Subgrade & SubBase 101

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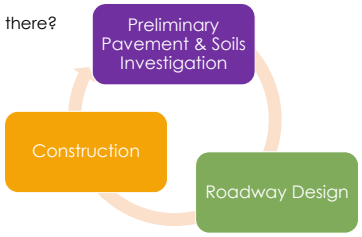
Goal: Have a properly designed and placed base and subgrade.

How do we get there?



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Answer: It takes all of the disciplines working together!

- Know what's there first!
- Have a set of plans and specifications that clearly defines what needs to be done.
- Constructed correctly.

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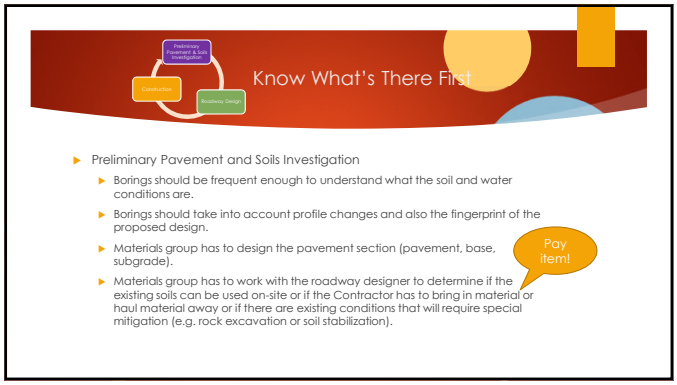
Preliminary Pavement & Soils Investigation
Construction
Roadway Design
Know What's There First
Preliminary Pavement and Soils Investigation
Borings should be frequent enough to understand what the soil and water conditions are.
Borings should take into account profile changes and also the fingerprint of the proposed design.
Materials group has to design the pavement section (pavement, base, subgrade).
Materials group has to work with the roadway designer to determine if the existing soils can be used on-site or if the Contractor has to bring in material or haul material away or if there are existing conditions that will require special mitigation (e.g. rock excavation or soil stabilization).
Pay item!

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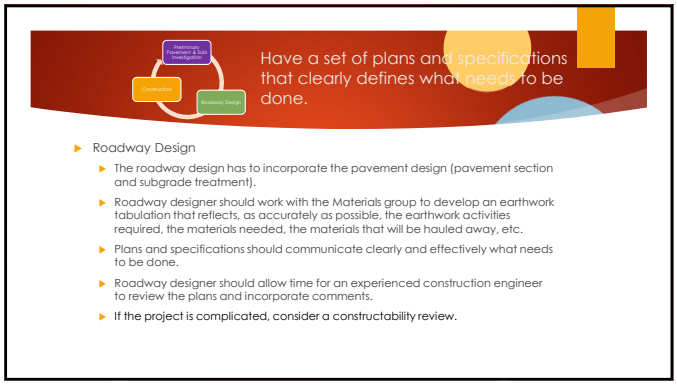
Preliminary Pavement & Soils Investigation
Construction
Roadway Design
Have a set of plans and specifications that clearly defines what needs to be done.
Roadway Design
The roadway design has to incorporate the pavement design (pavement section and subgrade treatment).
Roadway designer should work with the Materials group to develop an earthwork tabulation that reflects, as accurately as possible, the earthwork activities required, the materials needed, the materials that will be hauled away, etc.
Plans and specifications should communicate clearly and effectively what needs to be done.
Roadway designer should allow time for an experienced construction engineer to review the plans and incorporate comments.
If the project is complicated, consider a constructability review.

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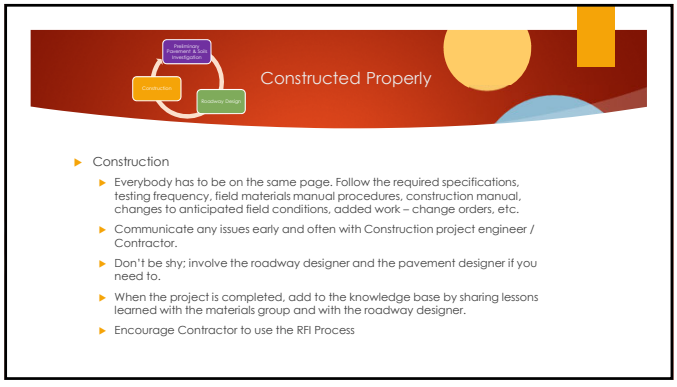
Preliminary Pavement & Soils Investigation
Construction
Roadway Design
Constructed Properly
Construction
Everybody has to be on the same page. Follow the required specifications, testing frequency, field materials manual procedures, construction manual, changes to anticipated field conditions, added work – change orders, etc.
Communicate any issues early and often with Construction project engineer / Contractor.
Don't be shy; involve the roadway designer and the pavement designer if you need to.
When the project is completed, add to the knowledge base by sharing lessons learned with the materials group and with the roadway designer.
Encourage Contractor to use the RFI Process

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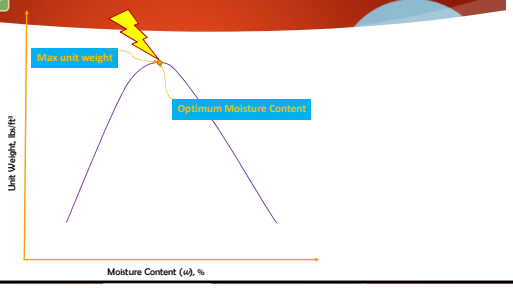
Moisture Density Relationship Curve



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Want to stabilize the soil?

- In general, adding compactive effort is good:
  - Increase in shear strength
  - Increase in swell potential
  - Increase in unit weight
  - Decrease in shrinkage potential
  - Decrease in permeability
  - Decrease in compressibility

Note: Information gleaned from really smart college professors and from *Engineering Properties of Soils and Their Measurements* by Joseph E. Bowles. Only the best soils lab manual ever!

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It's "Complicated."

Compaction Dry of Optimum	Compaction Wet of Optimum
Flocculated	Dispersed
Higher Ultimate Strength	Lower Ultimate Strength
Failure is Brittle (Sudden)	Failure is Plastic (Gradual)
Less Susceptible to Shrinkage on Drying	More Susceptible to Shrinkage on Drying
More susceptible to swelling on saturation	Less susceptible to swelling on saturation
Settlement with Cracking	Larger Settlement Without Cracking
Higher Permeability	Lower Permeability

- Where we want to be on the curve depends on what the application is.
- Where we want to be on the curve depends on what the soil properties are.

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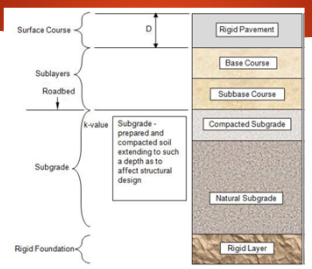
Introduction to Soils



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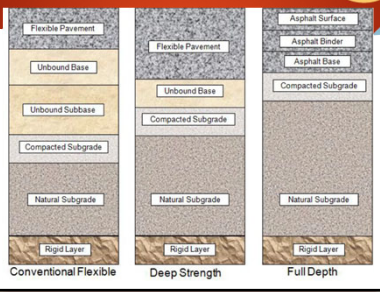
Introduction to Soils



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Introduction to Soils

- **Organic soils** – Top Soil, great in your garden, but a poor performer beneath a roadway. Organic soils cannot be easily compacted and must be removed and replaced with a compressible fill.
- **Granular soils** - Granular Soils like sand or gravel. Individual particles are visible and water drains quite easily from them. Granular soils have the highest bearing strength and compact easily, but do not bind together easily

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Introduction to Soils

- **Cohesive soils** - Finer soils like silts and clays. Deform easily when wet, and feel smooth between your fingers. Individual particles are too small to see. Cohesive soils are often difficult to compact and take on a rock-hard consistency when dry, but they have a lower bearing strength than granular soils. Some clays expand when wet and shrink when dry. The best counter to this problem is with good compaction and to not let them get wet (by providing drainage). But if the ground beneath the slab dries over time, it will shrink and the slab may sink.

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Introduction to Soils

- **Natural soils** - Most natural soil, of course, is a mixture and so is characterized by the type of material that is predominant. The amount of weight the soil can support before it fails is its bearing capacity, typically given in pounds per square foot. The design, however, is based on the allowable soil pressure, which adds a safety factor to the ultimate bearing capacity.

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Layers in Construction Pavements

- **From Bottom up:**
  - **Subgrade** – Native material underneath the roadway or pavement. Embankment (fill) and Excavation (cut) are common practices in roadway construction and generally classified as subgrade materials.
  - **SubBase** – Typically comprised of granular material placed between Subgrade and Base Course (often omitted in roadway construction).
  - **Base Course** – Generally a Construction Aggregate (granular) mixture of soils placed immediately below the pavement section.
  - **Pavement** – The "Wearing Course" typically comprised of aggregate material typically bound together using Asphaltic or Cementitious binders as a adhesive and cement.

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Best Practices in Pavement Construction

- **Pavement Life:**
  - The long term performance of a pavement is dependent on:
    - Pavement Design (Structural Design)
    - Local Climate
    - Locally Available Aggregates
    - Binder type (flexible vs rigid)
    - Load Bearing Capacity of the Subgrade

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Best Practices in Pavement Construction

- **Subgrade Preparation:**
  - Load Bearing Capacity of the Subgrade
    - Greater subgrade capacity may result in a thinner pavement design (reducing roadway costs)
    - In order of $/SY of pavement
      - Lowest – Subgrade
      - Moderate – Base Course
      - Highest – Pavement

      $/SY
    - Increased attention to subgrade capacity has the biggest impact to lower construction costs.
    - Promoting uniformity in the pavement will limit pavement deflections and increase support

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Best Practices in Pavement Construction

- **Biggest Factors Affecting Subgrade Capacity:**
  - Soil type and gradation
    - Soil classification, R-Value or Resilient Modulus, soil granularity, soil binding characteristics
  - Optimum Moisture Content
  - Maximum Soil Density (typically > 95% of maximum laboratory density)
  - Unusually high water table, leading to high moisture content
  - Makeup of underlying materials (soft or wet, vs. dry and stable)

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Best Practices in Pavement Construction

- **Types of Subgrade Preparation:**
  - Modification/Stabilization
  - Removal and Replacement
    - (e.g. - 18 to 24 inches of R-20 material immediately beneath the base course within the roadway prism)
    - Rockfill to stabilize and bridge excessively wet soil conditions
    - Geo-synthetic reinforcement with overlying aggregates

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Best Practices in Pavement Construction

- **Modification/Stabilization:**
  - Chemical additives:
    - Lime (chemically reactive)
    - Fly Ash (chemically reactive and self cementing)
    - Cement (chemically reactive and self cementing)
  - Blending superior imported materials with inferior on-site materials
  - Soil moisture conditioning
  - All of the above combined with maximum density process control

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Best Practices in Pavement Construction

- **Chemical Stabilization:**
  - Blending chemicals such as Lime, Fly Ash or Cement with unconsolidated soil and water at specified depths and compaction requirements.
  - Lime (typically used with finer silty/clayey soils):
    - Dries wet soils
    - Modifies and permanently stabilizes clayey soils
    - Increases strength of subgrade
  - Fly Ash (typically used with finer silty/clayey soils :
    - Dries wet soils
    - Reduces Shrink/Swell potential of clayey soils
    - Increases strength of subgrade

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Best Practices in Pavement Construction

- **Chemical Stabilization:**
  - Cement (typically used with more granular soils)
    - Reduces Shrink/Swell potential of clayey soils
    - Reduces freeze thaw movement potential
    - Increases strength of subgrade and gains strength with age

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Best Practices in Pavement Construction

- **Subgrade Stabilization Benefits:**
  - Lower material cost as compared to Bases and Pavements
  - Lower construction costs by eliminating the costs of material removal and replacement
  - Increased subgrade capacity

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Best Practices in Pavement Construction

- **Subgrade Stabilization Benefits:**
  - Lower material cost as compared to Bases and Pavements
  - Lower construction costs by eliminating the costs of material removal and replacement
  - Increased subgrade capacity
  - "Greener" construction methods, uses less fuel, reduces or eliminates import and export of materials.
  - Longer durability and is more resistant to water and frost increasing the lifespan of the subgrade

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Best Practices in Pavement Construction

- **Removal and Replacement:**
  - Simple construction methods
  - Common method directly under the pavement section
    - (e.g. - 18-24 inches of R-20 material immediately beneath the base course within the roadway prism)
    - Rockfill to stabilize and bridge excessively wet soil conditions
    - Geo-synthetic reinforcement with overlying aggregates
      - Provides reinforcement, separation, filtration and lateral strength (reducing deflection potential)
      - Allows the use of inferior soils, can reduce construction time and increases subgrade durability

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Best Practices in Pavement Construction

- **Moisture Conditioning:**
  - The technique of blending, blading, mixing, shaping, wetting (any combination of these to achieve homogeneous soil conditions), combined with moisture and density control
  - Increases or reduces the soil moisture content to the optimum level to achieve the maximum density of the material being worked
  - Helps control shrink/swell potential of soils
  - Most commonly used roadway construction technique, and allows faster construction

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Best Practices in Pavement Construction

- **Base Course:**
  - Typically a man-made aggregate with blend of coarse, intermediate and fine particles.
    - Coarse and intermediate materials provide superior structural strength
    - Finer particles provide binding properties and assist with cohesiveness of the base coarse material
  - Very common construction practice
  - Almost always imported material, making it more expensive
  - Typical thicknesses range from 4 to 8 inches (6 inches is very common)

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Best Practices in Pavement Construction

- **Earth Work Equipment:**
  - Transport
    - Haul trucks, trailers, tandems, scrapers
    - Excavators, loaders
  - Modifying/Placing/Shaping
    - Water trucks, water buggy, blade, dozer
  - Compaction Density
    - Steel drum rollers, vibratory rollers, sheep's foot
  - Grading
    - Blade, trimmer

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Best Practices in Pavement Construction

- **Inspection CheckList:**
  - Water truck on-site
  - Proper type of equipment on-site
  - Properly sized equipment
  - Well blended homogeneous placement of material
  - Soft spots are removed or repaired (look for rutting)
  - Surveying:
    - Grades stakes placed, string line used to check for high/low spots (0.08 feet for subgrade and 0.04 feet for base coarse)
    - Cross-slopes and super-elevations placed and checked

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Best Practices in Pavement Construction

- **Inspection CheckList (cont'd):**
  - Proof Rolling
    - 18 kips per axle vehicle
    - Get a weight ticket on the truck
    - Traverse the entire roadway prism at walking pace, mark out any soft spots
    - Soft spots are where the vehicle easily deflects the subgrade or base by an inch or more
    - Remove and replace or re-work all soft spots and re-check
    - Proof Rolling paid by the hour

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Best Practices in Pavement Construction

- **Grading:**
  - Grading prior to base coarse 0.08 feet (CDOT Specification 203)
  - Fine grading prior to pavement 0.04 feet (CDOT Specification 203)
  - Typical equipment:
    - Blades
    - Trimmer with conveyor
    - GPS Equipment

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Best Practices in Pavement Construction

- **Questions ???????**

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