Subgrade Preparation

Tim Crosby: Grading Superintendent
Chris DeJulio: Project Engineer
Subgrade Preparation
Subgrade Preparation

- Typical equipment used
Subgrade Preparation

- Typical equipment used
- Purpose of equipment
Subgrade Preparation

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

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

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

- Typical equipment used
- Purpose of equipment
- Types of subgrade preparation
- Grading
- Compaction
- Soil Classification
What is Subgrade?
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- Subgrade is the foundation for a roadway, on which the subbase is laid.
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- Subgrade can consist of different materials so long as they meet engineer’s requirements.
What is Subgrade?

- Subgrade is the foundation for a roadway, on which the subbase is laid.
- Subgrade can consist of different materials so long as they meet engineer’s requirements.
- Subgrade should be constructed to meet elevations and cross sections indicated in the plans.
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

- 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
  - Moisture conditioning
Moisture Conditioning
Mixing Additives

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

- Simple Procedure that does not require specialized equipment
- Expensive !!!
Replacing existing soils with aggregates
Geosynthetic reinforcement with aggregates
Choosing the right equipment
Typical Equipment Used

- Reclaimers
- Front End Loaders and Excavators
Typical Equipment Used

- Motor Graders
- Compactors
Typical Equipment Used

- Water Trucks and Tankers
- End and Belly Dump Trucks
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
Adding chemicals like fly ash or cement
Loaders and Excavators

- Removing existing pavement
- Excavating excess or unsuitable soils
- Loading trucks
Motor Graders

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

- Apply water to subgrade surface directly
- Proof rolls
Tanker Trucks

- Deliver water
- Deliver emulsion materials to reclaimer
Grading
Fine Grading

- Fine grade is required for the final trimming and checking of the cross section.
Uniform Subgrade
Importance of uniform subgrade
Importance of uniform subgrade

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

- **Strength**
  - Make sure you have full pavement section.

- **Yield**
  - Uniform subgrade will optimize yield.
Importance of uniform subgrade

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- **Cost**
  - Asphalt is for more expensive than base.
Importance of uniform subgrade

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- **Yield**
  - Uniform subgrade will optimize yield.

- **Cost**
  - Asphalt is for more expensive than base

- **Smoothness**
  - HMA compacts differentially, thicker areas compact more than thinner areas which will affect pavement smoothness
Establishing Grade
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

- 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
Tools needed for setting grade
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
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 more severe 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
Why Compact?

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- Increases load-bearing capacity
- Prevents soil settlement and frost damage
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  - Reduces water seepage, swelling and contraction
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  - Increases load-bearing capacity
  - 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

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

- Static force is the deadweight of the machine, applying downward force on the soil surface, compressing the soil.
- Static compaction is confined to upper soil layers.
Static Force

- Static force is the deadweight of the machine, applying downward force on the soil surface, compressing the soil.
- Static compaction is confined to upper soil layers.
- Kneading and pressure are two examples of static compaction.
Vibratory Force
Vibratory Force

- Vibratory force uses a mechanism, usually engine-driven, to create a downward force.
Vibratory 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.
Vibratory 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.
- Based on the materials being compacted, a certain amount of force must be used to overcome the cohesive nature of particular particles.
Soil types
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.
Soil types

• Soil types are classified by grain size, determined by passing the soil through sieves to screen or separate the different grain sizes.
• 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
Three Soil Groups

- Cohesive
Three Soil Groups

- Cohesive
- Granular
Three Soil Groups

- Cohesive
- Granular
- Organic (this soil is not suitable for compaction)
Cohesive
Cohesive soils have the smallest particles. Clays range from .00004" to .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

- 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>
</tr>
</tbody>
</table>
## Materials

<table>
<thead>
<tr>
<th>Gravel</th>
<th>Lift Thickness</th>
<th>Impact</th>
<th>Pressure (with kneading)</th>
<th>Vibration</th>
<th>Kneading (with pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12+</td>
<td>Poor</td>
<td>No</td>
<td>Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>Sand</td>
<td>10+/−</td>
<td>Poor</td>
<td>No</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Silt</td>
<td>6+/−</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Excellent</td>
</tr>
<tr>
<td>Clay</td>
<td>6+/−</td>
<td>Excellent</td>
<td>Very Good</td>
<td>No</td>
<td>Good</td>
</tr>
</tbody>
</table>

**Notes:**
- Vibrating Sheepfoot Rammer
- Static Sheepfoot Grid Roller Scraper
- Vibrating Plate Compactor Vibrating Roller Vibrating Sheepfoot Scraper Rubber-tired Roller Loader Grid Roller

**Dates:**
- Thursday, April 19, 2012
<table>
<thead>
<tr>
<th>Fill Materials</th>
<th>Permeability</th>
<th>Foundation Support</th>
<th>Pavement Sub grade</th>
<th>Expansive</th>
<th>Compaction Difficulty</th>
</tr>
</thead>
<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>
</tr>
<tr>
<td>Silt</td>
<td>Medium Low</td>
<td>Poor</td>
<td>Poor</td>
<td>Some</td>
<td>Some</td>
</tr>
<tr>
<td>Clay</td>
<td>None+</td>
<td>Moderate</td>
<td>Poor</td>
<td>Difficult</td>
<td>Very Difficult</td>
</tr>
<tr>
<td>Organic</td>
<td>Low</td>
<td>Very Poor</td>
<td>Not Acceptable</td>
<td>Some</td>
<td>Very Difficult</td>
</tr>
</tbody>
</table>
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

- 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.
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 decreases voids.
- Not enough water particles cannot slide past each other.
- Too much water and water voids are created.
Density Curve

Maximum Density 121 lbs per cubic foot

Optimum moisture 11%

Dry Density - lbs per cubic foot

0 5 10 15 20

Moisture - percent of Dry Weight

2098 kg/m³

Optimum Moisture 11%

120

115

110

105

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
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

- 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.
Hand Test
## Field Density Testing Method

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Sand Cone</th>
<th>Balloon Densimeter</th>
<th>Shelby Tube</th>
<th>Nuclear Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Large sample</td>
<td>* Large sample</td>
<td>* Fast</td>
<td>* Fast</td>
<td></td>
</tr>
<tr>
<td>* Accurate</td>
<td>* Direct reading</td>
<td>* Deep sample</td>
<td></td>
<td>* Easy to redo</td>
</tr>
<tr>
<td></td>
<td>* Open graded</td>
<td>* Under pipe haunches</td>
<td></td>
<td>* More tests (statistical reliability)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Sand Cone</th>
<th>Balloon Densimeter</th>
<th>Shelby Tube</th>
<th>Nuclear Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Many steps</td>
<td>* Slow</td>
<td>* Small Sample</td>
<td>* No sample</td>
<td></td>
</tr>
<tr>
<td>* Large area required</td>
<td>* Balloon breakage</td>
<td>* No gravel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Slow</td>
<td>* Awkward</td>
<td>* Sample not always retained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Halt Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Tempting to accept flukes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Errors</th>
<th>Sand Cone</th>
<th>Balloon Densimeter</th>
<th>Shelby Tube</th>
<th>Nuclear Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Void under plate</td>
<td>* Surface not level</td>
<td>* Overdrive</td>
<td>* Miscalibrated</td>
<td></td>
</tr>
<tr>
<td>* Sand bulking</td>
<td>* Soil pumping</td>
<td>* Rocks in path</td>
<td>* Rocks in path</td>
<td></td>
</tr>
<tr>
<td>* Sand compacted</td>
<td>* Void under plate</td>
<td>* Plastic soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Soil pumping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost</th>
<th>Sand Cone</th>
<th>Balloon Densimeter</th>
<th>Shelby Tube</th>
<th>Nuclear Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Low</td>
<td>* Moderate</td>
<td>* Low</td>
<td></td>
<td>* High</td>
</tr>
</tbody>
</table>
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.
Compaction Equipment
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

- 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
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
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 Compactor
- Wheel Rolling
Smooth Drum Roller
Plate Compactor
Wheel Rolling
Thickness of Lift and Machine Performance

- The thicker the lift the heavier piece of equipment needs to be.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Vibrating Sheepfoot Rammer</th>
<th>Static Sheepfoot Grid Roller Scraper</th>
<th>Vibrating Plate Compactor Vibrating Roller Vibrating Sheepfoot Scraper Rubber-tired Roller Loader Grid Roller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>Lift Thickness: 12+</td>
<td>Impact: Poor</td>
<td>Pressure (with kneading): No</td>
</tr>
<tr>
<td>Sand</td>
<td>Lift Thickness: 10+-</td>
<td>Impact: Poor</td>
<td>Pressure (with kneading): No</td>
</tr>
<tr>
<td>Silt</td>
<td>Lift Thickness: 6+-</td>
<td>Impact: Good</td>
<td>Pressure (with kneading): Good</td>
</tr>
<tr>
<td>Clay</td>
<td>Lift Thickness: 6+-</td>
<td>Impact: Excellent</td>
<td>Pressure (with kneading): Very Good</td>
</tr>
</tbody>
</table>
Compaction Specifications

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

- **Method Specification**
  - Detailed instructions specify machine type, lift depths, 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 Compactors
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.
Vibratory Plates
Vibratory Plates

- Low amplitude and high frequency, designed to compact granular soils and asphalt.
Vibratory Plates

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

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

- Appropriate for cohesive soils.
Padded Drum / Sheep Foot

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

- 7 to 11 tires that have an overlapping pattern
Rubber Tire Roller

- 7 to 11 tires that have an overlapping pattern
- Typically a static roller
Rubber Tire Roller

- 7 to 11 tires that have an overlapping pattern
- Typically a static roller
- Compaction effort is pressure and kneading
Walk Behind
Questions ?