Subgrade Preparation

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Monday, February 3, 14
Subgrade Preparation
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- Types of subgrade preparation
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- Types of subgrade preparation
- Typical equipment used
Subgrade Preparation

- Types of subgrade preparation
- Typical equipment used
- Purpose of equipment
Subgrade Preparation

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- Typical equipment used
- Purpose of equipment
- Grading
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- Soils
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- Compaction
- Soils
- Testing
Importance of Quality Subgrade
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- Provide good support for placement and compaction of pavement
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- Limit pavement deflections to acceptable limits
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- Minimize differential movement due to frost and Shrinking/swelling soils
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- Limit pavement deflections to acceptable limits
- Minimize differential movement due to frost and Shrinking/swelling soils
- Promote uniformity of support (Key element for good long term pavement performance)
Types of subgrade preparation
Types of subgrade preparation

- Modification and Stabilization
Types of subgrade preparation

- Modification and Stabilization
- Removal and Replace
Modification and Stabilization

- Subgrade treatment that is intended to provide a stable working platform during construction.
  - Adding chemicals like fly ash or cement
  - Replacing existing soils with aggregates
  - Geosynthetic reinforcement with aggregates
  - Moisture conditioning
Adding chemicals like fly ash or cement
Chemical Stabilization

- This work consists of treating the subgrade by combining chemicals such as fly ash, lime, or cement and water with the pulverized soil material to the specified depth and compaction requirements
Soil Stabilization Benefits
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- Lower material costs – reduces base and pavement thickness
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- Lower construction costs – eliminates cost of material removal and replacement. 30% - 50% savings
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- Increased Strength – a dramatic increase in the CBR can be achieved
Soil Stabilization Benefits
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- Longer durability – stabilized soil is highly resistant to water and frost, which increases the lifespan of the subgrade
Soil Stabilization Benefits

- Longer durability – stabilized soil is highly resistant to water and frost, which increases the lifespan of the subgrade
- Increased environmental responsibility – stabilizing the existing soil eliminates the need to export the poor undesirable soil and import new fill
Remove and Replace

- Simple Procedure that does not require specialized equipment
Removal and Replace
Removal and Replace

- This process will consist of removing the unsuitable soil and replacing it with aggregates such as base or sand.
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- Geosynthetics are often placed on the surface of the excavated subgrade prior to placement of aggregates.
Geosynthetic reinforcement with aggregates
Geosynthetics

- Products such as fabric grids, composites or membranes
Geosynthetics

- Placed in pavement bases to preform following function
  - Reinforcement
  - Separation
  - Filtration
Geosynthetics

- The primary purpose of using geosynthetics in the pavement design is to reduce reflective cracking in the asphalt and resist moisture intrusion into the underlying pavement structure.
Geosynthetic Benefits
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- Improves structural capability of soil
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- Allows the use of poorer quality of soils to be used in construction
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- Allows the use of poorer quality of soils to be used in construction
- Construction time can be reduced
- Drastically increases the durability of subgrade
Moisture Conditioning
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- Moisture Conditioning reduces or increases the soil moisture content to be compacted to the required density.
- Controls shrinking and swelling of soils.
Moisture Conditioning Benefits
Moisture Conditioning
Benefits

- Allows contractors to expedite work
Moisture Conditioning

Benefits

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- Reduction of construction costs
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- Improved utilization of existing materials
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- Improved utilization of existing materials
- Greater environmental protection
Moisture Conditioning
Benefits

- Allows contractors to expedite work
- Reduction of construction costs
- Improved utilization of existing materials
- Greater environmental protection
- Increased short-term and long-term savings
Full Depth Reclamation
Full Depth Reclamation Process
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- The total asphalt surface is pulverized plus a predetermined portion of the base
Full Depth Reclamation Process

- The total asphalt surface is pulverized plus a predetermined portion of the base
- The pulverized base is compacted and graded
Full Depth Reclamation Process

- The total asphalt surface is pulverized plus a predetermined portion of the base.
- The pulverized base is compacted and graded.
- The new stabilized base is now ready for paving.
FDR Benefits
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- Cheaper – At least 50% less expensive than traditional road repair methods
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- Faster – Get 2-3 times more repairs done in the same time period
FDR Benefits

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- **Faster** – Get 2-3 times more repairs done in the same time period
- **Easier** – No excavating, no loading, no hauling off and dumping old asphalt
FDR Benefits
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- Base is stabilized with pulverized road surface
FDR Benefits

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- No reflective cracking!
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- Permanent repair, not a temporary fix
FDR Benefits

- Base is stabilized with pulverized road surface
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- Environmentally friendly
Types of Equipment Needed
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- Reclaiming machine
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- Reclaiming machine
- Compactors
Types of Equipment Needed

- Reclaiming machine
- Compactors
- Motor Graders
Types of Equipment Needed

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- Tanker Trucks (Water and Emulsion)
Types of Equipment Needed

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Types of Equipment Needed

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- Loaders and Excavators
Reclaiming Machine
Reclaiming Machine

- Pulverization of existing materials
  - Asphalt
  - Dirt
  - Asphalt with base
Sizing Material

- Controlled by the operator who controls the speed and rear door opening
Mixing Additives

- Reactive – Lime
- Self cementing – Portland cement and fly ash
- Water
Compactors
Compactors

- Compact material to desired density
- Typical compaction sequence
  - Initial or breakdown – pad foot rollers
  - Intermediate – rubber tire rollers and vibratory rollers
  - Finish – smooth drum and rubber tire rollers
Motor Graders

- Placing material at desired grade
- Scarify material
- Process material
Tanker Trucks

- Deliver water
- Deliver emulsion materials to reclaimer
Water Trucks

- Apply water to subgrade surface directly
- Proof rolls
Loaders and Excavators

- Removing existing pavement
- Excavating excess or unsuitable soils
- Loading trucks
Grading
Fine Grading

- Fine grade is required for the final trimming and checking of the cross section.
Establishing Grade
Grade stakes
Grade stakes

- What do they tell us?
  - Offset
  - Cut or fill at ditch
  - Cut or fill at edge of road
  - Cut or fill at centerline
  - Stationing
Setting grade

- Stakes are usually set at variable intervals near each edge of the subgrade and the centerline.
- When the distance is too far apart from stake to stake, intermediate stakes may be required.
How to establish cross slope
How to establish cross slope

- Measure distance from edge of road to centerline
How to establish cross slope

- Measure distance from edge of road to centerline
- Multiply the distance to the desired cross slope
  - For example: 25’ * 2% (.02) = .5 or 6’’
How to establish cross slope

- Measure distance from edge of road to centerline
- Multiply the distance to the desired cross slope
  - For example: 25’ * 2% (.02) = .5 or 6”
- That is the elevation difference from the edge of the road to centerline
Checking grade
Checking grade

- A string line can be stretched across adjoining grade stakes
Checking grade

- A string line can be stretched across adjoining grade stakes
- The subgrade is checked by measuring down to the known offset distance from the string line to the dirt
Checking grade

- A string line can be stretched across adjoining grade stakes
- The subgrade is checked by measuring down to the known offset distance from the string line to the dirt
- Straight edge – easiest way to check uniformity of subgrade
Importance of uniform subgrade
Importance of uniform subgrade

- Strength
  - Make sure you have full pavement section.
Importance of uniform subgrade

- **Strength**
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- **Yield**
  - Uniform subgrade will optimize yield.
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  - Asphalt is for more expensive than base.
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- **Smoothness**
  - HMA compacts differentially, thicker areas compact more than thinner areas which will affect pavement smoothness

Monday, February 3, 14
Compaction
Compaction
Compaction
Compaction occurs when a force compresses the soil and pushes air and water out of it so that it becomes more dense. Compaction is achieved easier when the soil is wet and less able to withstand compression.
Why Compact?
Why Compact?

- 5 reasons to compact
Why Compact?

- 5 reasons to compact
- Increases load-bearing capacity
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- 5 reasons to compact
  - Increases load-bearing capacity
  - Prevents soil settlement and frost damage
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  - Prevents soil settlement and frost damage
  - Provides stability
  - Reduces water seepage, swelling and contraction
  - Reduces settling of soil
Types of compaction
Types of compaction

• There are four types of compaction effort on soil or asphalt:
Types of compaction

- There are four types of compaction effort on soil or asphalt:
  - Vibration
Types of compaction

- There are four types of compaction effort on soil or asphalt:
  - Vibration
  - Impact
Types of compaction

- There are four types of compaction effort on soil or asphalt:
  - Vibration
  - Impact
  - Kneading
Types of compaction

- There are four types of compaction effort on soil or asphalt:
  - Vibration
  - Impact
  - Kneading
  - Pressure
Two types of compaction force
Two types of compaction force

- Static force
Two types of compaction force

- Static force
- Vibratory force
Static Force

- Static force is the deadweight of the machine, applying downward force on the soil surface, compressing the soil.
Static Force

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- Static compaction is confined to upper soil layers.
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- Static compaction is confined to upper soil layers.
- Kneading and pressure are two examples of static compaction.
Vibratory Force
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- Vibratory force uses a mechanism, usually engine-driven, to create a downward force.
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- The compactors deliver a rapid sequence of blows (impacts) to the surface, affecting the top layers as well as deeper layers. Vibration moves through the material, setting particles in motion and moving them closer together for the highest density possible.
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- The compactors deliver a rapid sequence of blows (impacts) to the surface, affecting the top layers as well as deeper layers. Vibration moves through the material, setting particles in motion and moving them closer together for the highest density possible.
- Based on the materials being compacted, a certain amount of force must be used to overcome the cohesive nature of the soil.
Compaction Equipment

- Choosing the right equipment for the job is vital to achieving proper compaction.
Deciding Factors
Deciding Factors

- Soil type
  - Cohesive
  - Granular
Deciding Factors

- Soil type
  - Cohesive
  - Granular

- Thickness of Lift and Machine Performance
Deciding Factors

- Soil type
  - Cohesive
  - Granular
- Thickness of Lift and Machine Performance
- Compaction Specifications
Cohesive soils
Cohesive soils

- A machine with a high impact force is required to ram the soil and force the air out to achieve compaction.
Cohesive soils

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- Pad Foot or Sheep Foot Roller
Cohesive soils

- A machine with a high impact force is required to ram the soil and force the air out to achieve compaction.
- Pad Foot or Sheep Foot Roller
- Jumping Jack
Granular soils
Granular soils

- Require a shaking or vibratory action to move them
Granular soils

- Require a shaking or vibratory action to move them
- Smooth Drum Roller
Granular soils

- Require a shaking or vibratory action to move them
- Smooth Drum Roller
- Plate Compacter
Granular soils

- Require a shaking or vibratory action to move them
- Smooth Drum Roller
- Plate Compacter
- Wheel Rolling
The thicker the lift the heavier piece of equipment needs to be.

<table>
<thead>
<tr>
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<th>Pressure (with kneading)</th>
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Compaction Specifications
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- Method Specification
  - Detailed instructions specify machine type, lift thickness, number of passes, machine speed and moisture content.
Compaction Specifications

- **Method Specification**
  - Detailed instructions specify machine type, lift thickness, number of passes, machine speed and moisture content.

- **End-result Specification**
  - Engineers indicate final compaction requirements, allowing the contractor to choose what is the best method to achieve compaction.
Types of Equipment
Rollers
Rollers

- Smooth drum
Rollers

- Smooth drum
- Padded drum Sheep Foot
Rollers

- Smooth drum
- Padded drum Sheep Foot
- Rubber-tired
Rollers

- Smooth drum
- Padded drum Sheep Foot
- Rubber-tired
- Static and vibratory sub-categories
Rollers

- Smooth drum
- Padded drum Sheep Foot
- Rubber-tired
- Static and vibratory sub-categories
- Walk-behind and ride-on
Smooth Drum Roller
Smooth Drum Roller
Smooth Drum

- Smooth-drum machines are ideal for both soil and asphalt
Sheep Foot Roller
Sheep Foot Roller
Padded Drum / Sheep Foot

- Appropriate for cohesive soils.
- The drum pads provide a kneading action on soil.
Rubber Tire Roller

- 7 to 11 tires that have an overlapping pattern
- Typically a static roller
- Compaction effort is pressure and kneading
Wheel Rolling
Jumping Jack
Jumping Jack
Rammers / Jumping Jack
Rammers / Jumping Jack

- Deliver a high impact force (high amplitude) making them an excellent choice for cohesive and semi-cohesive soils
Rammers / Jumping Jack

- Deliver a high impact force (high amplitude) making them an excellent choice for cohesive and semi-cohesive soils

- Three types of compaction: impact, vibration and kneading.
Plate Compacter
Vibratory Plates

- Low amplitude and high frequency, designed to compact granular soils and asphalt.
- Type of compaction: vibration
Walk Behind

- Appropriate for cohesive soils
- Ideal for small areas

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Soil types
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- Soil types are classified by grain size, determined by passing the soil through sieves to screen or separate the different grain sizes.
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• A well-graded soil consists of a wide range of particle sizes with the smaller particles filling voids between larger particles.
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• A well-graded soil consists of a wide range of particle sizes with the smaller particles filling voids between larger particles.

• The are three basic soil groups:
Three Soil Groups

- Cohesive
- Granular
- Organic (this soil is not suitable for compaction)
Cohesive

- Cohesive soils have the smallest particles. Clays range from 0.00004" to 0.002".
- Cohesive soils are dense and tightly bound together. They are plastic when wet and can be molded, but become very hard when dry.
- Proper water is essential for proper compaction.
- Cohesive soils usually require a force such as impact or pressure.
- Silt has a noticeably lower cohesion than clay. However, silt is still heavily reliant on water content.
Granular

• Granular soils range from .003" to .08" (sand) and .08" to 1.0" (fine to medium gravel).
• Granular soils are known for their water-draining properties.
• Sand and gravel obtain maximum density in either a fully dry or saturated state.
• Testing curves are relatively flat so density can be obtained regardless of water content.
# Guide to Soil Types

<table>
<thead>
<tr>
<th>What to look for</th>
<th>Appearance/Feel</th>
<th>Water Movement</th>
<th>When Moist</th>
<th>When Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Granular soils</strong>, fine sands and silts</td>
<td>Coarse grains can be seen. Feels gritty when rubbed between fingers</td>
<td>When water and soil are shaken in palm of hand, they mix. When shaking is stopped they separate</td>
<td>Very little or no plasticity</td>
<td>Little or no cohesive strength when dry. Soil sample will crumble easily.</td>
</tr>
<tr>
<td><strong>Cohesive soils</strong>, mixes and clays</td>
<td>Grains cannot be seen by naked eye. Feels smooth and greasy when rubbed between fingers</td>
<td>When water and soil are shaken in palm of hand, they will not mix</td>
<td>Plastic and sticky. Can be rolled</td>
<td>Has high strength when dry. Crumbles with difficulty. Slow saturation in water.</td>
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</table>
# Materials

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<tr>
<td><strong>Silt</strong></td>
<td>6+/−</td>
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**Notes:**

- Sand: 10+/−
- Silt: 6+/−
- Clay: 6+/−
<table>
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<tr>
<th>Material</th>
<th>Permeability</th>
<th>Foundation Support</th>
<th>Pavement Sub grade</th>
<th>Expansive</th>
<th>Compaction Difficulty</th>
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<tbody>
<tr>
<td>Gravel</td>
<td>Very High</td>
<td>Excellent</td>
<td>Excellent</td>
<td>No</td>
<td>Very Easy</td>
</tr>
<tr>
<td>Sand</td>
<td>Medium</td>
<td>Good</td>
<td>Good</td>
<td>No</td>
<td>Easy</td>
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<tr>
<td>Silt</td>
<td>Medium Low</td>
<td>Poor</td>
<td>Poor</td>
<td>Some</td>
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<tr>
<td>Clay</td>
<td>None+</td>
<td>Moderate</td>
<td>Poor</td>
<td>Difficult</td>
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<tr>
<td>Organic</td>
<td>Low</td>
<td>Very Poor</td>
<td>Not Acceptable</td>
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Moisture vs. Soil Density
Moisture vs. Soil Density

- Moisture or water content is key to achieving density in compaction. Water allows the particles of material to move together and decrees voids.
Moisture vs. Soil Density

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- Not enough water particles can not slide past each other.
Moisture vs. Soil Density

- Moisture or water content is key to achieving density in compaction. Water allows the particles of material to move together and decrees voids.
- Not enough water particles can not slide past each other.
- Too much water and water voids are created.
Density Curve

Maximum Density 121 lbs per cubic foot
2098 kg/m³

Optimum moisture 11%

Dry Density - lbs per cubic foot
120
115
110
105

Moisture - percent of Dry Weight
0 5 10 15 20

Optimum Moisture 11%

2002
1922
1842
Testing
Why Should We Test?
Why Should We Test?

- Measures density of soil for comparing the degree of compaction vs. specs
Why Should We Test?

- Measures density of soil for comparing the degree of compaction vs. specs
- Measures the effect of moisture on soil density vs. specs
Why Should We Test?

- Measures density of soil for comparing the degree of compaction vs. specs
- Measures the effect of moisture on soil density vs. specs
- Provides a moisture density curve identifying optimum moisture
Why Should We Test?

- Measures density of soil for comparing the degree of compaction vs. specs
- Measures the effect of moisture on soil density vs. specs
- Provides a moisture density curve identifying optimum moisture
- Save Money
Types of Tests
Types of Tests

- Proctor Test
Types of Tests

- Proctor Test
- Modified Proctor Test
Types of Tests

- Proctor Test
- Modified Proctor Test
- Hand Test
Types of Tests

- Proctor Test
- Modified Proctor Test
- Hand Test
- Sand Cone
Types of Tests

- Proctor Test
- Modified Proctor Test
- Hand Test
- Sand Cone
- Nuclear Density
Proctor Test
Proctor Test

- Determines the maximum density of a specific soil.
Proctor Test

- Determines the maximum density of a specific soil.
- Tests the effects of moisture on soil density
Proctor Test

- Determines the maximum density of a specific soil.
- Tests the effects of moisture on soil density
- Standard Proctor
Proctor Test

- Determines the maximum density of a specific soil.
- Tests the effects of moisture on soil density
- Standard Proctor
- Modified Proctor
Standard Proctor

- A small soil sample is taken from the jobsite. A standard weight is dropped several times on the soil. The material weighed and then oven dried for 12 hours in order to evaluate water content.
Modified Proctor

- This is similar to the Proctor Test except a hammer is used to compact material for greater impact. The test is normally preferred in testing materials for higher shearing strength.
Field Testing
Hand Test
Hand Test
Hand Test

- Pick up a handful of soil.
Hand Test

- Pick up a handful of soil.
- Squeeze it in your hand.
Hand Test

- Pick up a handful of soil.
- Squeeze it in your hand.
- If the soil is powdery and will not retain the shape made by your hand, it is too dry.
Hand Test

- Pick up a handful of soil.
- Squeeze it in your hand.
- If the soil is powdery and will not retain the shape made by your hand, it is too dry.
- If it shatters when dropped, it is too dry.
Hand Test

- Pick up a handful of soil.
- Squeeze it in your hand.
- If the soil is powdery and will not retain the shape made by your hand, it is too dry.
- If it shatters when dropped, it is too dry.
- If the soil is moldable and breaks into only a couple of pieces when dropped, it has the right amount of moisture for proper compaction.
Hand Test

- Pick up a handful of soil.
- Squeeze it in your hand.
- If the soil is powdery and will not retain the shape made by your hand, it is too dry.
- If it shatters when dropped, it is too dry.
- If the soil is moldable and breaks into only a couple of pieces when dropped, it has the right amount of moisture for proper compaction.
- If the soil is plastic in your hand, leaves traces of moisture on your fingers and stays in one piece when dropped, it has too much moisture for compaction.
Sand Cone Test
(ASTM D1556-90)

- A small hole (6" x 6" deep) is dug in the compacted material to be tested. The soil is removed and weighed, then dried and weighed again to determine its moisture content. A soil's moisture is figured as a percentage. The specific volume of the hole is determined by filling it with calibrated dry sand from a jar and cone device. The dry weight of the soil removed is divided by the volume of sand needed to fill the hole. This gives us the density of the compacted soil in lbs per cubic foot. This density is compared to the maximum Proctor density obtained earlier, which gives us the relative density of the soil that was just compacted.
Weigh with sand before

Weigh with sand after

SAND MUST BE DRY

Difference = weight to fill cone plus hole

Subtract sand to fill cone and plate

Weight of sand to fill hole
Nuclear Density
(ASTM D2292-91)

- Nuclear Density meters are a quick and fairly accurate way of determining density and moisture content. The meter uses a radioactive isotope source (Cesium 137) at the soil surface (backscatter) or from a probe placed into the soil (direct transmission). The isotope source gives off photons (usually Gamma rays) which radiate back to the meter's detectors on the bottom of the unit. Dense soil absorbs more radiation than loose soil and the readings reflect overall density. Water content (ASTM D3017) can also be read, all within a few minutes. A relative Proctor density with the compaction results from the test.
Questions?