Subsurface Exploration Program

A. General Information

A subsurface exploration program is conducted to make designers aware of the site characteristics and properties needed for design and construction. The horizontal and vertical variations in subsurface soil types, moisture contents, densities, and water table depths must be considered during the pavement design process. The purpose of conducting a subsurface exploration is to describe the geometry of the soil, rock, and water beneath the surface; and to determine the relevant engineering characteristics of the earth materials using field tests and/or laboratory tests. More importantly, special subsurface conditions, such as swelling soils and frost-susceptible soils, must be identified and considered in pavement design. The phases of the subsurface exploration program, as well as the in-situ test, are summarized below.

B. Program Phases

The objective of subsurface investigations or field exploration is to obtain sufficient subsurface data to permit selection of the types, locations, and principal dimensions of foundations for all roadways comprising the proposed project. These explorations should identify the site in sufficient detail for the development of feasible and cost-effective pavement designs. Often the site investigation can proceed in phases, including desk study prior to initiating the site investigation. For the desk study, the geotechnical engineer needs to:

1. Review existing subsurface information. Possible sources of information include:

   a. Previous geotechnical reports

   b. Prior construction and records of structural performance problems at the site

   c. U.S. Geological Survey (USGS) maps, reports, publications, and Iowa Geological Survey website

   d. State geological survey maps, reports, and publications

   e. Aerial photographs

   f. State, city, and county road maps

   g. Local university libraries

   h. Public libraries

2. Obtain from the design engineer the geometry and elevation of the proposed facility, load and performance criteria, and the locations and dimensions of the cuts and fills.

3. Visit the site with the project design engineer if possible, with a plan in-hand. Review the following:

    a. General site conditions

    b. Geologic reconnaissance

    c. Geomorphology

    d. Location of underground and aboveground utilities

    e. Type and condition of existing facilities

    f. Access restriction for equipment

    g. Traffic control required during field investigation

    h. Right-of-way constraints

    i. Flood levels

    j. Benchmarks and other reference points

4. Based on the three steps above, plan the subsurface exploration location, frequency and depth. General guidelines are provided below.

C. Site Characterization

1. **Frequency and Depth of Borings:**

    a. Roadways: 200 feet is generally the maximum spacing along the roadway. The location and spacing of borings may need to be changed due to the complexity of the soil/rock conditions.

    b. Cuts: At least one boring should be performed for each cut slope. If the length of cuts is more than 200 feet, the spacing between borings should be 200 to 400 feet. At critical locations and high cuts, provide at least three borings in transverse direction to explore the geology conditions for stability analysis. For an active slide, place at least one boring upslope of the sliding area.

    c. Embankment: See criteria for cuts.

    d. Culverts: At least one boring should be performed at each major culvert. Additional borings may be provided in areas of erratic subsurface conditions.

    e. Retaining Walls: At least one boring should be performed at each retaining wall. For retaining walls more than 100 feet in length, the spacing between borings should be no more than 200 feet.

    f. Bridge Foundations: For piers or abutments greater than 100 feet wide, at least two borings should be performed. For piers or abutments less than 100 feet wide, at least one boring should be performed. Additional borings may be performed in areas of erratic subsurface conditions.

2. **Depth Requirements for Borings:**

   a. **Roadways:** Minimum depth should be 6 feet below the proposed subgrade.

   b. **Cuts:** Minimum depth should be 16 feet below the anticipated depth of the cut at the ditch line. The depth should be increased where the location is unstable due to soft soils, or if the base of the cut is below groundwater level.

   c. **Embankments:** Minimum depth should be up to twice the height of the embankment unless hard stratum is encountered above the minimum depth. If soft strata are encountered, which may present instability or settlement concerns, the boring depth should extend to hard material.

   d. **Culverts:** See criteria for embankments.

   e. **Retaining Walls:** Depth should be below the final ground line, between 0.75 and 1.5 times the height of the wall. If the strata indicate unstable conditions, the depth should extend to hard stratum.

   f. **Bridge Foundations:**
      1) **Spread Footings:** For isolated footings with a length (L) and width (B):
         a) If $L \leq 2B$, minimum 2B below the foundation level.
         b) If $L \geq 5B$, minimum 4B below the foundation level.
         c) If $2B \leq L \leq 5B$, minimum can determined by interpolation between the depths of 2B and 5B below the foundation level.
      2) **Deep Foundations:**
         a) For piles in soil, use the greater depth of 20 feet or a minimum of two times of the pile group dimension below the anticipated elevation.
         b) For piles on rock, a minimum 10 feet of rock core needs to be obtained at each boring location.
         c) For shaft supported on rock or into the rock, use the greatest depth of 10 feet, three times the isolated shaft diameter, or two times of the maximum of shaft group dimension.

3. **Types of Borings:**

   a. **Solid Stem Continuous Flight Augers:** Solid stem continuous flight auger drilling is generally limited to stiff cohesive soils where the boring walls are stable for the whole depth of boring. This type of drilling is not suitable for investigations requiring soil sampling.

   b. **Hollow Stem Continuous Flight Augers:** Hollow stem augering methods are commonly used in clay soils or in granular soils above the groundwater level, where the boring walls may be unstable. These augering methods allow for sampling undisturbed soil below the bit.

   c. **Rotary Wash Borings:** The rotary wash boring method is generally suitable for use below groundwater level. When boring, the sides of the borehole are supported with either casing or the use of drilling fluid.

   d. **Bucket Auger Borings:** Bucket auger drills are used where it is desirable to remove and/or obtain large volumes of disturbed soil samples. This method is appropriate for most types of soils and for soft to firm bedrock. Drilling below the water table can be conducted where materials are firm and not inclined to large-scale sloughing or water infiltration.

e. **Hand Auger Borings:** Hand augers are often used to obtain shallow subsurface information from the site with difficult access or terrain that a vehicle cannot easily reach.

f. **Exploration Pit Excavation:** Exploration pits and trenches permit detailed examination of the soil and rock conditions at shallow depths at relatively low cost. They can be used where significant variations in soil conditions, large soil, and/or non-soil materials exist (boulders, cobbles, debris, etc.) that cannot be sampled with conventional methods, or for buried features that must be identified.

D. Sampling

1. **Disturbed Sampling:** Disturbed samples are those obtained using equipment that destroys the macrostructure of the soil without altering its mineralogical composition. Specimens from these samples can be used to determine the general lithology of soil deposits, identify soil components and general classification purposes, and determine grain size, Atterberg limits, and compaction characteristics of soils. There are four well-known types of samplers for distributed samples, which are shown in Table 6B-1.01.

Table 6B-1.01: Types of Samplers (Disturbed)

Sampler	Appropriate Soil Types	Method of Penetration	Frequency of Use
Split-barrel (split-spoon)	Sands, silts, clays	Hammer-driven	Very frequent
Modified California	Sands, silts, clays, gravels	Hammer-driven (large split-spoon)	Rare
Continuous auger	Cohesive soils	Drilling with hollow stem augers	Rare
Bulk	Gravels, sands, silts, clays	Hand tools, bucket augering	Rare

2. **Undisturbed Sampling:** Clay and granular samples can be obtained with specialized equipment designed to minimize the disturbance to the in-situ structure and moisture content of the soils. Specimens obtained by undisturbed sampling methods are used to determine the strength, stratification permeability, density, consolidation, dynamic properties, and other engineering characteristics of soils. There are six types of samplers to obtain undisturbed samples, of which the thin-walled Shelby tube is the most common. These samplers are shown in Table 6B-1.02.

Table 6B-1.02: Types of Samplers (Undisturbed)

Sampler	Appropriate Soil Types	Method of Penetration	Frequency of Use
Thin-walled Shelby tube	Clays, silts, fine-grained soils, clayey sands	Mechanically or hydraulically pushed	Frequent
Continuous push	Sands, silts, clays	Hydraulic push with plastic lining	Less frequent
Piston	Silts, clays	Hydraulic push	Less frequent
Pitcher	Stiff to hard clay, silt, sand, partially weathered rock, and frozen or resin-impregnated granular soil	Rotation and hydraulic pressure	Rare
Denison	Stiff to hard clay, silt, sand, and partially weathered rock	Rotation and hydraulic pressure	Rare
Block	Cohesive soils and frozen or resin-impregnated granular soil	Hand tools	Rare