Soils and Excavation

Earth as structure

- The earth is the first surface from which the building is raised
- It's also the last structural member, where all forces are resolved
  - Wind load
  - Snow load
  - Rain load
  - Furniture loads
  - People dancing loads
  - Weight of the materials loads

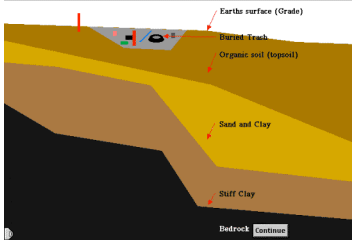
A geo what?

- Subsurface materials and moisture are the basis for determining the degree of concentration or dispersal of these loads through the foundation.
- A ***Geotechnical engineer*** is the professional hired by the Owner to work with the design team to survey soil and water conditions below the surface in locations and likely depths for load distribution

Looking below

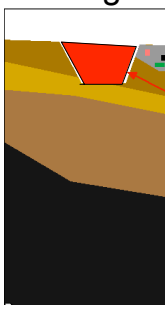
- The geotechnical engineer can use these methods to survey subsoil conditions.
  - Sounding rod - resistance probe (seldom used..why?)
    - A fixed diameter probe struck with a calibrated driver. Certain number of blows drives the probe a distance…soil resistance calculated from driven distance.
    - Does not compensate for obstructions (hit an old boot?)
    - Does not yield sample for lab testing of soil properties / settlement calculations
    - Does not give any info on the water table height
    - Samples a very small area

Standard resistance rod test



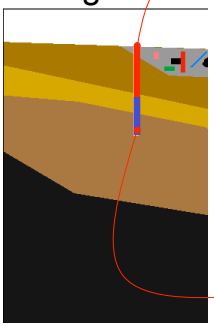
- ASTM D1586
- 5 lb hammer, 1/2 inch diameter rod, driven to 1 foot penetration
  - 0-4 blows = 20% density very loose soil
  - 4-10 blows = 20-40% density loose soil
  - 10-30 blows= 40-60% density medium dense soil
  - 30-50 blows= 60-80% density dense soil
  - 50-80 blows= 100% density, very dense soil…or you hit a good boot!

Looking below



- Test pits (less common)
  - Hole is dug with backhoe to the assumed footing depth.
  - Soil types can be observed in the sides of the hole and it's bottom
  - Load tests can be conducted on the bottom of the hole
  - Water table can be observed rising over a 24 hour period
    - Downside
    - Requires a backhoe
    - Open pit can be a hazard…trip, drowning…
    - Many pits (for large site) are expensive
    - Only good for fairly shallow footing depths

Boring



- Soil Borings are a common sampling method used by the geotechnical engineer.
  - A 3” dia hollow core bit is drilled into the earth slightly deeper than the anticipated footing depth.
  - The core bit takes a plug of earth with it as it is pulled from the earth
  - The core bit is split open, and a cylinder of earth inside is removed and taken to the lab. Tests for
    - composition
    - compressive strength / settlement rates
    - moisture content and liquid limit
    - soil expansion are conducted to determine
  - Bearing Capacity
  - Settlement projections
  - Water table (monitored in 3” remaining hole in earth)

Acoustics

- Acoustic soundings are also used to map subsurface rock formations.
- Ground Penetrating radar also sees use in certain dry soil types to map objects 6 - 12” below surface.

You only know what you test

- Ultimately, one can only know what is in the sample tested.
- Two feet over could be a toxic waste dump…or an underground river…or a cavern.
- “Discoveries” by the excavator beyond a reasonable assumption are not the fault of the Excavator, the Geotechnical Engineer, or the Contractor, Architect…they are simply unexpected, and are a cost to the owner as part of making the site buildable.

Boulder, Cobble, Gravel...

- A boulder is any rock taking two hands or more to lift
- A cobble takes one hand to lift
- Gravel particles can be held between the thumb and forefinger
- Sand particles are large enough to see, but too small to pick up individually
- Clays, and silts are particles too small to see or pick up individually

From worst to best

- Highly Organic Soils
  - bearing capacity is less than 1,500 pounds per square foot…
    - Peat
    - Organic clays
    - Inorganic clays of high plasticity (bentonite clay expands to 15 times its volume dry)
    - Inorganic silts

- Fine grained soils - 3,000 pounds per square foot
  - Low plasticity organic silts and clays
  - Gravelly or sandy clays, silty clays
  - Inorganic silts and fine sands
- Coarse grained soils, 6,000 pounds per square foot
  - Silty sands, poorly graded sand / silt mixtures
  - Clayey sands, poorly graded sand / clay mixtures

- Coarse grained gravels and sands up to 20,000 pounds (10 tons) per square foot
  - Well graded sands, gravelly sands,
  - Clayey gravels, poorly graded gravel / sand / clays
  - Silty gravels, poorly graded gravel / sand / silt mixtures
  - Well graded gravels, gravel and sand mixtures
  - Poorly graded gravels, gravel and sand mixtures
- Sedimentary rock - up to 50,000 pounds (25 tons) per square foot
- Crystalline bedrock - up to 200,000 pounds (100 tons) per square foot

How much bearing capacity does a building require?

- If a 4-story concrete building like Cowgill had 60,000 square feet, and if you assumed a live and dead load of approx 120 pounds per square foot, Cowgill would exert a force of 36,000 tons on the earth.
- If, like cowgill, the building touched the earth at 28 points, each point (column) would exert a force of 1,285 tons on the earth.
- If the foundation under each column was approx 2 feet by 4 feet, each square foot of earth would have to accept 160 tons of force (about 320,000 pounds) so the foundations are bigger, about 20 square feet so the load on the bedrock is 64 tons per square foot.

Never trust organics...

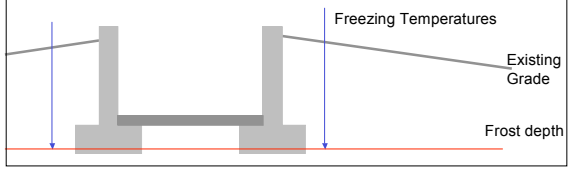
- The organic layer of the earth usually extends from the surface down to about 18 to 24 inches. This topsoil layer is usually stripped away and stored for replacement by the excavator.
- The organic layer, and any organic layers found at lower depths should always be removed and replaced with engineered fill where they would fall under the building.
- This is because continuing bacterial action breaks down the organics in the soil, decreasing the soil volume…contributes to settling!

Never trust debris

- Any debris…trash, bottles, boots, chevy vegas, should never be built on.
- Remove any debris found in the excavation lines and replaced with engineered fill to the required footing depth.
- Debris can decay, crush, mash, slip, slide, or otherwise fail, contributing to building movement. Not a good thing.

Footings below frost

- Footings carrying the perimeter of the building footprint must always be protected from frost action.
- Frost only forms in the presence of freezing temperatures.
- Freezing temperatures change the water in the soil to ice, which takes up more volume, pushing the soil up (with over 100,000 pounds of force!) and with it any foundation bearing on the soil.
- To protect from frost:
  - Dig the footings to a depth below the frost line 30" in Blacksburg, 60" in Fargo.
  - Or build a frost protected footing.



Frost protected footings

- Developed by HUD with builders in the great frozen north (Fargo) This method proposes keeping the ground warm, because warm earth will not freeze.
- To keep warm, dig down through the organics, (approx 24 inches) and lay insulation 6 inches below grade extending out from the foundation line a distance equal to just over the required footing depth.