be tamped to minimize additional settlement which could result in an open hole at some later time.

4.0 ROCK CORING

Core drilling, if carefully executed and properly reported, can produce invaluable subsurface information. Details of coring log requirements are provided in EM1110-1-1804. Each feature logged shall be described in such a way that other persons looking at the core log will recognize what the feature is, the depth at which it occurred in the boring, and its thickness or size. They should also be able to obtain some idea of the appearance of the core and an indication of its physical. Each lithologic unit in the core shall be logged. The classification and description of each unit shall be as complete as possible. A simple and widely used measure of the quality of the rock mass is provided by the Rock Quality Designation (RQD), which incorporates only sound, intact pieces 10 cm (4 in.) or longer in determining core recovery. In practice, the RQD is measured for each core run. See EM1110-1-1804 for details. Backfilling Boreholes and Excavations

5.0 GEOTECHNICAL REPORT CONTENT AND ORGANIZATION.

Geotechnical reports submitted for review with design analysis shall be organized to present the key findings and conclusions at the beginning of the report in a clear, concise written narrative that allows the reader easy access to the main design parameters that have been determined. The organization of the report is important. Report conclusions shall not be "buried" in an obscure part of the report. Details of the field investigation and laboratory testing shall be provided as appendices. General dissertations on geotechnical engineering are neither helpful nor welcome. For the most part, USACE-AED projects do not require seismicity information and it is not required as part of the usual geotechnical report. Under special circumstance where it is required it will be identified as a requirement in the contract section 01015.

5.1 MINIMUM CONTENT OF THE GEOTECHNICAL REPORT

5.1.1 REPORT SUMMARY AND CONCLUSIONS -

- a. Summary paragraph of the scope of work as stated in the contract documents.
- b. Summary of site location and description of the project site, indicating principal topographic features in the vicinity including site photos showing subsurface investigation methods at the project site (not generic illustrations).
- c. A plan map that shows the surface contours, the location of the proposed structure, and the location of all borings or test pits.

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- d. Tables that summarize the geotechnical findings for easy reference by designers and reviewers including:
 - i. Number of soil sample and location relative to foundations or road segments.
 - ii. Soil classification for samples.
 - iii. Summary of design parameters (see example in Appendix B).
- e. Summary of settlement analysis with calculations and references provided. Calculations shall consist of the equation utilized, definition of all variables, values used for all variables, and the calculation (substitution of values for the variables). Every step of the analysis shall be included for verification. If assumptions are made, then those assumptions shall be clearly stated and supported with verifiable information.
- f. Summary of allowable bearing capacity analysis with calculations and references provided. Calculations shall consist of the equation utilized, definition of all variables, values used for all variables, and the calculation (substitution of values for the variables). Every step of the analysis shall be included for verification. If assumptions are made, then those assumptions shall be clearly stated and supported with verifiable information contained within the report. Note soils laboratories shall report the allowable bearing capacity values. These values will be provided to the design engineer based on the supporting strength test data provided by the laboratory. In each case the design shall be approved and stamped by a registered professional engineer. USACE-AED will require minimum design standards that insure uniformity in project design throughout Afghanistan and sufficient conservatism in design to insure that uncertainties in sampling and testing are not a significant risk to the integrity of the project functionality or a life safety issue for the users. Contract technical requirements will state these minimum design parameters for the designer in the request for proposal RFP for the project. The designer shall insure, with the assistance of geotechnical investigations and tests based on the approved standard methods cited herein that the minimum is sufficiently conservative as stated in the technical requirements, a basis for a selection of a more conservative design parameter.
- g. The Factor of Safety (FS) utilized for analysis shall be clearly stated within the report. It shall be obvious that the Factor of Safety was implemented in the calculations reported. Due to the nature of projects USACE-AED is contracting and the seismology of Afghanistan the minimum Factor of Safety utilized for analysis shall be as follows in Table 3.

Table 3 Minimum foundation design factors of safety

Structure	FS
Retaining	
walls	3
excavations	> 2
Bridges	3.5
Buildings	
Warehouses	> 3
Offices	3
Industrial, Public	3.5

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Footings	3
Mats	> 3

5.1.2 REPORT APPENDICES

5.1.2.1 SURFACE INVESTIGATIONS

- a. Difference in topographic elevation over the site; in other words the highest and lowest elevation, examples of steep and flat existing slope across the project site, major drainage channel within the site, and presence of exposed bedrock.
- b. Evidence of in situ soil performance as indicated by localized subsidence, existing building deformations and settlements, landslide scars
- c. Evidence of seasonal high surface and ground water for example related to proximity to river channels and springs
- d. Potential sources of construction material including quarries, borrow areas, and river gravel and sand deposits
- e. Results of plate-load bearing tests (ASTM D 1194) if applicable.

5.1.2.2 SUBSURFACE INVESTIGATIONS

- a. Detailed geologic profiles describing by depth of strata the soil types, visual observations and photographic record
- b. Ground water elevations if encountered during subsurface explorations
- c. Depths at which cores or samples were taken in relation to important structures as shown on a site plan drawing
- d. Boring boring logs shall be provided for all borings (see Appendix A). The logs shall have a depth scale starting at the ground surface and scaled vertically in meters below ground surface. Show visual descriptions (e.g. light brown Silt with trace of gravel) and soil classifications (e.g. SM) and make clear the elevation of transitions between soil types. Classifications shall be based on Unified Soil Classification System. Record blow counts (for each 152 mm) and N-values. Show ground water symbol level at time of drilling and 24 hours later. Also, record sampling information as shown in Appendix A.

5.1.2.3 LABORATORY TEST RESULTS

- a. water content (ASTM D 2216)
- b. specific gravity of soil solids (ASTM D 854)
- c. Atterberg limits (ASTM D 4318)
- d. Grain size analysis (ASTM D 422)
- e. Density and unit weight of soil in place using sand cone method (ASTM D 1556)
- f. Soil classification according to Unified Soil Classification System (ASTM D 2487)

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- g. Laboratory compaction characteristics using modified effort (ASTM D 1557)
- h. Unconfined compressive strength of cohesive soil (ASTM D 2166)
- i. CBR (ASTM D 1883)

Note variations in the above list of required tests will occur between projects that contain vertical and horizontal construction features.

5.1.2.4 ADDITIONAL ADVANCED LABORATORY TESTS

- a. One dimensional consolidation properties of soils (ASTM D 2435)
- b. Direct shear test of soils under consolidated drained conditions (ASTM D 3080)

6.0 USACE-AED CERTIFICATION REQUIREMENT

All geotechnical investigations as well as laboratory and field methods of testing shall be performed by laboratories that have been certified by USACE-AED Quality Assurance Branch. A roster of certified laboratories and test certified to be performed is maintained by the branch. Failure to maintain certification shall be grounds for rejection of the geotechnical report.

A copy of the current certification shall be included with each geotechnical report.

7.0 REFERENCES

1. UFC 3-220-10N Soil Mechanics, 2005
2. UFC 3-220-01N Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures, 2004
3. UFC 3-220-03FA Soils and Geology Procedures for Foundation Design of Buildings and Structures, 2004
4. UFC 3-220-07 Foundations in Expansive Soils, 2004
5. EM 1110-1-1804 Geotechnical Investigations, 2001
6. EM 1110-1-1904 Settlement Analysis, 1990
7. EM 1110-1-1905 Bearing Capacity of Soils, 1992
8. EM 1110-2-1902 Slope Stability, 2003
9. Department of the Navy Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction, 1983

Appendix A
EXAMPLE FIELD BORING LOG

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Field Boring Log			Project:			Boring #:		Page of	
County:			Site:			Location:			
Drilled by:			Start Date:			Completion Date:		Total Depth:	
Drilling Method & Equipment:						Logged by:			
DEPTH (m)	SPT Blow Count			SAMPLE			Lithology Strip	Visual Description/Other Field Test	
				% Recovery	Type	#			

Appendix B
EXAMPLE OF DATA SUMMARY

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Summary Table of Geotechnical Tests for Vertical Construction																													
Sample No	Sample Location	Sample Depth	Particle Size (ASTM D-422)		Atterberg Limits (ASTM D 4318)			Soil Class (ASTM D 2487)		Compression (ASTM D 2166)			ASTM D 2216			ASTM D 1586			ASTM D 2435		ASTM D 3080								
			Gravel (4.75 - 87.2mm)	Silt & Clay (<0.075 mm)	LL	PL	PI	USCS Group Symbol	USCS Name	Type of soil by AASHTO	Compressive strength, q _u (kpa)	ASTM D 1556	Natural Water content, %	Dry density, kg/m ³	SPT Blow Counts	Compression index, C _c	Swollen index, C _s	Shear stress-1, Kpa	Shear stress-2, Kpa	Shear stress-3, Kpa	Recompression index, Cr	Shear stress-1, Kpa	Shear stress-2, Kpa	Shear stress-3, Kpa	Peak friction angle, phi, o				
Project Name & Contract			Date of Investigation			Site Surface Description (attach photos)																							
Project Location			Investigation Supervisor																										
Sample Location			Date of this Report																										

AED Design Requirements
Geotechnical Investigations

Summary Table of Geotechnical Tests for Horizontal Construction																						
Project Name & Contract	Date of Investigation	Site Surface Description (attach photos)																				
Project Location	Investigation Supervisor																					
Sample Location	Date of this Report																					
Sample No	Sample Location	Sample Depth	Particle Size (ASTM D422)						USCS Group Symbol	USCS Name	Type of soil by AASHTO	Compression (ASTM 2166)		ASTM 2216	ASTM 1556	ASTM 1883	ASTM D2435			ASTM D3080		
			Gravel (4.75-87.2mm)	Sand (0.076-4.75mm)	Silt & Clay (<0.075 mm)	LL	PL	PI				Compressive strength, kpa	C				Natural Water content, %	Dry density, kg/m ³	CBR	Compression index, Cr	Shear stress-1, kpa	Shear stress-2, Kpa

Appendix C
EXAMPLE OF DATA PRESENTATION

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Geotechnical Investigations

Step 1: Plot graphs.

See Fig. E5.5.

Step 2: Determine whether the sand is dense or loose.

The sand appears to be dense—it shows a peak horizontal force and dilated.

Step 3: Extract the required values.

Cross-sectional area of sample: $A = 10 \times 10 = 100 \text{ cm}^2 = 10^{-2} \text{ m}^2$

$$(c1) \tau_p = \frac{(P_x)_p}{A} = \frac{1005 \text{ N}}{10^{-2}} \times 10^{-3} = 100.5 \text{ kPa}$$

$$(c2) \tau_{cs} = \frac{(P_x)_{cs}}{A} = \frac{758 \text{ N}}{10^{-2}} \times 10^{-3} = 75.8 \text{ kPa}$$

$$(c3) \alpha_p = \tan^{-1}\left(\frac{-\Delta z}{\Delta x}\right) = \tan^{-1}\left(\frac{0.1}{0.8}\right) = 7.1^\circ$$

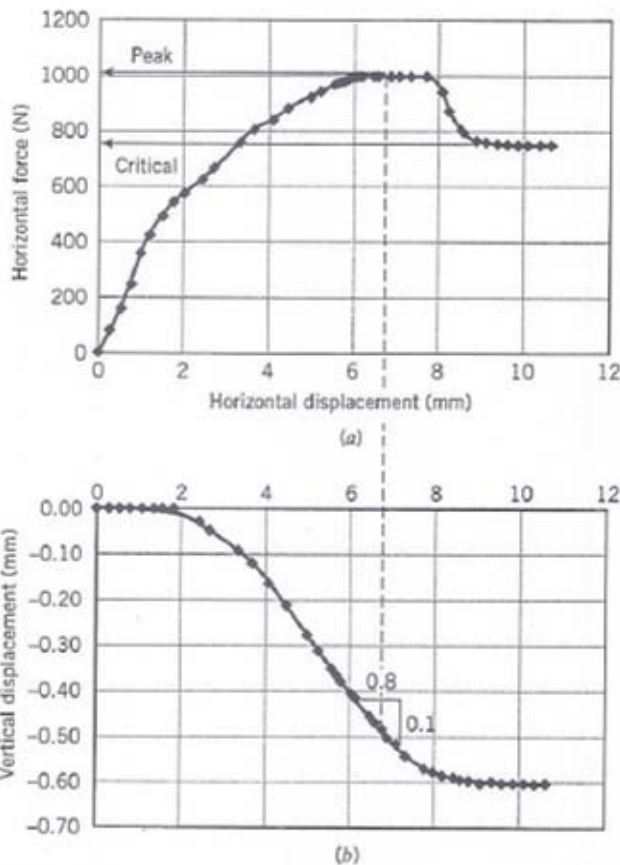


FIGURE E5.5

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Geotechnical Investigations

Soil	Test number	Vertical force (N)	Horizontal force (N)
A	Test 1	250	150
	Test 2	500	269
	Test 3	750	433
B	Test 1	100	98
	Test 2	200	175
	Test 3	300	210
	Test 4	400	248

Determine the following:

- (a) ϕ'_{cs}
- (b) ϕ'_p at vertical forces of 200 N and 400 N for sample B
- (c) The dilation angle at vertical forces of 200 N and 400 N for sample B

Strategy To obtain the desired values, it is best to plot a graph of vertical force versus horizontal force.

Solution 5.3

Step 1: Plot a graph of the vertical forces versus failure horizontal forces for each sample. See Fig. E5.3.

Step 2: Extract ϕ'_{cs} .
All the plotted points for sample A fall on a straight line through the origin. Sample A is a nondilatant soil, possibly a loose sand or a normally consolidated clay. The effective friction angle is $\phi'_{cs} = 30^\circ$.

Step 3: Determine ϕ'_p .
The horizontal forces at 200 N and 400 N for sample B do not lie on the straight line corresponding to ϕ'_{cs} . Therefore, each of these forces has a ϕ'_p associated with it.

$$(\phi'_p)_{200\text{ N}} = \tan^{-1}\left(\frac{175}{200}\right) = 41.2^\circ$$

$$(\phi'_p)_{400\text{ N}} = \tan^{-1}\left(\frac{248}{400}\right) = 31.8^\circ$$

Step 4: Determine α_p .

$$\alpha_p = \phi'_p - \phi'_{cs}$$

$$(\alpha)_{200\text{ N}} = 41.2 - 30 = 11.2^\circ$$

$$(\alpha)_{400\text{ N}} = 31.8 - 30 = 1.8^\circ$$

Note that as the normal force increases α_p decreases.

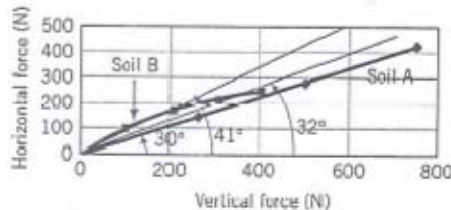


FIGURE E5.3

**APPENDIX D
GEOTECHNICAL REPORT CHECKLIST**

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AED Design Requirements
Geotechnical Investigations

A. General

1. Has the appropriate geotechnical engineer reviewed the report to ensure that the design and construction recommendations have been incorporated as intended and that the subsurface information has been presented correctly? **This is absolutely necessary.**
(Yes / No / Unknown or N/A)
2. Are the finished profile exploration logs and locations included in the plans?
(Yes / No / Unknown or N/A)
3. Have the following common pitfalls been avoided:
 - a. Has an adequate site investigation been conducted (reasonably meeting or exceeding the minimum criteria given in the AED Design Guide)?
(Yes / No / Unknown or N/A)
 - b. Has the use of "subjective" subsurface terminology (such as relatively soft rock or gravel with occasional boulders) been avoided?
(Yes / No / Unknown or N/A)
 - c. Have multiple soil classifications for a single sample in a soil horizon been reduced to only those permitted using ASTM D 2487
(Yes / No / Unknown or N/A)
 - d. If alignment has been shifted, have additional subsurface explorations been conducted along the new alignment?
(Yes / No / Unknown or N/A)
 - e. Do you think the wording of the geotechnical special provisions are clear, specific and unambiguous?
(Yes / No / Unknown or N/A)

B. Centerline Cuts and Embankments

1. Where excavation is required, are excavation limits and description of unsuitable organic soils shown on the plans?
(Yes / No / Unknown or N/A)
2. Are plan details and special provisions provided for special drainage details, such as lined surface ditches, drainage blanket under sidehill fill, interceptor trench drains, etc.?
(Yes / No / Unknown or N/A)
3. Are special provisions included for fill materials requiring special treatment, such as nondurable shales, lightweight fill, etc.?
(Yes / No / Unknown or N/A)
4. Are special provisions provided for any special rock slope excavation and Stabilization measures called for in plans, such as controlled blasting, wire mesh slope protection, rock bolts, shotcrete, etc.?
(Yes / No / Unknown or N/A)

C. Embankments Over Soft Ground

1. Where subexcavation is required, are excavation limits and description of unsuitable soils clearly shown on the plans?
(Yes / No / Unknown or N/A)
2. If instrumentation will be used to control the rate of fill placement, do special provisions clearly spell out how this will be done and how the readings will be used to control the contractor's

operation?

(Yes / No / Unknown or N/A)

D. Retaining Structures

1. Are select materials specified for wall backfill with gradation and compaction requirements covered in the specification?
(Yes / No / Unknown or N/A)
2. Are excavation requirements specified, e.g., safe slopes for excavations, need for sheeting, etc.?
(Yes / No / Unknown or N/A)

E. Structure Foundations - Spread Footings

1. Where spread footings are to be placed on natural soil, is the specific bearing strata in which the footing is to be founded clearly described, e.g., placed on Br. Sandy GRAVEL deposit, etc.?
(Yes / No / Unknown or N/A)
2. Where spread footings are to be placed in the bridge end fill, are gradation and compaction requirements, for the select fill and backfill drainage material, covered in the special provisions, standard specifications, or standard structure sheets?
(Yes / No / Unknown or N/A)

F. Ground Improvement Techniques

1. For fill, are minimum/maximum densities, gradation, lift thickness, and method of compaction specified?
(Yes / No / Unknown or N/A)