American Bar Association, Forum on Construction Law
2018 Regional Program

Infrastructure From the Ground Up: Civil Works Projects for Lawyers.

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Geotechnical Engineering

Presented by:
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Exponent
Agenda: Part 1*

- Soil Properties and Laboratory Testing
- Subsurface Exploration and Testing
- Ground Improvement
- Foundations
- Excavation Support Systems
- Roadways/Pavements

* From *Infrastructure from the Ground Up*, Chapter 1: Geotechnical Engineering, ABA Construction Forum.
Agenda: Part 2

- Roles and Responsibilities
- Limitations of Liability
- Typical Contract Disputes
- Brief Case History (optional)
- Legal Issues
Soil Properties and Laboratory Testing
Soil Classification

The primary mechanical properties of the soil:

- Compressibility
- Shear strength
- Permeability

Each depends on the arrangement, proportions, and properties of the various particles that comprise it.
Soil Classification

Gradation

Distribution of particle sizes -

▪ Grain-size distribution curve
▪ Percentage of fines (#200 sieve)

Plasticity

Response to water-

▪ Plastic limit
▪ Liquid limit
▪ Plasticity index
▪ Liquidity index
Soil Classification

Geotechnical Engineers typically classify soil in one of four primary categories:

- Clay
- Silt
- Sand
- Gravel
Soil Volume and Density

Soil is a three-phase material consisting of minerals, gas (air), and fluid (water).

www.nptel.ac.in
Soil Volume and Density

The density of the soil, measured via various means and evaluated and expressed in different terms, is critical to assessing the potential performance of soil:

- **Unit weight** – weight per unit volume (e.g., pcf)
- **Void ratio** – ratio of voids to solids volumes
- **Relative density** – density as a relative percentage of maximum and minimum densities
- **Relative compaction** – unit weight relative to maximum from laboratory compaction test
Flow of Water

- The voids encountered between the soil particles form pathways or channels for water to flow through the soil mass.
- The size of these channels determines the “permeability” \((k)\) of the soil – the ability of fluids to flow through the soil.

USACE, EM 1110-2-1901
Concept of Stresses

The stresses applied to fine-grained soils are carried in part by the soil particles and in part by the fluids (water) in the soil skeleton void space. The load carried by pore fluids dissipates with time ("consolidation").
Soil Compressibility

The deformation of soils is time-dependent and can occur almost instantaneously (in higher permeability soils like sand and gravel) or over long periods of time after the application of a load (in lower permeability soils like clay).
Shear Strength

The shear strength represents the ability of a material to resist applied shear forces. This is the critical type of design strength in geotechnical engineering.
Shear Strength (cont.)

There are numerous field and laboratory test apparatuses to measure and evaluate shear strength of soil, e.g.,

• Vane shear
• Direct shear
• Triaxial shear
• Direct simple shear
• Ring shear

Norwegian Geotechnical Institute, “Direct Simple Shear Test”
Shear Strength

For saturated or nearly-saturated fine-grained soils, the relative rate of loading is important:

- Relatively slow, long-term $\rightarrow$ Drained strength defined by friction ($\phi$) and cohesion (cohesion being relatively small)
- Relatively quick $\rightarrow$ Undrained strength, $S_u$ (no friction)
Shear Stiffness

- Not to be confused with shear strength or compressibility, shear stiffness relates to the deformability of soil under shear loading.
- This is a particularly important parameter when designing in seismic regions and requires specialized testing.
Response to Structural Loading

Compressibility → potential settlement
Shear strength → lateral loads, bearing capacity, global stability
Shear stiffness → deformability, earthquake response
Permeability → rate of settlement, excavation stability, rate of seepage, dewatering
Response to Wetting and Drying

- Water in soil affects its properties.
- Wetting of certain soils can cause hydro-collapse (typically in sand-silt mixtures with lesser amounts of clay); hydro-collapse is irreversible.
- Wetting and drying of certain soils can cause swelling and shrinkage (predominantly heavy or “fat” clays); swelling and shrinking can re-occur indefinitely.
Subsurface Exploration and Testing
Site Investigation

- Geologic and seismic hazard assessment
- Evaluate historic site/surface conditions
- Exploration and testing to evaluate subsurface conditions
- Depth and potential fluctuation of groundwater
Subsurface Exploration and Testing

Geotechnical Engineers use various exploration methods and techniques to obtain necessary soil information, including soil borings, cone penetration testing, in-situ testing, and test pits or trenches.
Soil Borings

Soil borings are commonly used for subsurface exploration:

- Small-diameter holes are drilled vertically into the ground.
- Standard Penetration Test (SPT) is the most common means to simultaneously test and sample soil → SPT blowcount or “N”-value.
- “Undisturbed” samples can also be taken using Shelby tubes and other means.
Cone Penetration Testing (CPT)

- Cone Penetrometer Testing (CPT) involves pushing an instrumented steel probe into the ground to continuously measure tip resistance and side friction.
- There are options to measure other properties like shear stiffness and pore water pressure.
Test Pits and Trenches

Test pits or trenches are very useful tools for:
- Identifying existing foundations (e.g., adjacent building) and subsurface obstructions
- Providing access to test in-place density of compacted fill using relatively precise procedures
- Observing contacts between materials, limits of fill, geologic bedding, and fault mapping
Test Pits and Trenches (cont.)
Ground Improvement
Ground improvement involves modifying the properties of soils primarily to improve their strength and stability. Techniques include:

- Grouting (permeation, jet or compaction)
- Deep soil mixing
- Stone columns
- Admixture stabilization
- Deep dynamic compaction
- Preloading
Ground Improvement (cont.)

Jet Grouting

Compaction Grouting
Ground Improvement (cont.)

Deep Soil Mixing (DSM)  Cutter Soil Mixing (CSM)
Ground Improvement (cont.)

Stone Columns

Admixture Stabilization
Ground Improvement (cont.)

Deep Dynamic Compaction

Preloading
Foundation Systems
Types of Foundation Systems

Structural loads are transferred to the ground via a foundation system. Generally, Geotechnical Engineers distinguish among shallow, mat, and deep foundation systems.

- Shallow – spread footings, strip footings, pier-and-post, etc.
- Mat – thick, heavily-reinforced concrete raft
- Deep – driven piles and drilled piers (aka drilled shafts)
Function of Foundations

Foundations spread out the loads over a large area or extend the foundation deep into the ground until it reaches a suitable soil or rock layer.
Design Approach

Foundations are selected and proportioned based on a need to not exceed the **bearing capacity** of the ground and stay within **settlement** criteria established by the Architect or Structural Engineer.
Shallow Foundation Systems

- Isolated column footings
- Strip footings under walls
- Combined footings under multiple columns
Deep Foundation Systems

- Required where shallow foundations would have insufficient capacity to resist structure loads or excessive settlement:
  - Large loads
  - Weak soil near ground surface

- Types include:
  - Driven piles (precast concrete or steel)
  - Cast-in-place piles (drilled shafts or augercast)
  - Micropiles
  - Helical piles
Deep Foundation Systems (cont.)

Driven Piles
Deep Foundation Systems (cont.)

Drilled Shafts
Deep Foundation Systems (cont.)

Augercast Piles
Excavation Support Systems
Excavation Support Systems

Excavation support systems (a.k.a. Support of Excavation, or SOE) are required where sloped excavations are not feasible:

- Insufficient space
- Excessive soil to be removed
- Dewatering not feasible
Excavation Support Systems (cont.)

- **Wall Types**
  - Soldier piles and lagging
  - Sheet piling
  - Slurry diaphragm
  - Secant and tangent piles
  - Deep soil mixing

- **Cantilevered Walls Systems for Limited Depths of Excavation**

- **Wall Support Elements**
  - Tiebacks
  - Internal bracing
  - Deadmen
Excavation Support Systems (cont.)

Soldier piles and wood lagging with tiebacks
Excavation Support Systems (cont.)

Internally braced deep soil mix shoring wall
Excavation Support Systems (cont.)

Soil nails and shotcrete
Excavation Support Systems (cont.)

Important design and construction considerations:

- Worker safety
- Limit ground movement
- Prevent the lowering of groundwater
- Limit vibrations where they could cause damage
- Construction should conform to specified construction sequences and design details
Roadways/Pavements
Roadways/Pavements

Design Criteria for Pavement Surfaces

- Traffic
  - Type
  - Load
  - Frequency
  - Distribution
  - Speed
- Facility type to be serviced
- Economics (life cycle cost)
Roadways/Pavements (cont.)

Subgrade Preparation
Roles and Responsibilities

- The Geotechnical Engineer is typically hired as a technical consultant and the Engineer of Record (EOR) by the Owner/Authority or Architectural or Structural/Civil Engineering firm.
- As EOR, the Geotechnical Engineer has responsibilities during design and construction.
Roles and Responsibilities (cont.)

- Alternatively, a Geotechnical Engineer may be hired as a consultant to the General Contractor or hired as the Owner’s Representative (OR) to oversee construction.
Limitations of Liability
Limitations on Liability

- Geotechnical Engineers, like other design professionals, attempt to limit their liability.
- Liability limitations are usually expressed either as:
  - The amount of fees charged for the services (or some multiple), or
  - A fixed dollar amount.
  - In some cases, limitation of liability clauses are written or construed to limit liability, in addition to any applicable insurance coverage.
Typical Contract Disputes
Typical Contract Disputes

- Differing site conditions
- Defective plans and specifications
- Responsible charge
- Professional negligence
Brief Case Study
Brief Case Study

- $25M public works improvement project
- Transportation Authority ("Owner") has an engineering firm ("AE") as the Program Manager under an existing contract.
- AE hires geotechnical firm to assess subsurface characterization and provide design parameters for embankment.
- Owner later hires same AE (different staff) to be the Task Manager to design embankment.
Brief Case Study (cont.)

- The AE develops plans and specifications for expansion onto wetlands.
- Plan requires removal and replacement of unsuitable soils down to competent material (up to 25 feet in depth).
- The AE lets plans and specifications out to bid (design-bid-build approach).
Brief Case Study (cont.)

- Included in the plans and specifications are designs for support of excavation sheeting that is to remain in place.
- Dewatering is left to Contractor’s means and methods (performance specification).
- Owner hires same AE (different staff) to act as the Owner’s Representative ("OR") during construction.
Brief Case Study (cont.)

- The AE’s wall design is contingent on the Contractor completing borings per the contract along alignment in areas previously inaccessible.
- The Contractor performs some, but not all borings; Owner’s Representative alerts Contractor to missing borings.
Contractor proposes an alternate, proprietary SOE system that uses minimal penetration of sheet piles below the depth of excavation.

AE does not perform normal review of shop drawings because SOE system is proprietary.

Contractor installs SOE system, but can’t sufficiently drawdown groundwater.

Contractor proposes and is allowed to excavate “in the wet.”
Brief Case Study (cont.)

- As excavation “in the wet” proceeds, alternate SOE system fails due to lack of penetration beneath excavation.
- The depth of excavation required during construction is much greater.
- Contractor hires the same geotechnical engineering firm used by AE in design study to investigate problems.
Brief Case Study (cont.)

- Contractor files differing site conditions claim for excessive water and soil type.
- Owner intends to require Contractor to use AE’s SOE design, but finds through its consulting expert that AE’s design is seriously flawed and OR did not enforce the Contractor performing soil borings.
Brief Case Study (cont.)

- Owner alleges professional negligence by AE for defective SOE design.
- In addition, Owner questions thoroughness of shop drawing reviews for SOE and dewatering systems.
Brief Case Study (cont.)

- Although a bit unusual, this case provides many examples of issues that may arise on geotechnical work and exemplifies complexities that can develop.
Technical Questions?
Legal Issues in Geotechnical

*Presented By:*

Elizabeth Walsh
Jones Day
Privity Issues

- If there is no privity with an engineer, can an owner or contractor (who relied on the accuracy of the geotechnical evaluation) bring contract claims?
  - Can the engineer rely on limitation of liability or other contract defenses?

- What about tort claims?
Third-Party Beneficiaries

- Generally must be provided by express terms of the contract.
- Requires more than just “benefitting” from the contract.
- Can only enforce specific promises made for the third-party’s benefit.
Third-Party Beneficiaries

- Third-party beneficiaries usually recover the same remedies available to parties to the contract.
  - Some courts have held that limitation of liability clauses do not apply to third-party beneficiaries.
- If you are not a third-party beneficiary or a party to the contract, contractual defenses (like limitations of liability) do not apply.
Economic Loss Rule

- Application is state-specific; approaches vary drastically from state to state
- Application is still unsettled in some states
- May depend on privity or functional privity
- May depend on whether an independent duty of care is owed
- A few states only apply the rule in the products liability context
Economic Loss Rule

Potential exceptions:

- Independent duty imposed by law/professional negligence
- Damage to other property/personal injury
- Fraud
- Negligent or intentional misrepresentation
Legal Questions?
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