Outline

- Compaction Basics
  - What is compaction?
  - Why do we compact?

- 4 Elements of compaction

- Roller Train
  - Varies with specifications and location

- Roller types

- Roller design specs affecting compaction

- External factors affecting compaction

- What affects roller patterns

- Summary
Basics of compaction
Why do we need compaction?
Why Compaction?

To build support foundations

- Hydro power dams
- Building pads
- Airport runways
- Roads & streets
Soil Material

The most important Characteristics of soil are:

- High load-bearing capacity
- Good stability
- Low water permeability
- Extremely level
- Grading curve
- Layer thickness
Most important parameters are:

- Mix type
- Particle size distribution curve
- Binder type and proportion
- Environmental conditions when paving
  - Temp, wind, overcast or sunny
- Course thickness
Basics of Compaction

Compaction system

- Static
- Vibration
- Oscillation
Why Compaction?
Why Compaction?

To build and rehabilitate roads

- Surface course
- Binder course
- Second base course
- First base course
- Subbases
- Embankment
- Substrate
- Roadbed (Embarkment and subbases)
- Paving
Why Compaction?

- Improve material stability
- Minimize permanent deformation / rutting
- Improve fatigue resistance / cracking
- Reduce moisture penetration & breakouts
Pavement Distresses

Typical damage patterns and their sources of error
Pavement Distresses

**Ruts are caused by:**

- **Over-compaction** - due to insufficient voids in the compacted asphalt body, the mix cannot "contract" or "relax" due to the traffic load. This results in plastic deformation and no visco-elastic deformation.

- **Under-compaction** - there is an insufficiently interlocked grain structure! This is compressed by traffic over time.

- **Defective mix**
Settlements are caused by:

- Insufficiently load-bearing soil that is compacted locally under the traffic load (weak point in the subsoil)

- Penetrating water (e.g. burst pipe) that penetrates into the road body and flushes out the subgrade
Binder enrichment (bleeding) results from:

- Too high binder content in asphalt mix
- Too much bitumen emulsion (tack)
- Incorrect use of the dynamic compaction binder is pulled to the surface by vibration compaction
- Too Intensive use of pneumatic tire rollers
- Over-compaction - bitumen is drawn to the surface by "ironing"
- Mix that is too hot
Outbreaks are caused by:

- **Faulty mix formulation** - adhesive effect between the grain structure is not sufficient
- **Frost damage** - through penetrating water
- **Dynamic compaction on cold asphalt**
- **Insufficient bond between layers**
Pavement Distresses

Longitudinal and transverse cracks are caused by:

- **Deformation** – settlements
- **Frost damage** - In dew periods, heavy vehicles can destroy the road surface by destroying frostbite
- **Incorrectly made seams**
- **Fatigue**
- **Low-temperature behaviour of the asphalt**
- **Error during paving:**
  - Too much dynamic compaction
  - Roller too heavy
  - Rolling start too early
  - Pan formation
Pavement Distresses

**Wave formation by the paver**
- Wrong screed setting
- Mix (temperature, material flow, ratio grain size / paving thickness)
- Uneven substructure
- Wrong sensors on the paver
- Insufficient pre-compaction of the screed
- No constant speed

**Wave formation through the roller**
- Rolling over the bow wave (speed)
- No steering in front of the paver
- Strong steering movements on hot mix
- Wrong frequency / amplitude / speed of the roller
Who’s Job is Compaction?

Everyone’s

Winner of the “Not My Job” Award - ADOT
Litchfield Park, AZ 85
What is Compaction?

Compaction is a sequence of STEPS in order to MANIPULATE aggregates & REDUCE the voids between them.

STEP #1
86% density

STEP #2
91% density

STEP #3
95% density

“Voids reduction”
What is Compaction?

Reduces voids
Increases friction
What is Compaction?

**Proctor Test**
*(Modified or Standard)*

What is Compaction?
What is Compaction?

Asphalt is a FLEXIBLE product. Too much rigidity would not be desirable.

95% DENSITY means that we still have 5% AIR VOIDS left in the compacted layer.
What is Compaction?

**How is compaction measured?**

*In the laboratory*
Producing test samples of the designed mix (Gyratory or Marshall)
Measuring the forces to break the test samples in a press

Provides the maximum theoretical density level attainable of the material (100% density)
What is Compaction?

How is compaction measured?

**On Site**
*Portable units measure the density*

These units give a good indication of density and assist the QC in establishing a rolling pattern.
What is Compaction?

How is compaction measured?

In the laboratory using core samples to analyze its quality

Provides the EXACT density level of the compacted core sample
What Are The Four Elements to Achieve Compaction?
The Four Elements can be Summarized as ...

- Static Weight
- Impacts
- Dynamics (Vibration) (Oscillation)
- Kneading (Oscillation)
Four Elements?

Static Weight

Applies a static pressure from **TOP** to **BOTTOM**
(Surface compaction)
Four Elements?

Overlapping imprints ensure uniform compaction.
Size of tamper and the height of drop determine the depth of treatment.

Hardcore Platform
Weak Soil or Fill
Compacted Ground
Firm Strata
Kneading effect
Matches contours of an uneven surface
Minimizes bridging and helps to identify soft spots
Applies a static pressure from TOP to BOTTOM (DEEPER surface compaction than a static drum)
Seals the mat by bringing fines to the surface.
Ideal tire pressure is dependent upon ballasted weight of the machine.

Optimum air pressure:
The complete width of the rubber wheels comes in contact with the asphalt and weight: power can be transferred to the soil over the entire cross section.

Kneading
Four Elements?

Air pressure too high: The rubber wheels are deflected outwards. This causes the contact area of the rubber wheels to the asphalt to be very small. Force is not applied over the entire width of the wheel.

Tire pressure too high

Kneading
Four Elements?

Tire pressure too low

Kneading
PTR’s provide a very effective form of compaction within a tender-zone on Superpave mixes.
## Tire Pressure Chart

### CA and GCP for Dunlop Tires

#### Dunlop Tires 11.00 R 20

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<td>CA: 146 GCP: 45</td>
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<tr>
<td>7700</td>
<td>CA: 162 GCP: 48</td>
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</table>

CA = Ground Contact Area [in²]
GCP = Ground Contact Pressure [lbs/in²]

* Values are subject to change, 18.12.2016
Dynamic energy puts aggregates in motion and compacts from the **BOTTOM - UP**
Four Elements?

- Oscillation (Drum has 100% ground contact) "Non-Aggressive compaction"
- Vibration (Drum is 50% in the air) "Aggressive compaction"

Dynamics
(Vibration)
(Oscillation)
Compaction system

- Static
- Vibration
- Oscillation
- Directed vibrator
Four Elements?

Dynamics
(Vibration)
(Oscillation)

Vibration
Vertical aggregate positioning

Oscillation
Horizontal aggregate positioning
The Roller Train
Roller Train?

A “roller train” can be summarized as...

A sequence of rollers following the asphalt paver
Each working the mat at a fixed distance range from the paver
The objective is to achieve required density & provide a quality mat finish

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<th>Intermediate</th>
<th>Finish</th>
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<td>Approx. 90-91%</td>
<td>Approx. 93-94%</td>
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<tr>
<td>Distance</td>
<td>Up to 200 ft</td>
<td>Up to 200 ft</td>
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</table>
**Roller trains are flexible...**

The “roller train” can be a mix of any compactor types & sizes
The main goal is to adapt to the asphalt mix design, jobsite conditions using equipment available in order to achieve required density & mat finish requirements in the least number of passes

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<td>Approx. 90-91%</td>
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<td>Distance</td>
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<tr>
<td>Up to 200 ft</td>
<td>Up to 200 ft</td>
<td>150 ft &amp; more</td>
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Summary Of Roller Types
Roller Types?

**Static steel wheel**

Element(s) involved: Static weight

Application(s): Mat smoothness (mainly finish rolling)  
Pinching a joint
**Pneumatic (rubber tires)**

Element(s) involved: Static weight, kneading, proof rolling

Application(s): Seal mat surface (All)
Track overlapping

Front and rear axle offset
Track overlapping

The track overlap is also guaranteed when cornering
When diesel is used as a separating compound, the rubber becomes soft. This forces the rock into the tyre material. Therefore only use the correct separating compound!
Roller Types?

Combination (steel drum & rubber tires)

Element(s) involved: Weight, kneading, dynamics
Application(s): Municipal jobs, steep grades, etc...
(Versatile unit for smaller jobs)
Roller Types?

**Tandem steel drums (vibration)**

Element(s) involved: **Weight, dynamics (vibration F & R)**

Application(s): **Breakdown and Intermediate, finish in static mode**
Roller Types?

**Tandem steel drums (OZZY)**

- Element(s) involved: Weight, dynamics (vibration F & oscillation R)
- Application(s): All roller train positions (Extended rolling time, no crushing, smoothness, joints)
Tandem rollers

(pivot-steered)  (articulated)
Steering types

Pivot-steered drums allow both drums to be steered separately from each other.

Articulated rollers have a pivot in the middle of the frame. This allows the frame to "buckle".

=steering point
=rolling direction
Split roller drum

Splitting the drum can reduce the lateral sliding by half

- Same size drum halves with one drive motor each
- ASC reduces the speed of the inner drum when cornering
- Less material displacement and cracks
Key Roller Design Specifications Affecting Compaction
Key roller design specifications affecting compaction

- Amplitude
- Frequency
- Static weight
- Centrifugal force
- Rolling speed
- Drum diameter
- Drum activation controls
- Drum water & scrapers
Amplitude

Low

High

Unfixed Imbalanced Weight
Fixed Imbalanced Weight

Resulting Direction

Effective direction of fixed imbalance weight

Effective direction of unfixed fixed imbalance weight
Vibration - different amplitudes

Operating direction - unbalance loose
Operating direction - unbalance fixed
Resulting operating direction
Comparison of amplitudes

Large amplitude

Small amplitude
Frequency vs. Speed

Speed can kill

3000 VPM

3000 VPM
**Centrifugal force principle**

Centrifugal forces are generated by eccentrics in rotation

- Heavier the eccentric weight – greater the generated force
- Faster the eccentric rotation – greater the generated force
Centrifugal Force is Calculated by:

Multiplying the **Amplitude** times the Un-sprung **Drum Weight**, times **Frequency** squared divided by 35,198.

*Makes you wonder!*
The animation will show the relation between Eccentric frequency – roller travel speed – impact spacing

Frequency + forward speed = (impact spacing)

Forward speed of 3.0 mph
3200 vpm
Approx. 1”
(12 impacts / linear foot)
For the **SAME** eccentric rotation of 3200 vpm, if I **ACCELERATE** to 4.0 mph the **IMPACT SPACING** will now **INCREASE** to …
"WARNING"

**Best practices** dictate that you should **REDUCE** your rolling speed

NEVER TO INCREASE impact spacing over 1.2”

Or

**NOT TO GO LOWER** than 12 impacts / linear foot

Optimal

12 impacts / linear foot)
Frequency & Rolling Speed

1800 rpm
4,5 km/h
45 Hz
120°C
100 cm

45 Hz
45 Hz
Frequency & Rolling Speed

### Drum Impact Spacing Chart

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**Standard**

**High Freq.**

- **OK**
- **To Fast**
### Frequency & Rolling Speed

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</table>
“WARNING”

“RIPPLE” problems can be generated by large impact spacing...

The problem may be WORSE with THICK asphalt layers.
Rolling Speed Example

- 4 impacts per foot
- Creates rough ride or could even create sound issues
- Watch your speed
POSITIVE ASPECTS

Allow for HIGHER travel SPEED
Allow for MORE roller mat COVERAGE (sq. ft / min)
Theoretically allows for MORE productivity
Good for “THIN LIFTS”
  ✓ Quick sealing of mat surface behind paver
  ✓ Could increase rolling time before tender zone occurs
Larger drum diameters ...

Provide for more UNIFORM mat contact
Are LESS prone to mat marking
Are LESS prone to bow waves

The effects may be MORE visible on THICK asphalt layers
Pressurized water system

High pressure water system ensures full coverage to drum surface.
Drum Water & Scrapers

Dual scrapers per drum

Top scraper
Mainly to build a water trough

Bottom scraper
Mainly to clean drum surface
External Factors Affecting Compaction
External Factors?

Don’t go blaming the roller...

Fact is, it’s rarely the rollers fault!
External Factors Affecting Compaction:

- Mix design
- Mix temperature
- Paver issues
- Operator Issues
- Ambient temperature
- Base Conditions
Mix Design

Particle shape

- round shape
- compact shape
- prismatic shape
- flaggy shape
- rod-shaped
- flat
A science of its own

The main components can be summarized as follows:

- **Bitumen**
- **Modifiers** (Polymers, rubber, liquid anti-strip)
- **Stabilizers** (Fibers, crumb rubber, sulfur, hydrated lime)

Gradation of stones & fines
Minimum mat thickness vs aggregate size

“CONVENTIONAL” Asphalt Mix Design

Largest aggregate size in the mix: 1/2 inch

Rule: X 2

Minimum Mat Thickness: 1 inch
Minimum mat thickness vs aggregate size

“SUPERPAVE” Asphalt Mix Design

Largest aggregate size in the mix

Rule

Minimum Mat Thickness

1/2 inch

X 3-4

1.5 - 2 inches
Lift Thickness

**Minimum mat thickness vs aggregate size**

**“CONVENTIONAL”**
- 1/2 inch
- X 2 min

**“SUPERPAVE”**
- 1/2 inch
- X 3-4 min

“Grain Crushing” may occur

“White” crushed gravel surface
Gradation Curve

- Dense Gradation
- Uniform Gradation
- Open Gradation
- Gap Gradation
Good to keep a log

Roller operators have NO control of the mix delivered

It is therefore a good practice to;
  o Identify the mix you are working on
  o Keep a log for future reference (see example...)

<table>
<thead>
<tr>
<th>Date</th>
<th>Worksite</th>
<th>Mix type</th>
<th>Mat Temp.</th>
<th>Weather</th>
<th>Rolling Pattern</th>
<th>Achieved Density</th>
<th>Target Density</th>
<th>Mat thickness</th>
</tr>
</thead>
<tbody>
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</table>

KNOWLEDGE & EXPERIENCE is priceless!!
**Hot mix & ambient temperature**

**Higher temp.**
- Bitumen is more fluid
- Bitumen is lubricating
  (Good for compaction)

**Lower temp.**
- Bitumen is more stiff
- Reduces ability to move particles
  (Limits compaction)
Compaction “starts”  
When hot mix can support rollers  

Compaction “stops”  
When asphalt is too stiff to move
Software has been developed to estimate the temperature window for rolling time.
Cooling rate = rolling time

MultiCool V2.0

Software has been developed to estimate the temperature window for rolling time

Can run from Computer

Android & iPhone App
Hot mix & ambient temperature

Temperature ranges can dictate the “roller train” set up

<table>
<thead>
<tr>
<th>Temp.</th>
<th>Breakdown</th>
<th>Intermediate</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>310 – 240 °F</td>
<td>240 – 200 °F</td>
<td>200 – 150 °F</td>
</tr>
<tr>
<td>Distance</td>
<td>Up to 200 ft</td>
<td>Up to 200 ft</td>
<td>150 ft &amp; more</td>
</tr>
</tbody>
</table>
Temperature

Hot mix & ambient temperature

Cooling rate affected by...

- Mat lift thickness
- Ambient & base temperature
- Asphalt mix lay down temperature
- Wind velocity
Temperature

**Monitoring system**

Constant temperature readout

Display & warning controller

Infrared temperature sensor
Monitoring system

Operator can set the temperature parameters

Temp. high:
300°F

Temp. low:
240°F
Grading and base compaction is critical

Compacted surface is only as good as its BASE
Grading and surface uniformity is critical
Base reconstruction or milling may be necessary
Preparation is critical

Deformation

Cracking
Base Conditions (Preparation is Critical)

Milling

Recycling
Base Conditions  (Preparation is Critical)

“Fine milling” for near perfect re-profiling before paving
Base Conditions (Preparation is Critical)

Near perfect finish
Preparing Your Roller for Work

- Do a walk around, look for obstacles or anything out of the ordinary
- Check water system, clean filter
- Check function of lights, indicators and beacon
- Check fluid levels
- Check scrapers, make sure they are in the correct position
- Allow for the equipment to warm up

Know your equipment!
Using a vibratory roller

- Deactivate vibration before reversing
- Choose the amplitude and frequency to match the job and the mix
- Compact surface course at low amplitude / high frequency
- Compact thick layers of more than 3” on high amplitude first, then switch to low
- On hills, only vibrate up hill and static down
- On asphalt temperatures under 175, only use static or oscillation
10 Commandments for Roller Operators

1) Roll as closely as possible behind the paver

2) When compacting, always begin at the lower edge

3) Compact the seams first (if next to a hot mat)

4) Deactivate vibration before reversing

5) Always change the rolling speed gently

6) Move forwards and backwards in the same track

7) Change the roller track on the cold side

8) Roll in parallel tracks

9) Water the drums sufficiently

10) Never leave the roller on the hot asphalt
And Three More...
After Finishing

- When parking, secure roller out of the way
- Inspect drums and scrapers
- Inspect water system
- If risk of freezing, drain water tanks and sprinkler system
- Flush with anti-freeze
- Pick up and remove your trash and belongings
- Turn off battery switch (if equipped) Lock up and don’t lose the keys
Key Factors Affecting Rolling Patterns
Key factors affecting pattern

- Basic rolling techniques
- Paver speed
- Number of passes
- Number of coverage’s
- Joints & edges
Basic rolling techniques

Never STOP on a soft mat
Never VIBRATE standing still
Basic rolling techniques

Overlap passes by approx 6”
Basic rolling techniques

Need for delicate transitions
- Smooth start
- Smooth stop

Rolling Pattern

Acceleration
Deceleration

Ramp Up
Ramp Down
Basic rolling techniques

Always stop at an angle
Basic rolling techniques

Always stop at an angle
- 1 pass = 1 way **up** towards the paver
- 2 passes = 1 way **up** and 1 way **down** on the mat in the same track
- Patterns need to be maintained for consistency
- Each rolling train zone has its own pattern
- Number of passes will always be an odd number

**Rolling Pattern** *(Number of Passes)*

- 1 pass = 1 way **up** towards the paver
- 2 passes = 1 way **up** and 1 way **down** on the mat in the same track
- Patterns need to be maintained for consistency
- Each rolling train zone has its own pattern
- Number of passes will always be an odd number
Coverage = Number of passes to cover the mat once
Number of coverages needed to achieve final density

In this example 2 passes are needed to make 1 coverage
Rolling Pattern (Longitudinal Joint – Vibration)

Vibration = risques de destruction des granulats
Rolling Pattern (Longitudinal Joint – Oscillation)

Oscillation = compactage dynamique des joints sans destruction des granulats
Compacting the seam \textit{transversely} to the road surface.

Compaction static or with oscillation.
Compaction of the seam in the **fan shape**

Compaction static or with oscillation
Reversing before the paver

Danger of wave formation in asphalt

Avoidance of wave formation by turning in

The next graphics will no longer show the turning in!
Rolling Pattern (Transverse Joint)

- COLD
  - Compact static or with oscillation

- HOT
  - Overlap of approx. 6”
Rolling Pattern (Transverse Joint)

Compact static or with oscillation

Overlap of approx. 6”
Compaction starts from the bottom up

4 elements of compaction
- Static weight, Impacts, Dynamics and Kneading

Roller Trains

Roller types
- Where and when to use

Roller Design Specs
- Impact spacing
- Water & Scraper system

External Factors
- Mix Designs (vary)
- Temperature, Temperature, Temperature

Rolling Techniques
- Stop on angle
- Smooth transitions

Consistency