Purpose of the Site Investigation

- Determine site-specific ground conditions relative to geotechnical design, constructability or post-construction performance
- Provide a basis for evaluation of foundation design alternatives for the structure or earthworks project
- Determine the design parameters
- Determine potential problems and Avoid Surprises
Factors to Consider

- Design requirements
- Budget for site investigation and overall value of the project
- Constructability and required schedule
- Legal implications
  (standard of professional competence, legal interpretation of technical terms)
- Regulations
- Consequence of Failure
  (more risk requires more investigation)

Elements of the Site Investigation System

[Diagram showing the elements of a site investigation system, including Stratigraphy, Physical Dimensions, Structure, Material Properties, Compressibility, Shear Strength, Permeability, Genetic Factors, Sedimentary Structure, Stress History, Environmental Constraints, Flow System, Groundwater, Hydraulic Pressure.]
Field Reconnaissance

- Always visit site first. AVOID SURPRISES

Database Information

- Maps
  - Topographical
  - Air photos
  - Geological maps (bedrock and surficial geology)
  - Soil survey maps (pedology)

- Water Well Logs

- Previous Reports
  - Internal studies
  - Old general reports of site and previous consultant’s reports
  - Local practice, foundation types for similar structures nearby
  - Representative samples, nearby boreholes

Field Reconnaissance

- **Plan from Database Information and site visit** - Field work is expensive

- **Air Photo Interpretation** - Useful for regional setting
  - Natural of man-made structures in the region
  - Changes in site over time (History)
  - Identifying major borrow areas for fillings

- **Utility Locates**
  - Major cost and safety concern
  - Underground – power, telephone, cable, fibre optics, water, sewer, etc.
  - Aboveground – power, telephone, cable, etc.
Field Reconnaissance

Field Observations

(a) Slope failures  (b) Evidence of seepage
(c) Check outcrops or open cuts  (d) Check surface materials
(e) Interview residents  (f) Problems with structures
(g) Shrinkage cracks  (h) Environmental contamination

Surface Geophysics

• May occasionally be useful BEFORE drilling, allows “ground proofing” of geophysics data.
• Seismic (refraction, reflection), Resistivity, Electromagnetic (EMI), GeoRadar

Components of a Subsurface Investigation

Drilling

• Up to a structural marker
• Requires stratigraphic and structural control

Logging

• Vertical profile of soils
• Downhole Geophysical logs

Sampling

• Visual classification
• Laboratory testing

Instrumentation

• Piezometers and/or standpipes
• Inclinometers
• In situ testing such as a standard penetration test (SPT), cone penetrometer (CPT), pressuremeter, packer tests
Interpretation

- **Stratigraphic Controls**
  - Geologic
  - Textural separation within stratigraphic units

- **Mapping Geological Structures**
  - Strike and dip
  - Continuity of beds
  - Shear zones
  - Joints and faults

- **Hydrogeology**
  - Groundwater flow system
  - Piezometric conditions

- **Assign material properties for design**
  - Requires representative samples
  - What to do with unknown zones not sampled, or zones within which there was poor sample recovery ??!!!

Sampling

- **Objectives**
  - Determine soil properties
  - Stratigraphic interpretation

- **Properties**
  - Project specific – highways, bridge foundation, dam, etc.

- **Constraints**
  - Cost
  - Type of soil. Soft clays and loose saturated sands are very difficult to sample. Recovery is often poor and sample disturbance can be a large factor. Where do we need the samples the most?

- **Sample Types**
  - Representative (or disturbed)
  - Undisturbed (difficult for complete undisturbed)

- **Block Samples**
  - Closest to truly undisturbed
  - Very expensive
  - Requires open excavation
  - Limited to cohesive materials
Tools and Techniques of Subsurface exploration

- **Test Pits**
  - For shallow investigation (2-3 m)
  - Undisturbed sample for laboratory investigation

- **Boring**
  - For general investigations
  - Stratigraphy and sampling through field testing

- **Geophysical Methods**
  - Non-intrusive techniques

Typical Geotechnical Testing Plan

- **Borings**: No. of bore holes, spacing
- **Ground Water Monitoring**: measure the ground water level
- **Soil sampling**: sampler (split spoon sampler, Shelby tube), Specimen (undisturbed, disturbed)
- **Laboratory Test**: Index properties, Consolidation, Shear strength properties, Relative density, Permeability etc.
- **Field Test**: in-situ dry density, Shear Strength, Plate Load Test
Boring Techniques

- Auger Boring
- Wash Boring
- Rotary Boring
- Percussion Boring

Use depends on

- Nature of soil
- Water table Depth
- Sample Disturbance
- Accuracy of soil exploration

Auger Boring for soils which can stay open without casing or drilling mud. It is not possible for sands below water table. Good for Highways, railways projects where small depth of soil exploration is needed.

Auger Boring

Procedure

1. Hand Auger
   - for shallow depth (3 - 5 m)
2. Power Driven Auger
   - for larger depth
3. Sand Bailer
   - Heavy duty pipe with cutting edge
   - Lifted and then left to fall freely under self weight. Additional weight (sinker) may be added for ease of sinking
Auger Boring

Hollow Stem Auger

- A casing pipe of 2-3 m length is driven into the soil by a heavy drop hammer.
- The soil inside the casing is removed by means of a chopping bit attached to a drill rod which forces water at high pressure.
- Soil mixed with water moves up in annular gap between drill rod and casing.
- Samples are obtained at certain depth by removing drill rod and pushing a sampler instead.

Wash Boring

- A casing pipe of 2-3 m length is driven into the soil by a heavy drop hammer.
- The soil inside the casing is removed by means of a chopping bit attached to a drill rod which forces water at high pressure.
- Soil mixed with water moves up in annular gap between drill rod and casing.
- Samples are obtained at certain depth by removing drill rod and pushing a sampler instead.
Rotary Boring

- Design similar to wash boring
- Useful when soil is resistant to auguring or wash boring
  - Boring is done by rapidly rotating drilling bits attached to bottom of drilling rod.
  - Soil/rock cuttings removed by circulating drilling fluid
  - Samples are taken a certain depths by removing drill rod and placing sampler.
  - **Mud Rotary Drilling:** Hollow drilling rods are used to flow mud slurry (Bentonite) to check caving in of the material (soil) at bottom.
  - **Core Drilling:** Core barrels with diamond bit are used.

Percussion Boring

- Dry boring or water circulated to remove loose soil
- **Heavy drilling** bit or chisel is dropped while inside the casing to chop the hard soil.
- Percussion drilling rods may be replaced by cables.
Bore Hole Stabilization

- Drilling Mud
- Use of Casing

Ground Water Observation

- High Permeability Soils
  - Bore hole/Observation wells
    (Observation time = 24 to 48 Hrs)

- Low Permeability Soils
  - Casagrande Piezometer
    (when water level in bore hole does not get stabilize in
    Piezometer is recommended)

- Piezometers may be installed in bore hole for seasonal
  variations in High permeability soils. Chemical analysis of
  ground water may be performed if its constituents can be
  damaging to foundation.
Soil Sampling

- **Disturbed Samples**: Natural soil structure is modified or destroyed during sampling
  - Representative Samples:
    - Natural water content and mineral constituents of particular soil layer are preserved
    - Good for soil identification and water content
  - Non-representative Samples:
    - Water content altered and soil layers mixed up
    - Of no use.

- **Undisturbed Samples**: Soil structure and the other mineral properties are preserved to an extent.
  - Some disturbance is always there, e.g. due to stress release. However it should be minimized in order to have suitable sample for our analysis.

**Standard Split Spoon Samplers**

- Thick wall (0.25in) cylinder
- Sampling tube (dia 51 mm) is split along the length
- Representative Disturbed soil samples
Shelby Tube (Thin-wall) Sampler

Thin wall (1/16in) sampling tube
Sampler pushed into the ground hydraulically
Sample extruded from tube and “Undisturbed” soil sample is obtained

Piston Sampler
Rock Coring

Sealing Sampling Tube
Borings: Number & Spacing

- No hard and fast rule
- Some guidelines – IS:1892-1979
- For small projects:
  - On plane site – 4 or 5 borings sufficient
  - On uneven site – add 1 or 2 more borings
- For large projects: 50-100 m spacing in grid pattern
- It is important to conduct borings as close as possible to column locations and strip footing locations.

Depth of Exploration

[Diagram showing different depth of exploration for infinitely long and square foundations]
Depth of exploration

Strip Footing  Square Footing  Combined Footing  Raft Foundation

Depth of exploration

Strip Footing  Square Footing  Combined Footing  Raft Foundation
Identifying Weak Plane: Boring? Sampling?

Estimated Slip Surface

Economics
Exploration Plan?

1. Multistory residential building
2. Multistory office building
3. On-site temporary office
4. Single floor health center
5. Water-supply tank
6. Light machinery work shop
7. Heavy machinery work shop
8. Children’s Park

India-Tech Headquarters

Dimensions in meters.

Thank You