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Compacting Fundamentals

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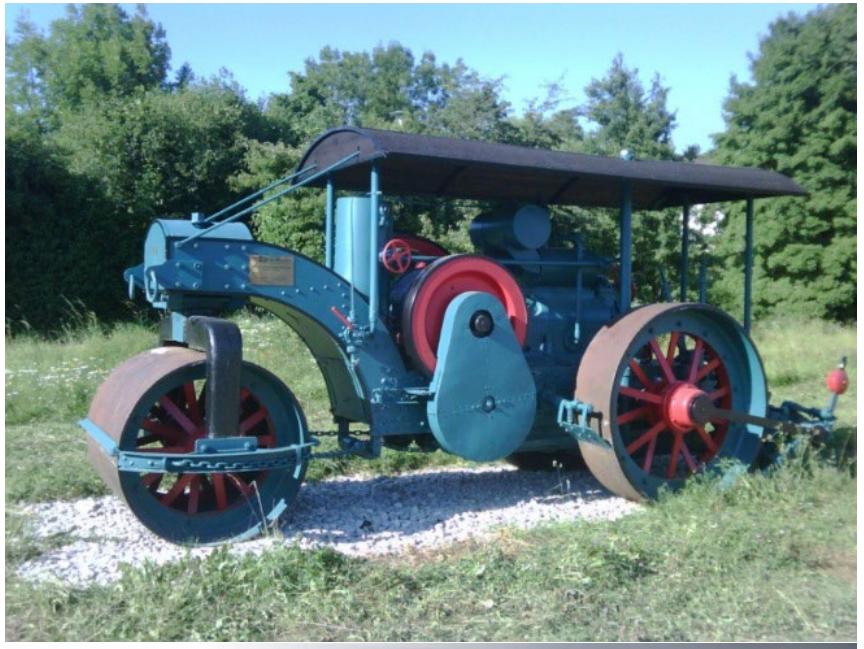
Application Support Manager - Hamm

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
- Key factors affecting roller patterns
- Intelligent Compaction
- Summary



Why do we need compaction?

Why Compaction?

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To build support foundations

Hydro power dams

Building pads

Airport runways

Roads & streets

Asphalt Material

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

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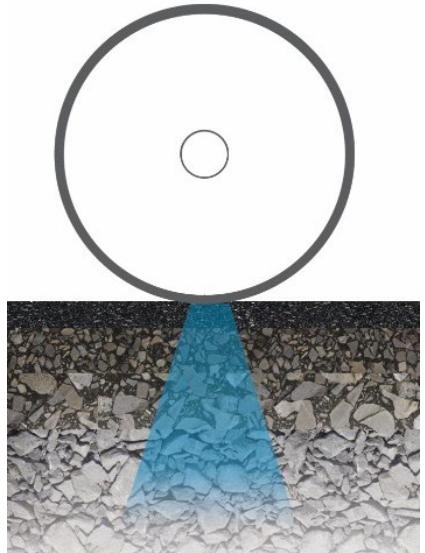
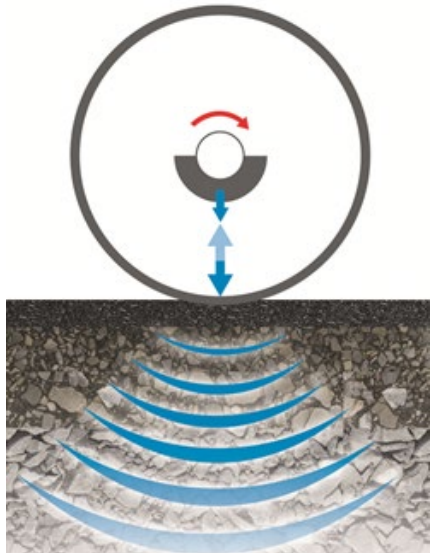
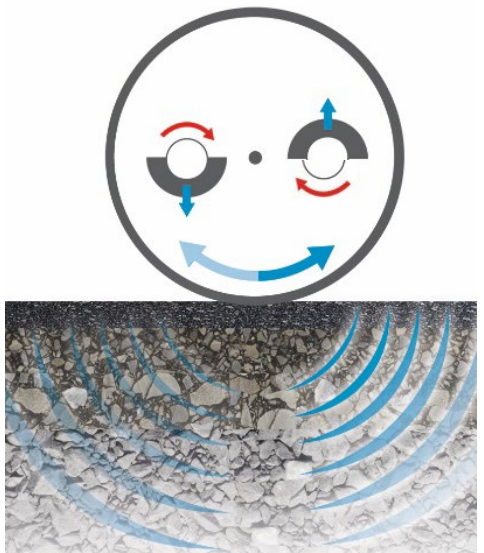
Compaction system

- Static
- Dynamic
  - Vibration
  - Oscillation







Why Compaction?

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Why Compaction?

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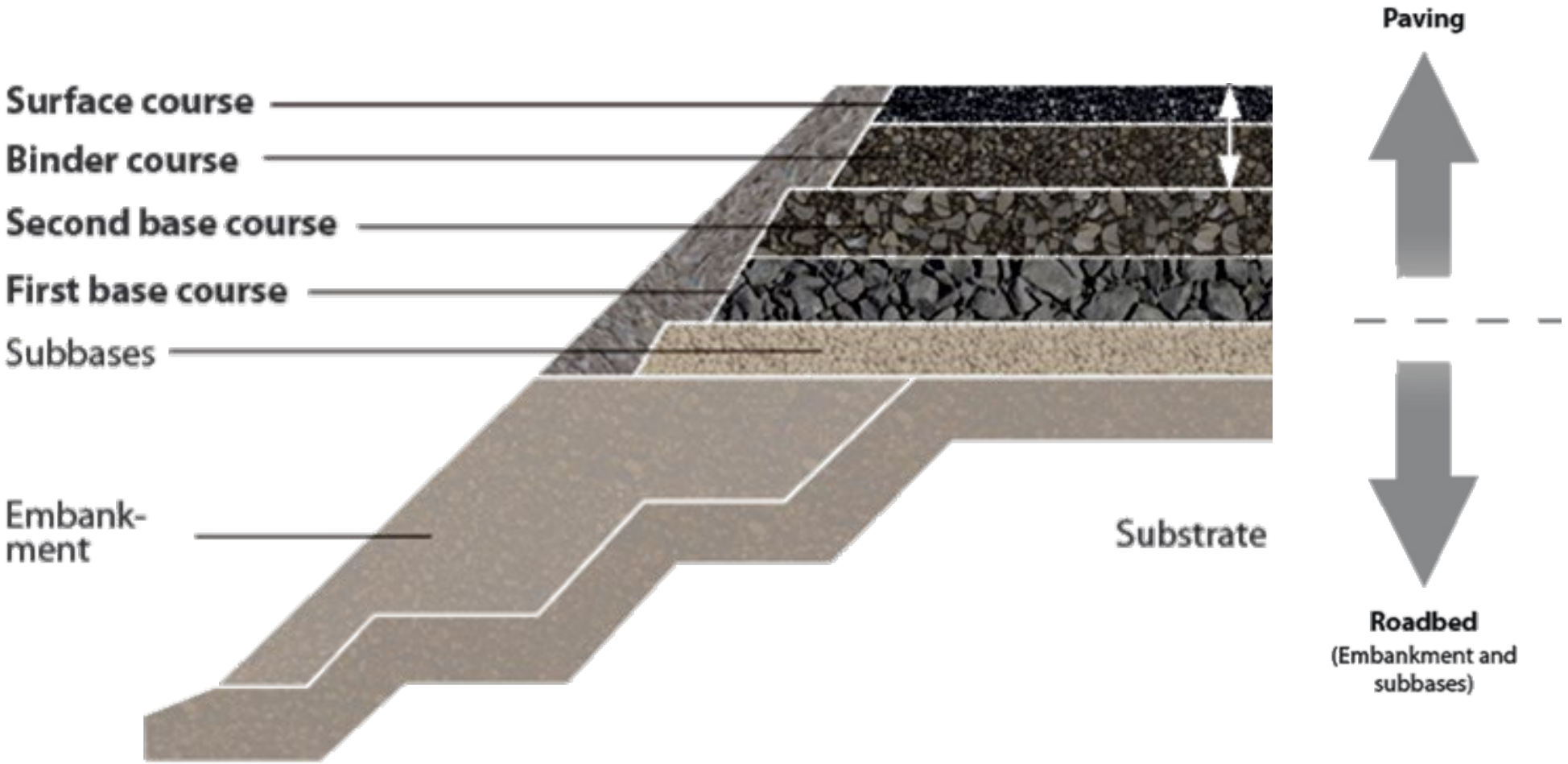
To build and rehabilitate roads



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**

Pavement Distresses

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

Pavement Distresses

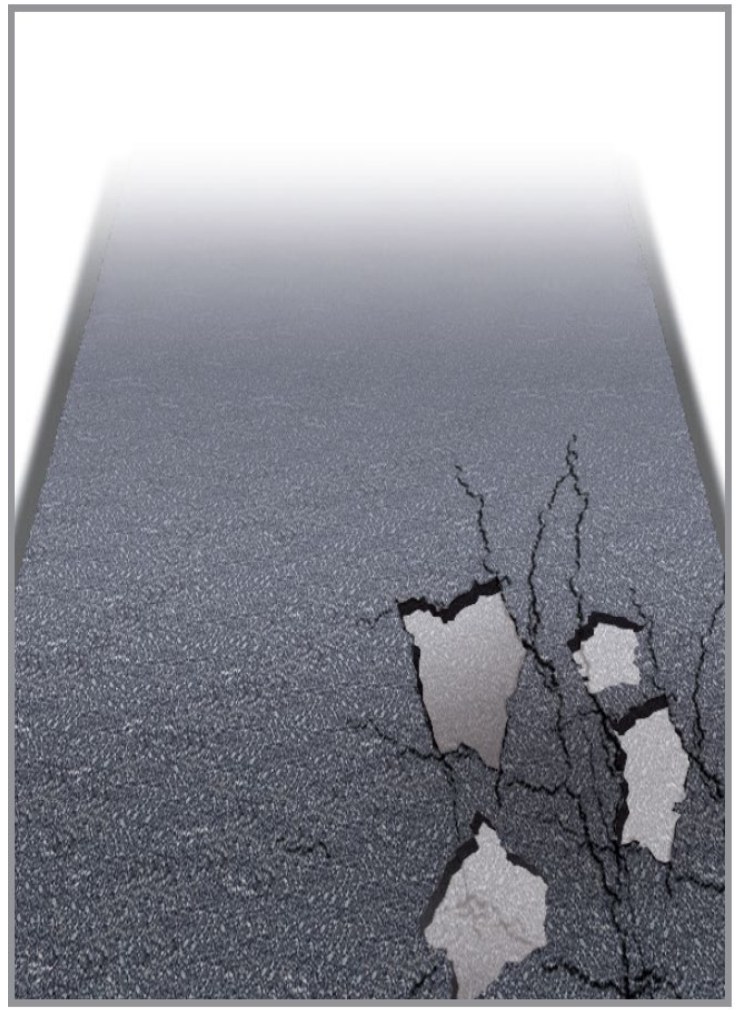
Binder enrichment results from:

- **Too high binder content in asphalt**
- **Too much tack coat**
- **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 “over rolling“
- **Mix that is too hot**

Pavement Distresses

Outbreaks are caused by:

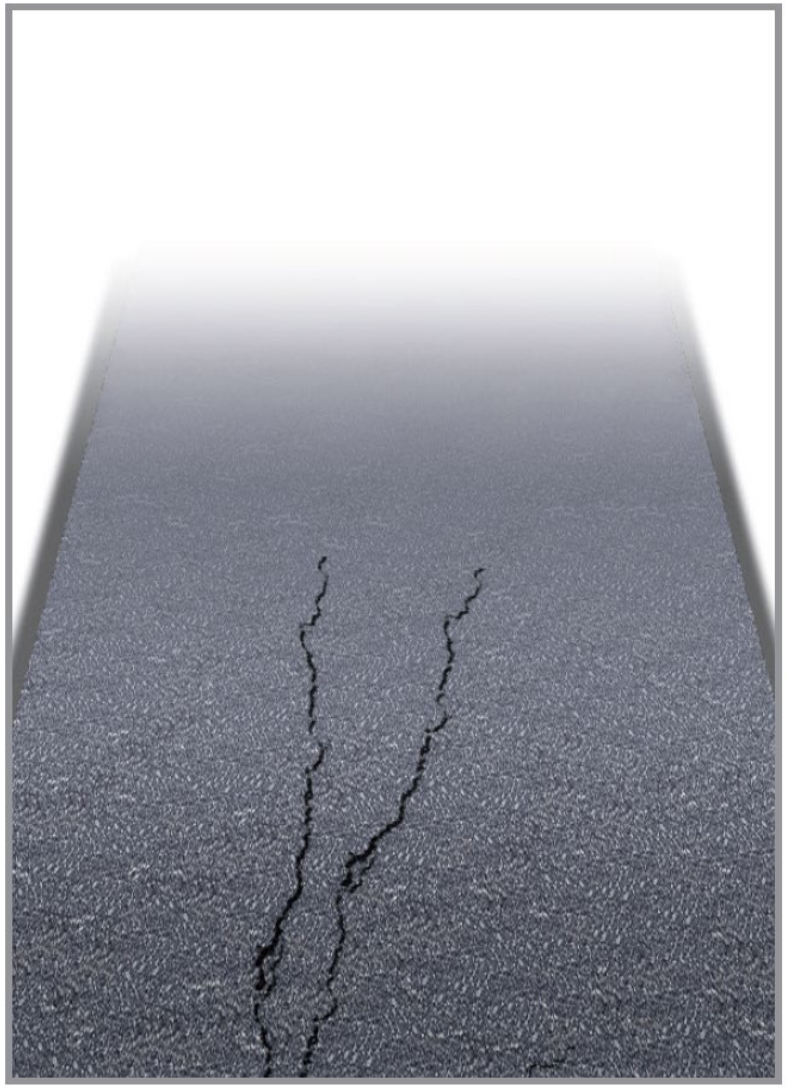
- **Faulty mix formulation**- adhesive effect between the grain structure is not sufficient
- **Bursting of ice lens** through penetrating water
- **Dynamic compaction on cold asphalt**
- **Insufficient bond between layers**
  - Not enough tack



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



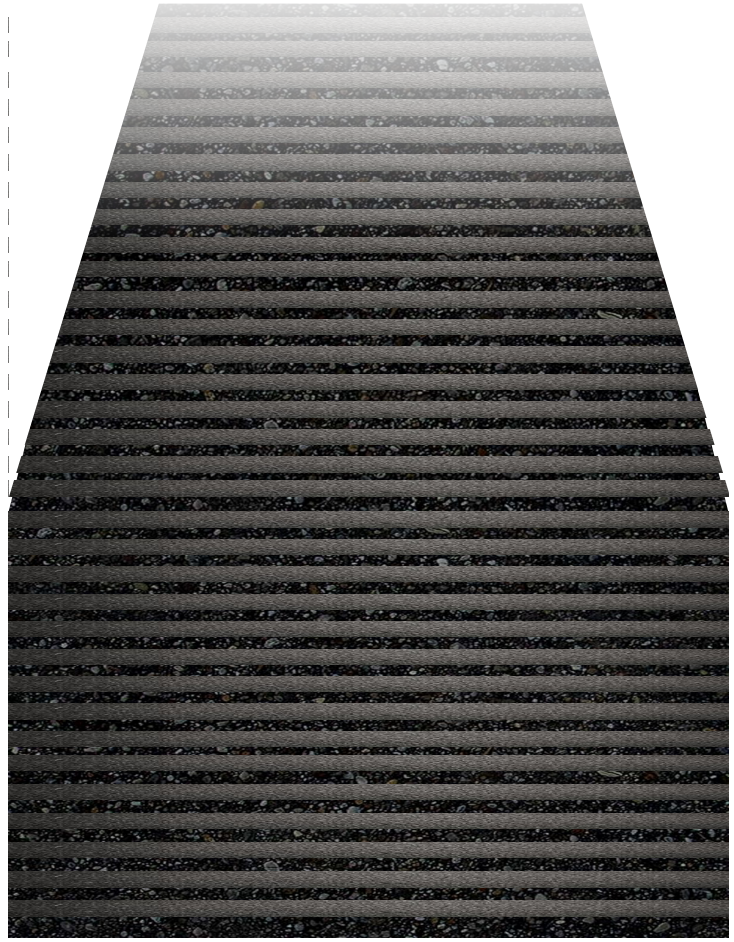
Pavement Distresses

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
- Varying speed of paver

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



Bump Removal

Who's Job is Compaction?

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What is Compaction?

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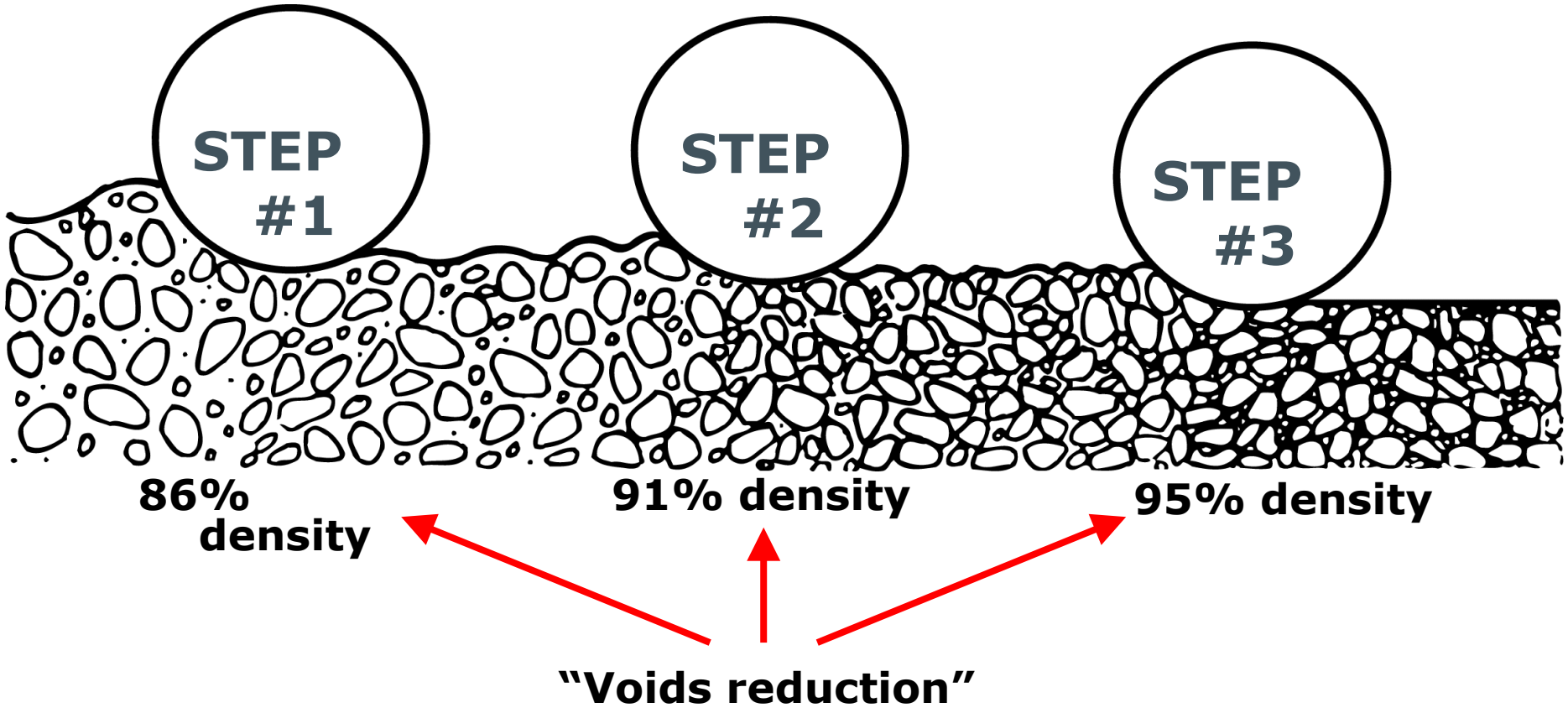
Compaction is a sequence of STEPS in order to MANIPULATE aggregates & REDUCE the voids between them.



What is Compaction?

Sample at 96% density

96% DENSITY means that we still have 4% AIR VOIDS left in the compacted layer

Asphalt is a FLEXIBLE product.

Too much rigidity would not be desirable.

What is Compaction?

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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?

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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?

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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?

Four Elements?

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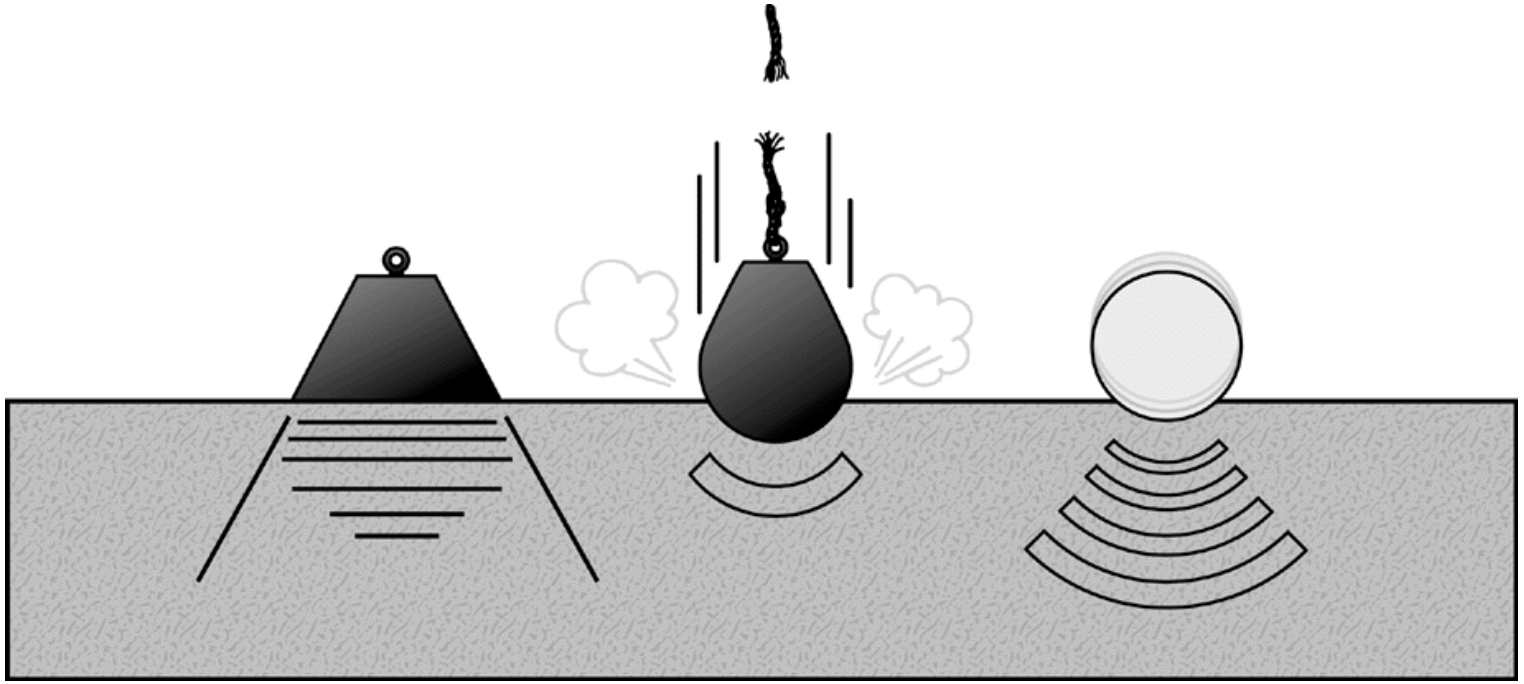
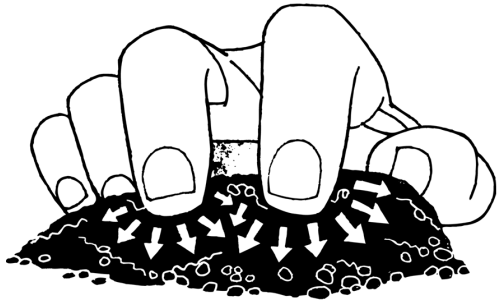
The Four Elements can be Summarized as …





Static
Weight

Impacts

Dynamics
(Vibration)
(Oscillation)

Kneading
(Oscillation)

Four Elements?

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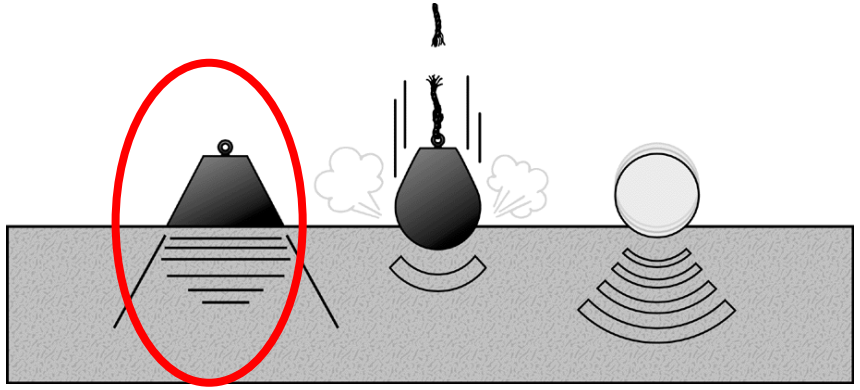
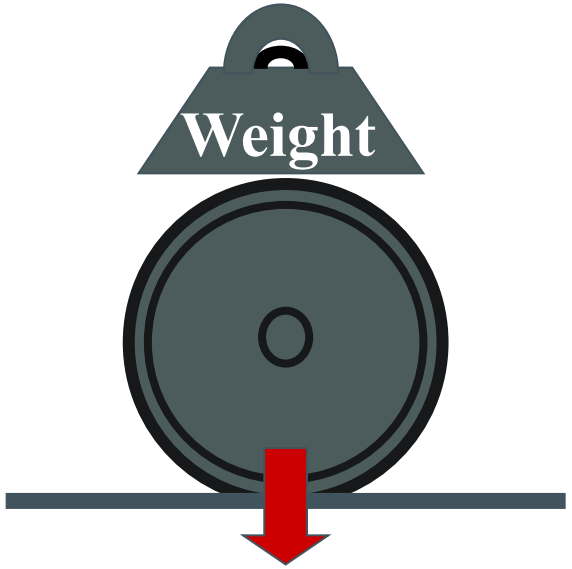
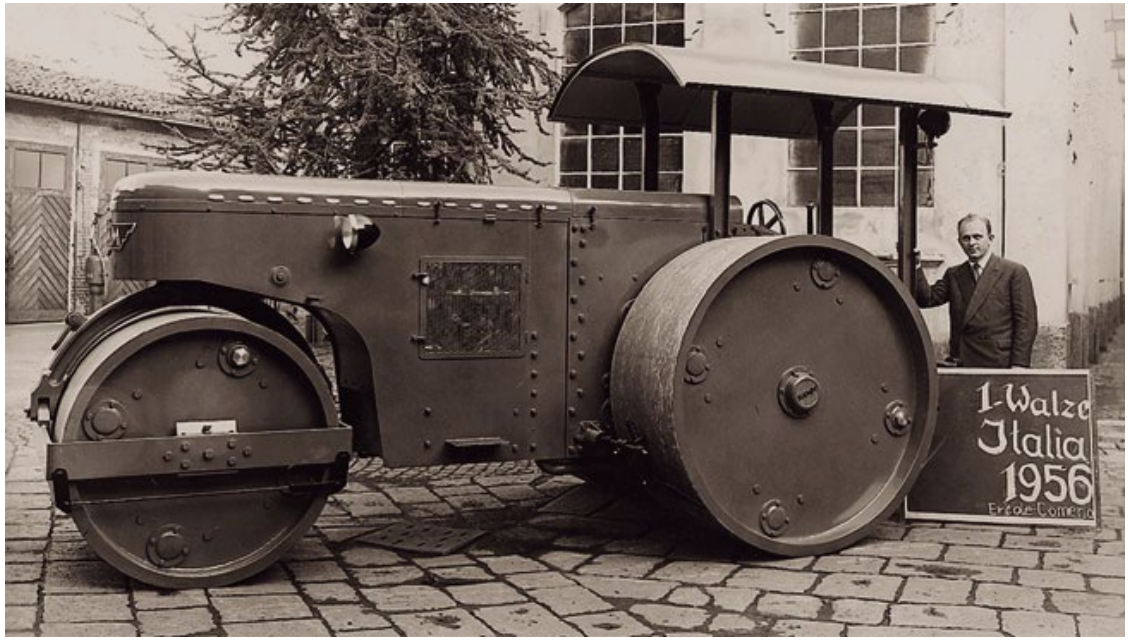




Static

Weight



Applies a static pressure from <u>TOP</u> to <u>BOTTOM</u>

(Surface compaction)

Four Elements?

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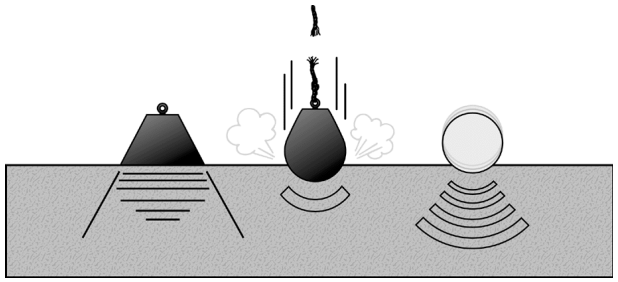
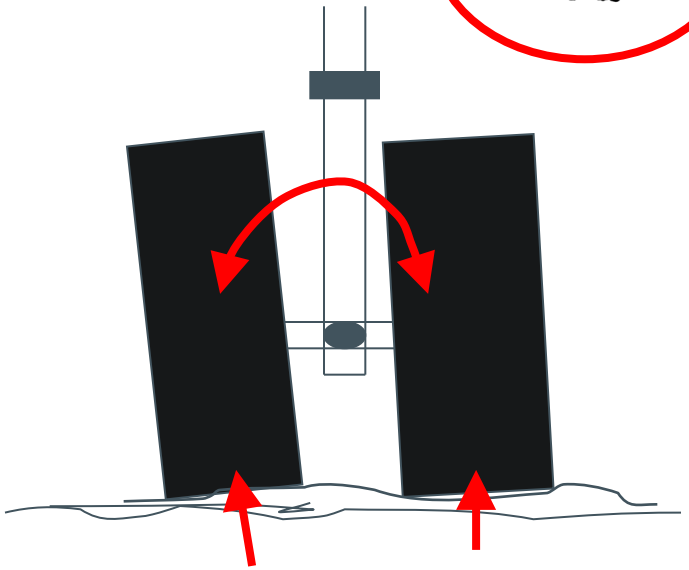


Kneading



<u>Kneading effect</u>

Matches contours of an uneven surface

Minimizes bridging and helps to eliminate soft spots

Four Elements?

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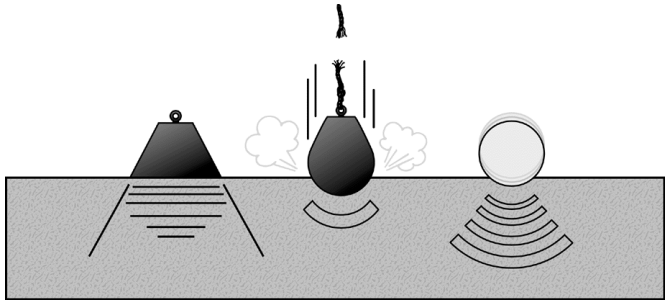

Kneading

Applies a static pressure from TOP to BOTTOM
(DEEPER surface compaction than a static drum)
Seals the mat by bringing fines to the surface.

Four Elements?

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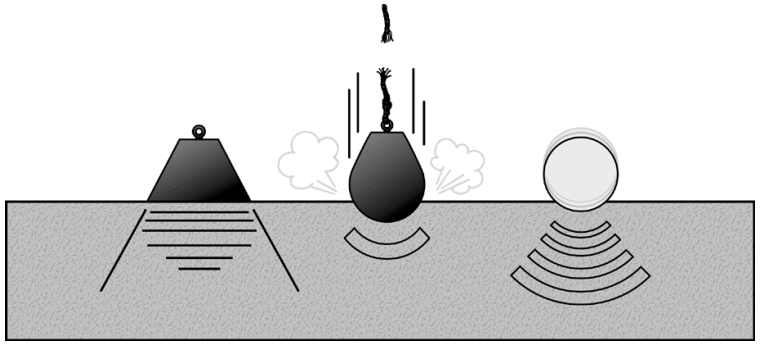
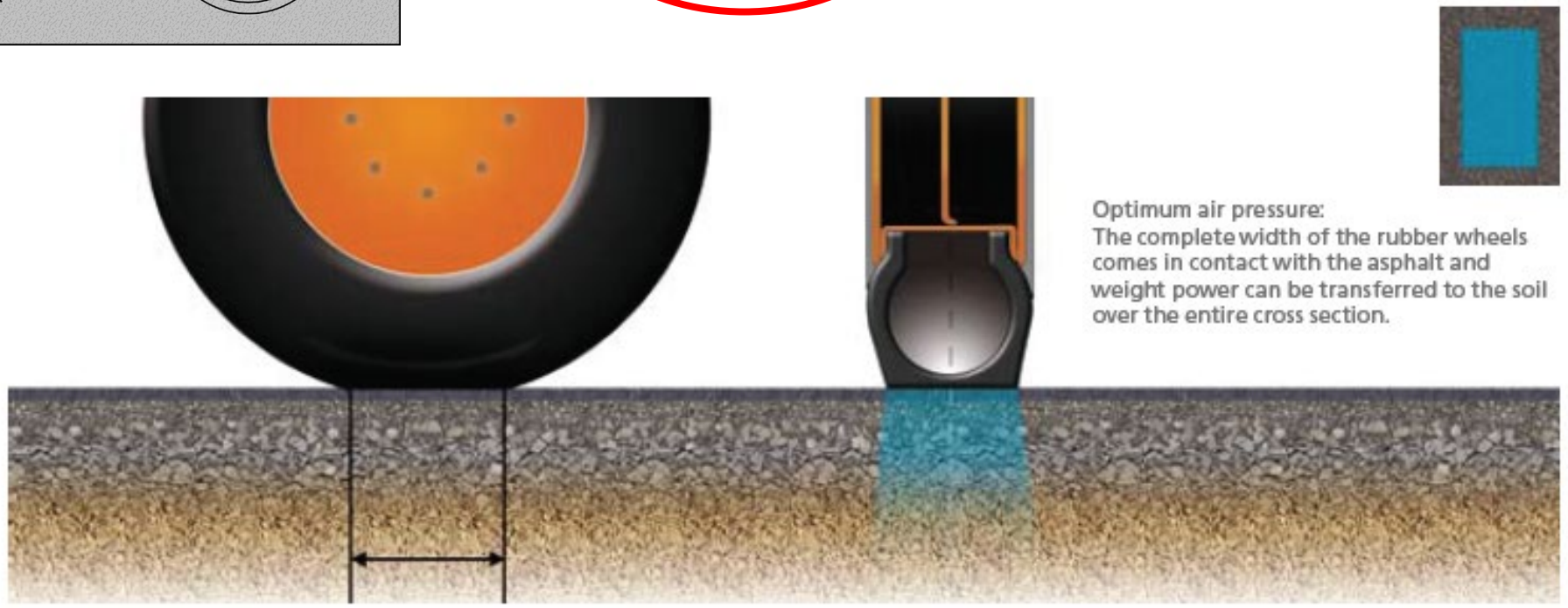
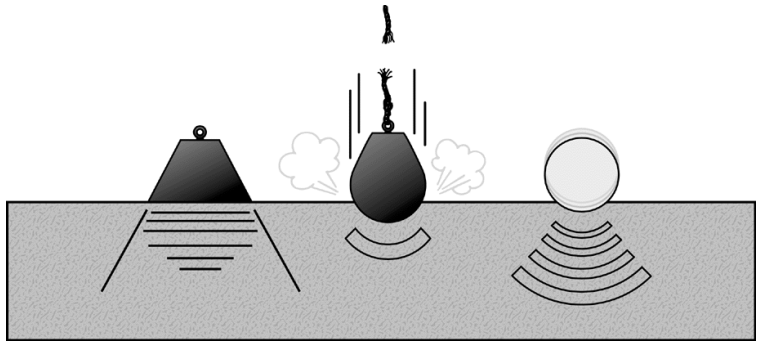


Kneading

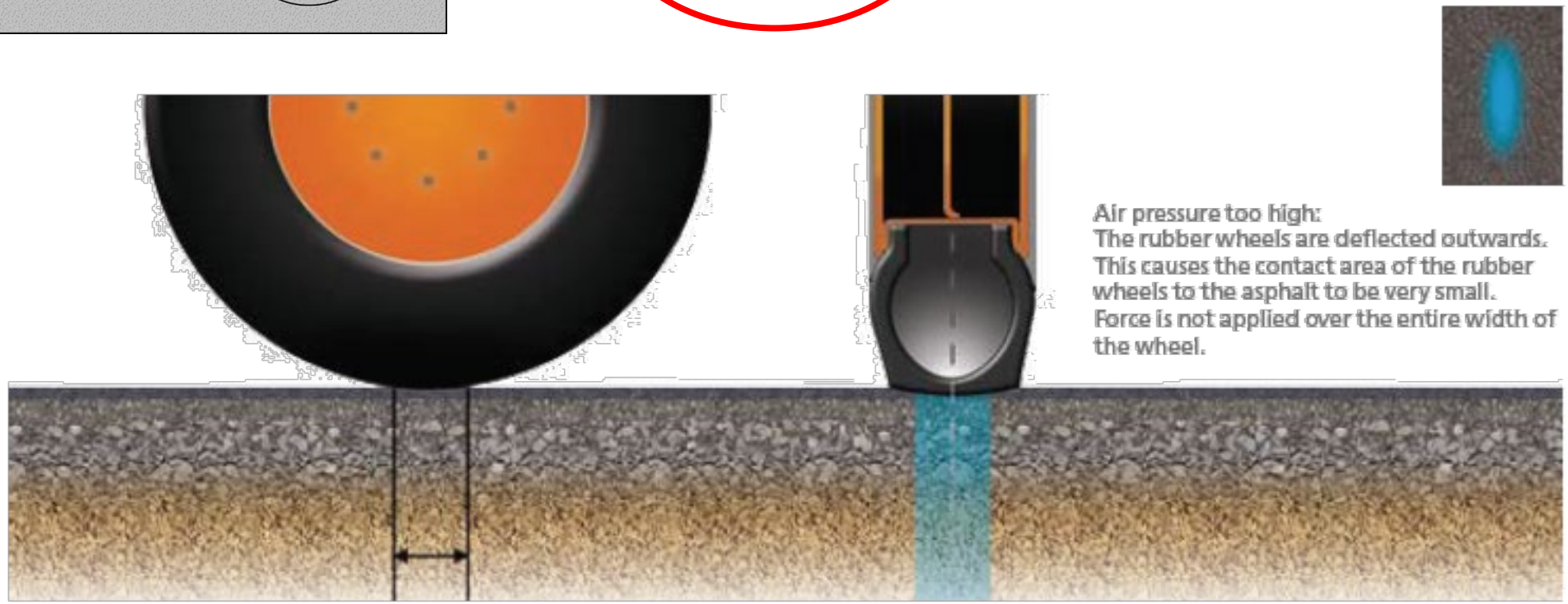


Ideal tire pressure is dependent upon ballasted weight of the machine

Four Elements?

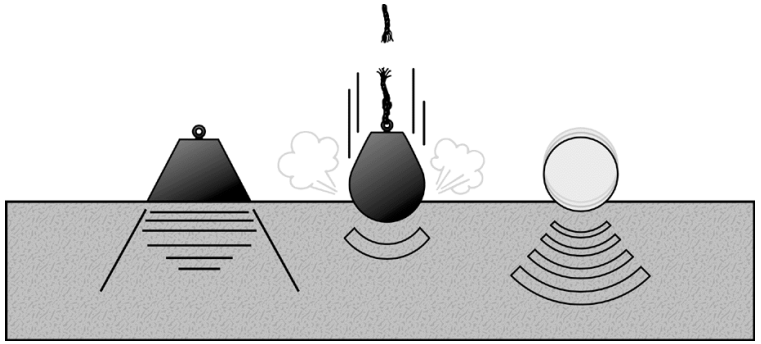


Kneading

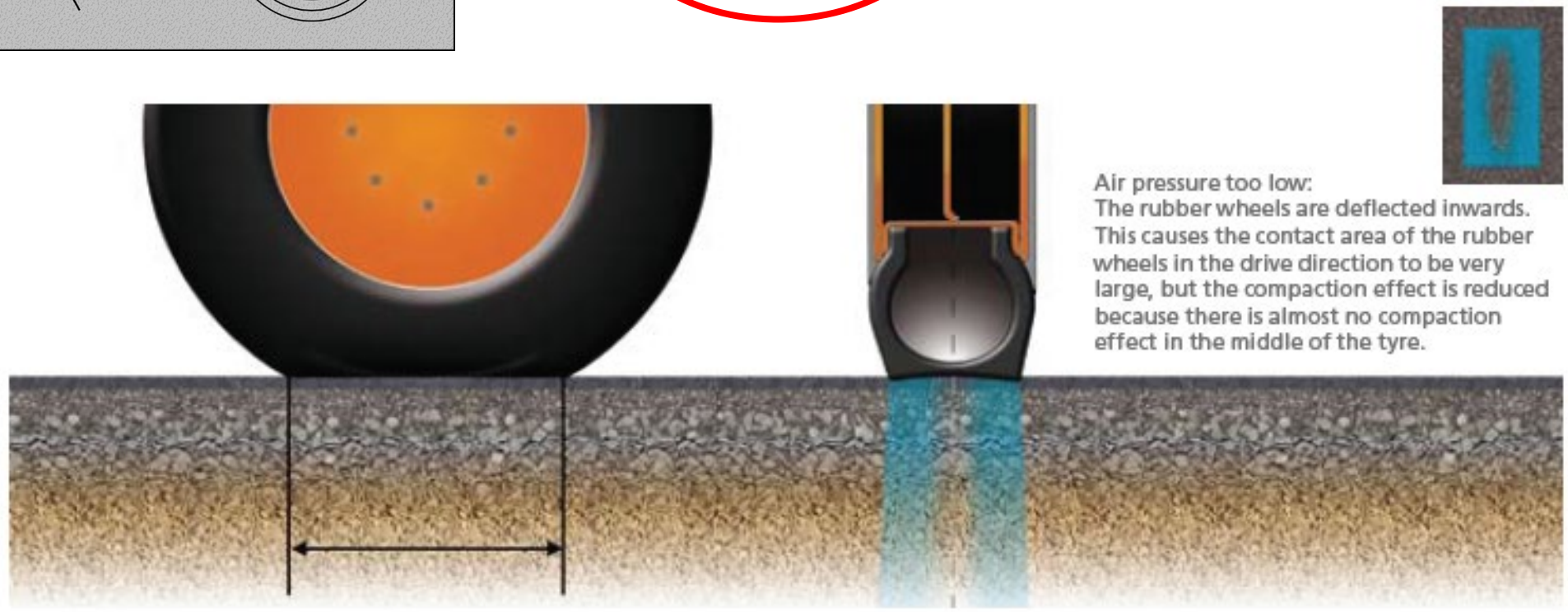


Tire pressure too high

Four Elements?



Kneading



Tire pressure too low

Four Elements?

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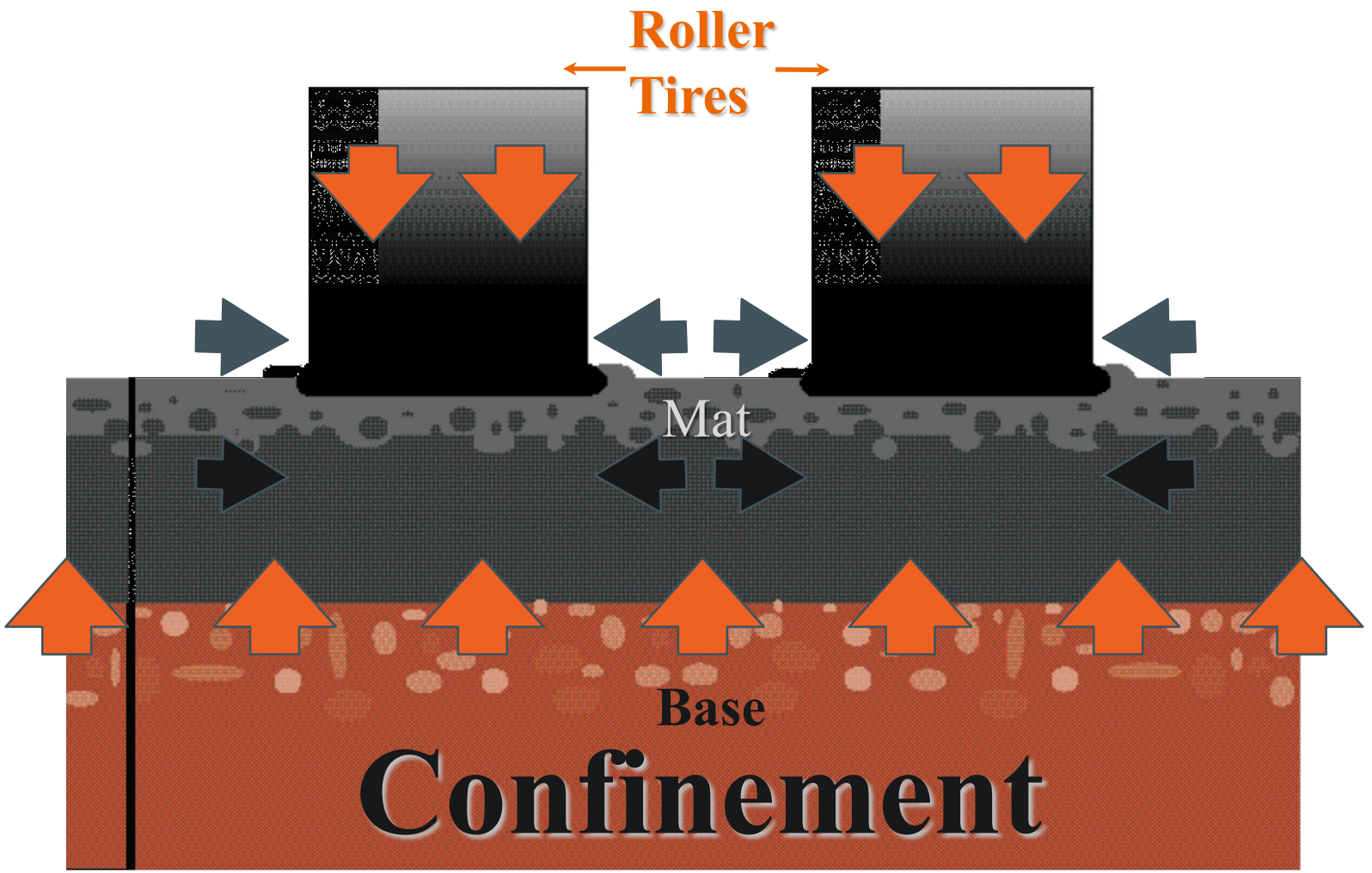
PTR´s provide a very effective form of compaction within a tender-zone on Superpave mixes



Tire Pressure Chart

CA and GCP for **Dunlop Tires**

Dunlop Tires 11.00 R 20

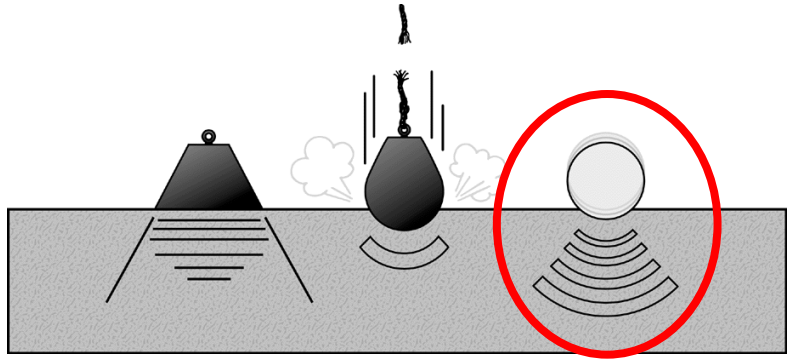
Inflation pressure [psi]		43,5	58,0	72,5	87,0	101,5	116,0
Wheel load [lbs]		Ground Contact Pressures and Contact Areas*					
2750	CA	74	62	52	46	42	39
	GCP	37	44	53	60	66	71
3300	CA	86	72	62	55	49	46
	GCP	38	46	53	60	67	72
4400	CA	109	92	81	71	64	59
	GCP	41	48	54	62	68	74
5500	CA	127	108	95	85	77	71
	GCP	43	51	58	65	72	77
6600	CA	146	124	110	99	89	83
	GCP	45	53	60	67	74	79
7700	CA	162	137	123	111	101	94
	GCP	48	56	63	70	76	82

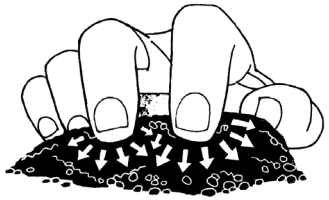
CA = Ground Contact Area [in^2]

GCP = Ground Contact Pressure [lbs/in^2]

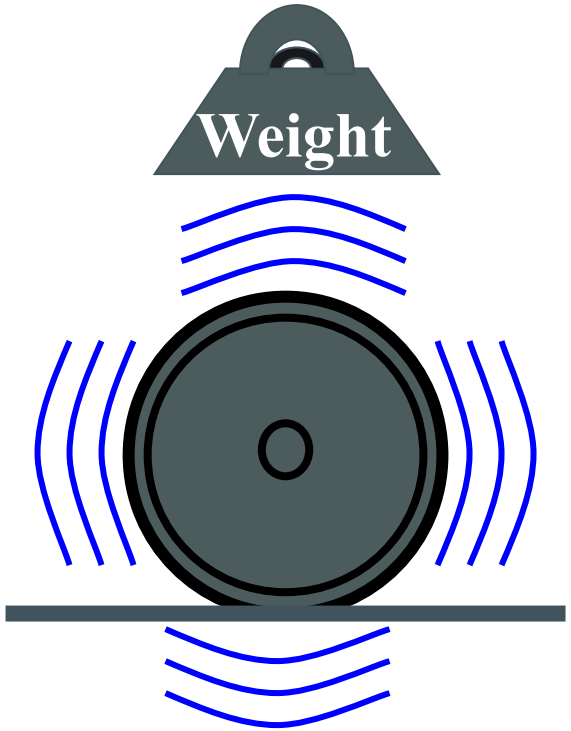
* Values are subject to change, 18.12.2016

Four Elements?



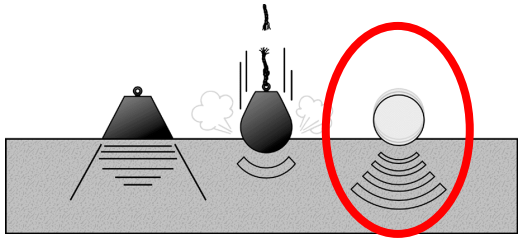


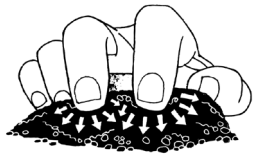
Dynamics
(Vibration)
(Oscillation)



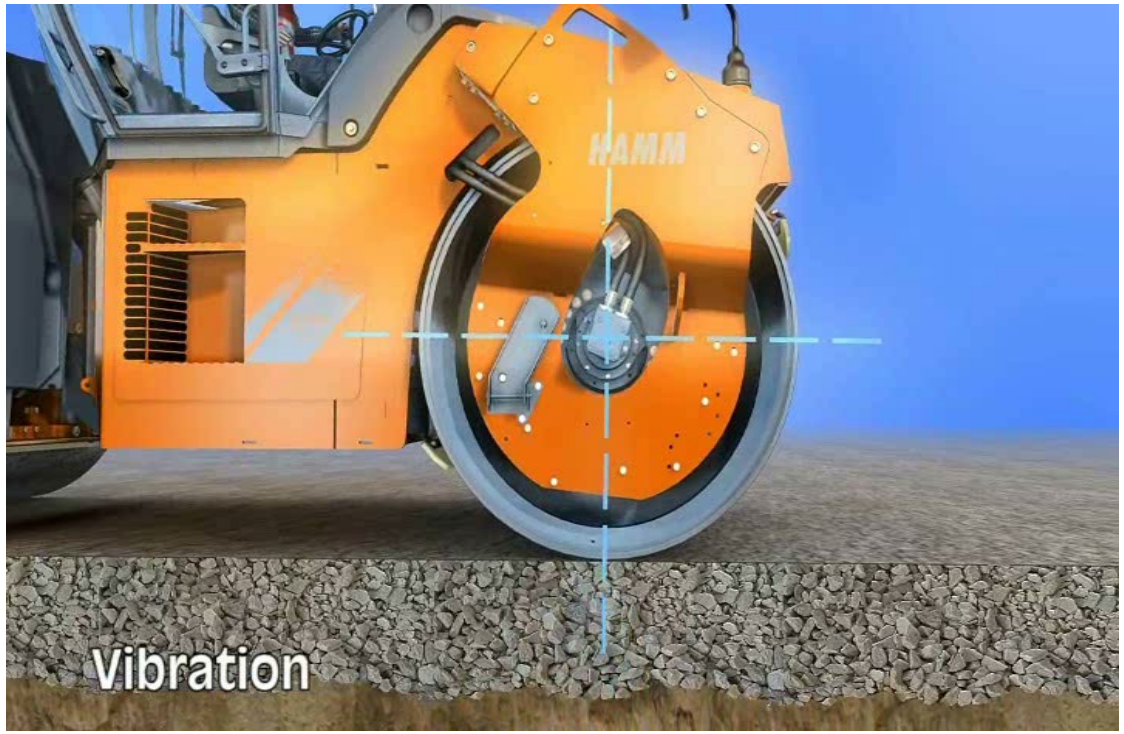
Dynamic energy puts aggregates in motion and compacts from the BOTTOM - UP

Four Elements?





Dynamics
(Vibration)
(Oscillation)



Oscillation
(Drum has 100% ground contact)

"Non-Aggressive compaction"

Vibration
(Drum is 50% in the air)

"Aggressive compaction"

Compaction system

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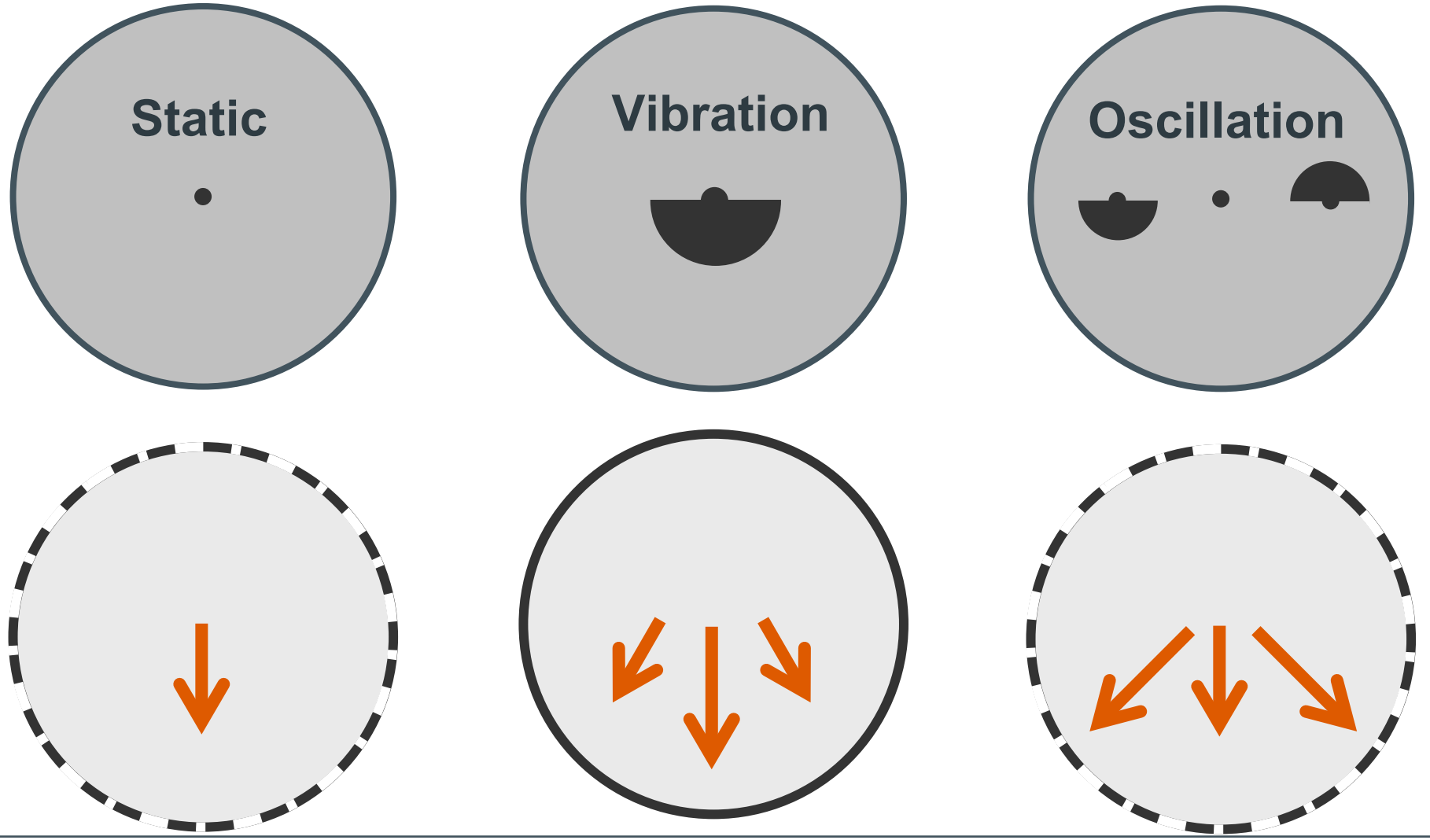

Four Elements?

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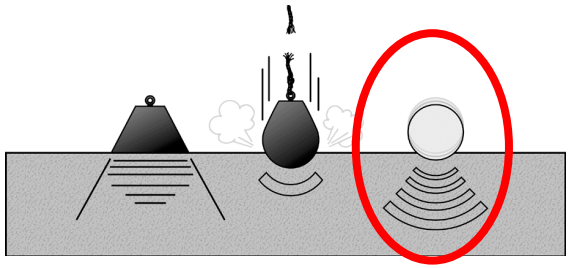
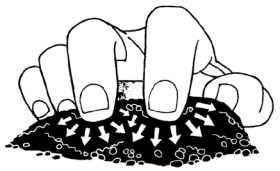
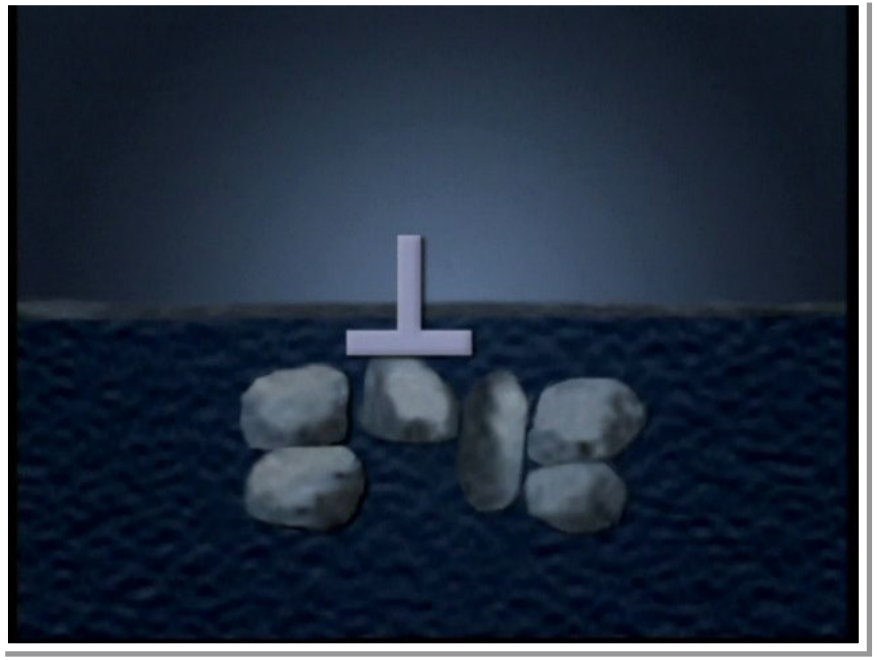


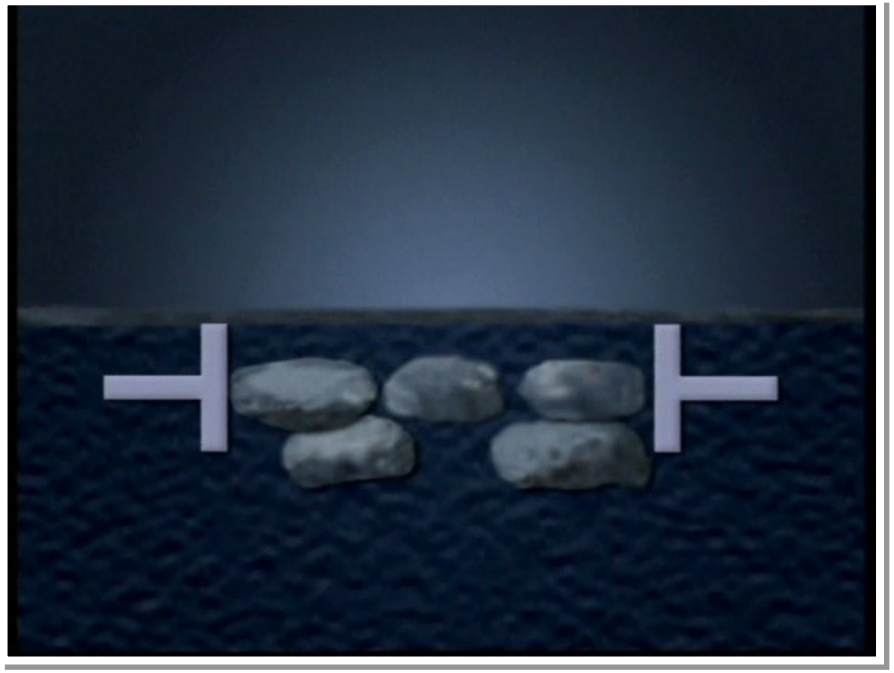


Dynamics
(Vibration)
(Oscillation)



Vibration

Vertical aggregate positioning



Oscillation

Horizontal aggregate positioning

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The Roller Train

Roller Train?

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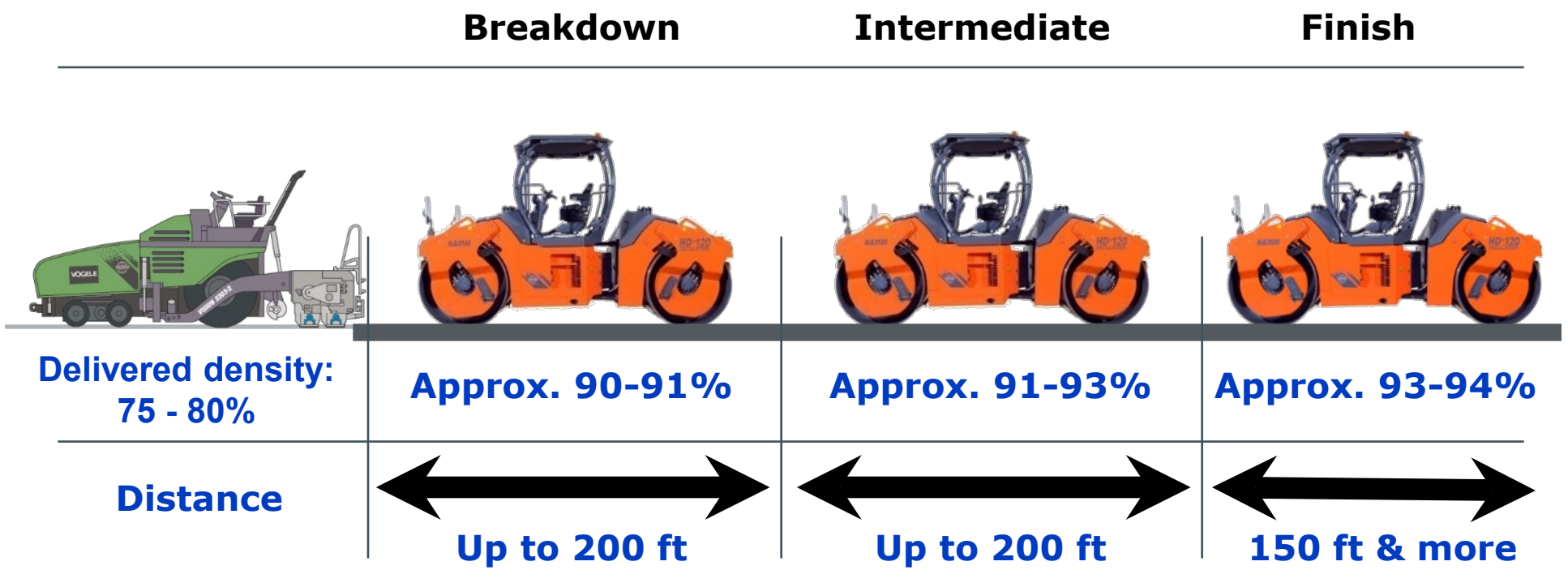
A "roller train" can be summarized as…

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



Roller Train?

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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 <u>in the least number of passes</u>

Summary Of Roller Types

Roller Types?

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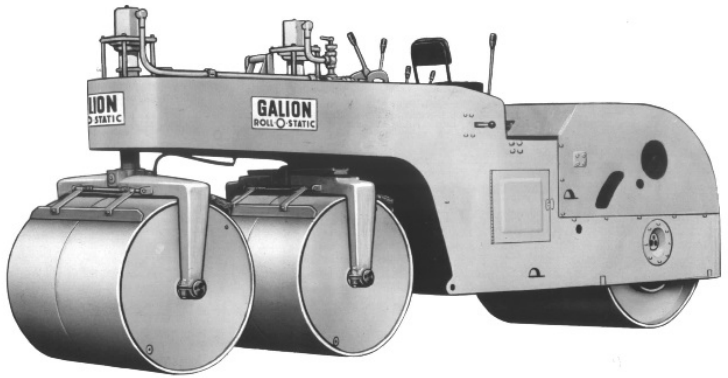
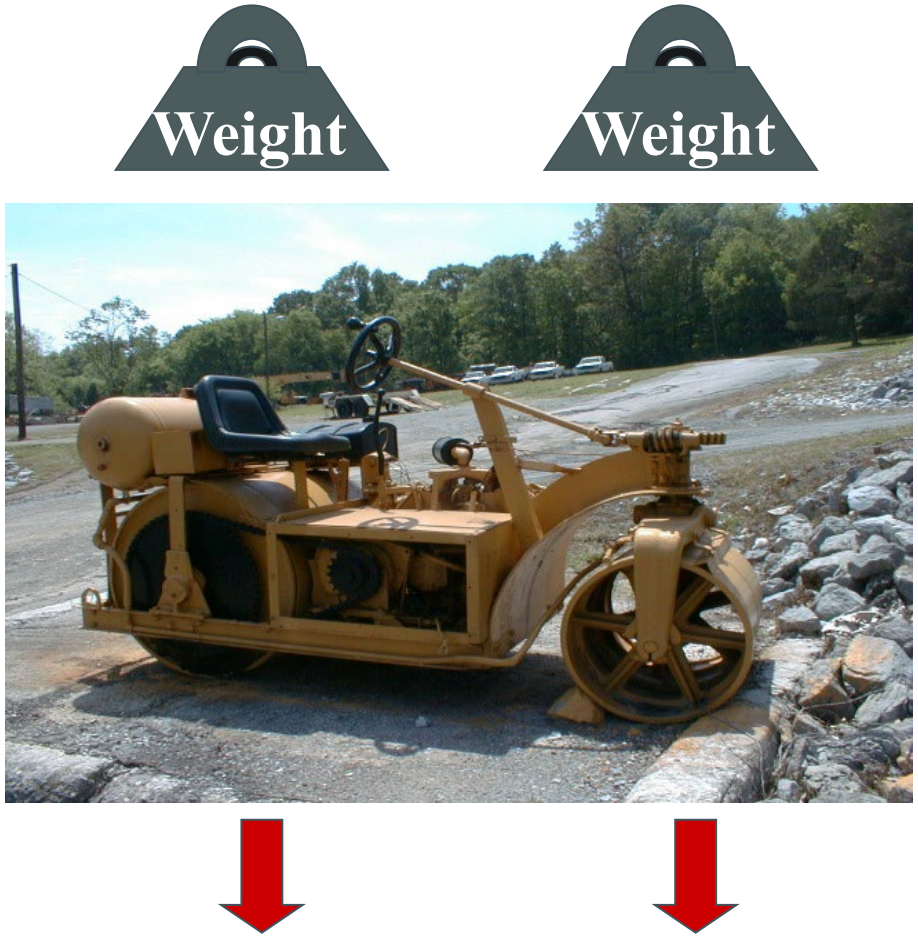
Static steel wheel





Element(s) involved: Static weight

Application(s): Mat smoothness (mainly finish rolling)
Pinching a joint

Roller Types?

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Pneumatic (rubber tires)

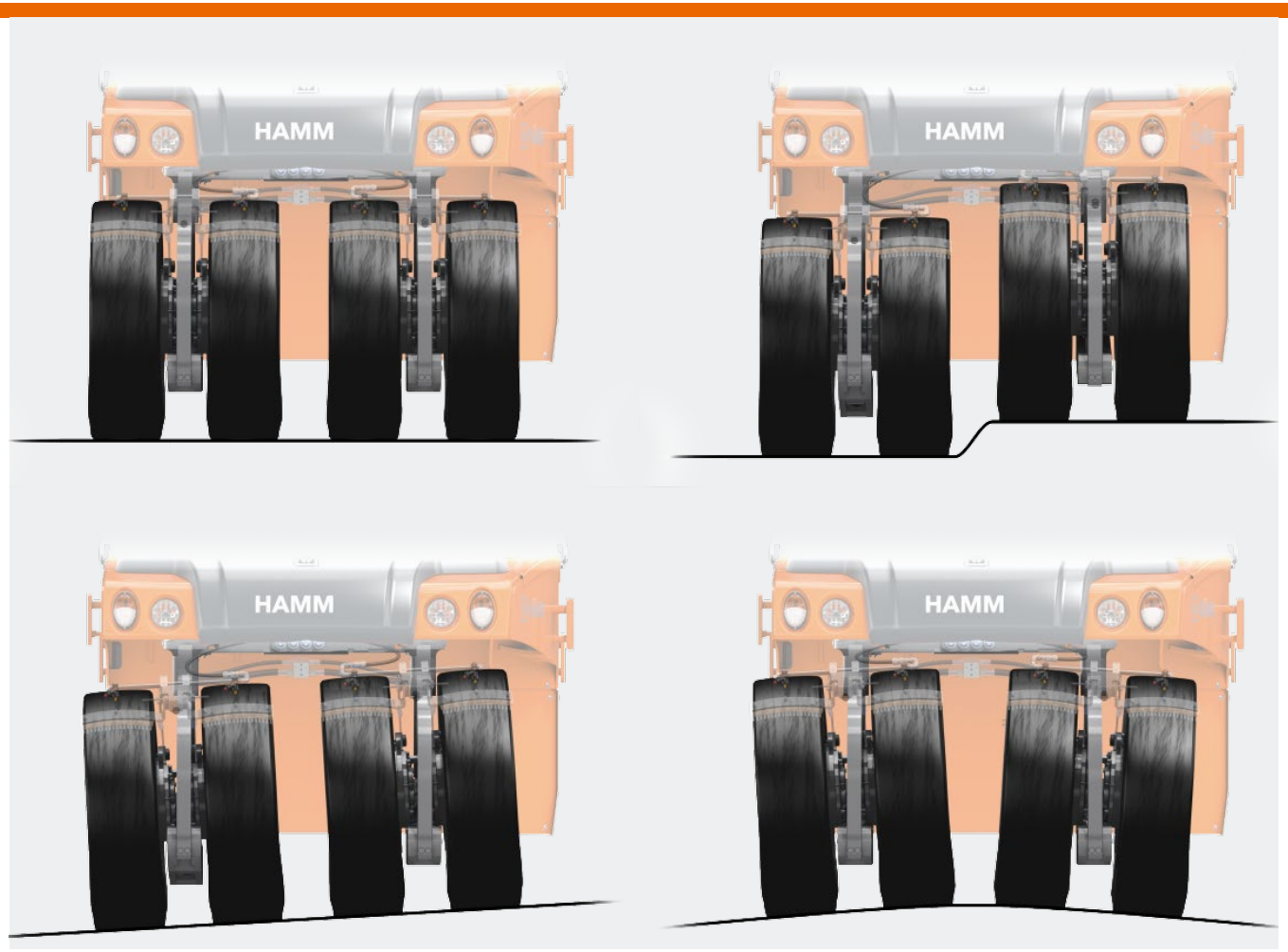
Element(s) involved: Static weight, kneading, proof rolling

Application(s): Seal mat surface (All)

Pneumatic tire rollers

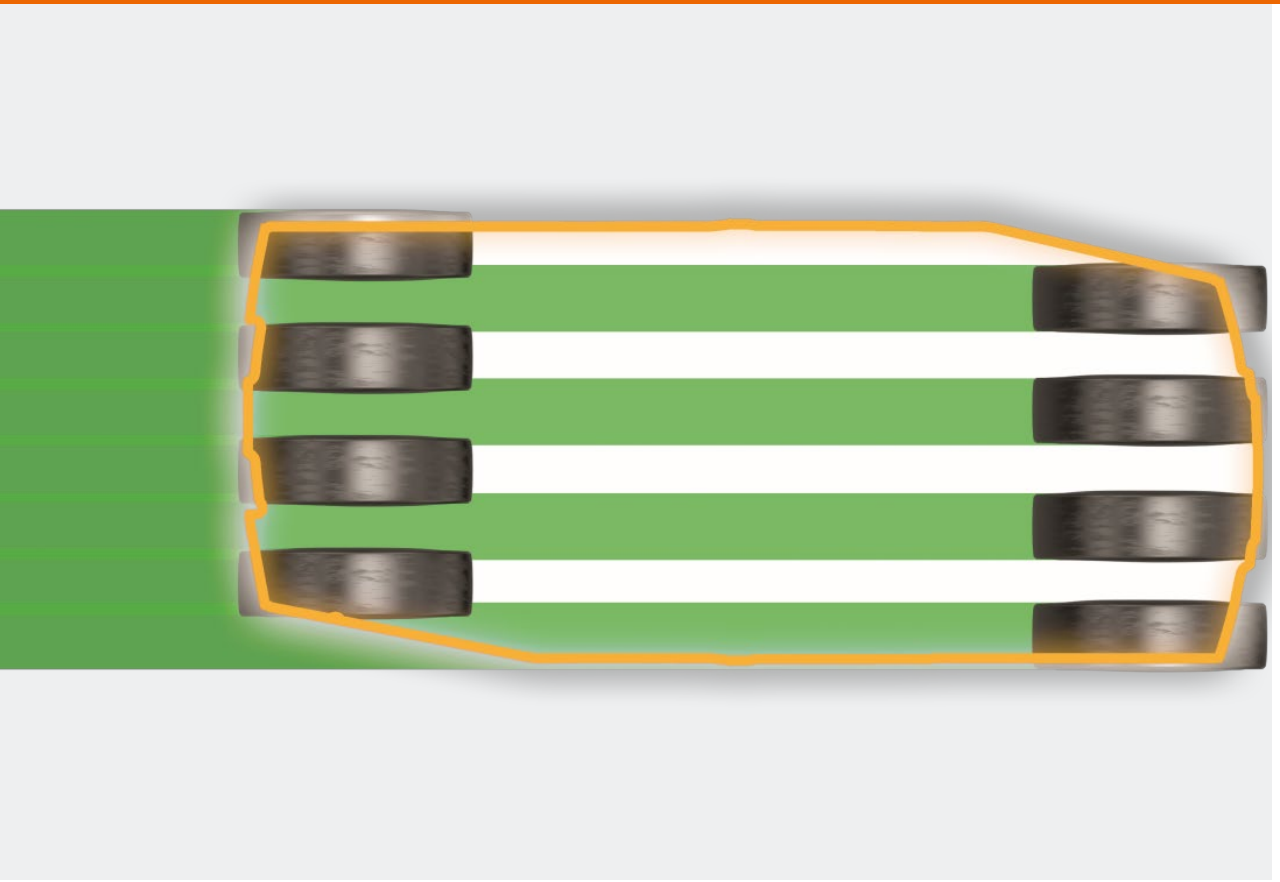
The pneumatic tire roller is also ideal for compacting fine cohesive material. It also has a good sealing effect on the surface.

Front axle pendulum



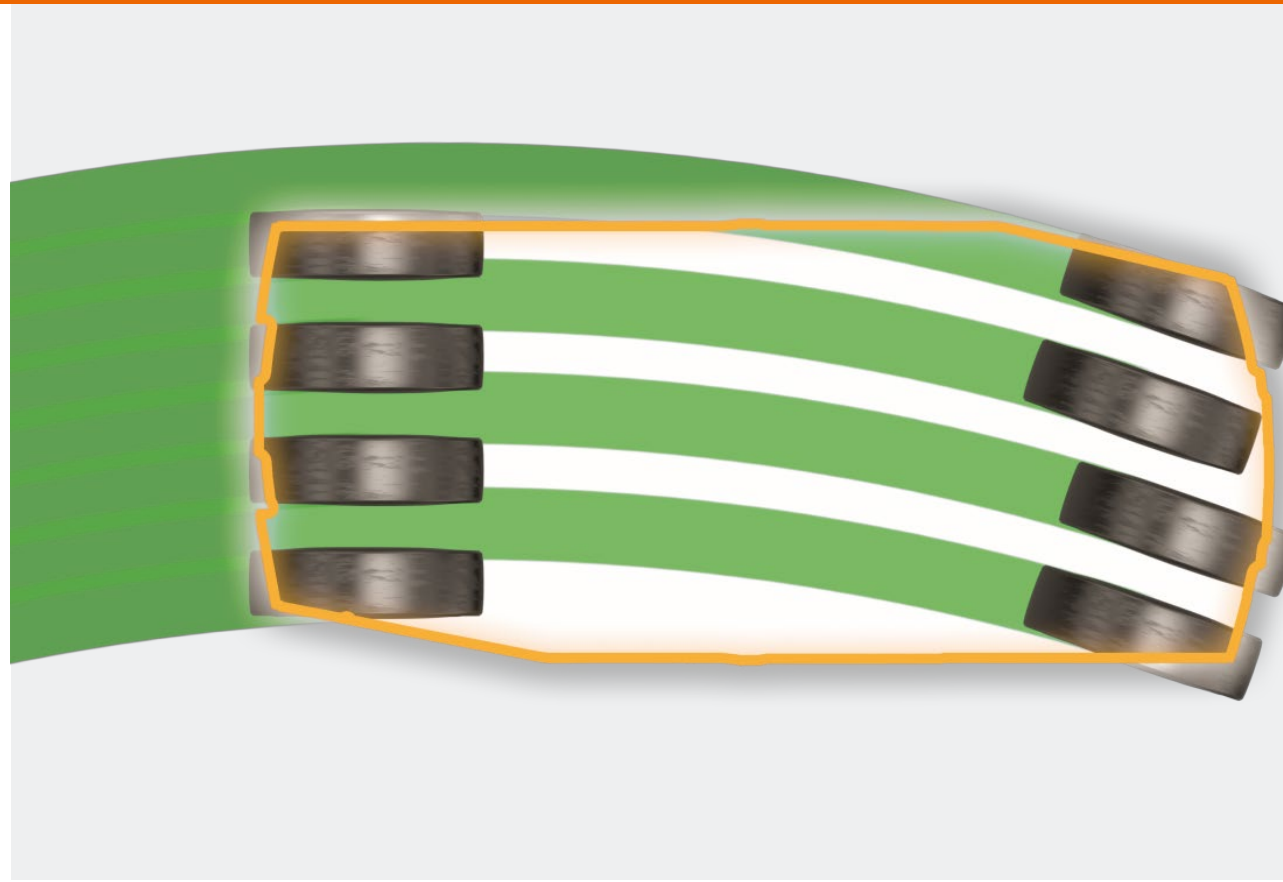
The front axle pendulum adapts ideally to the conditions.

Track overlapping



Front and rear axle offset

Track overlapping



The track overlap is also guaranteed when cornering

Roller Types?

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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?

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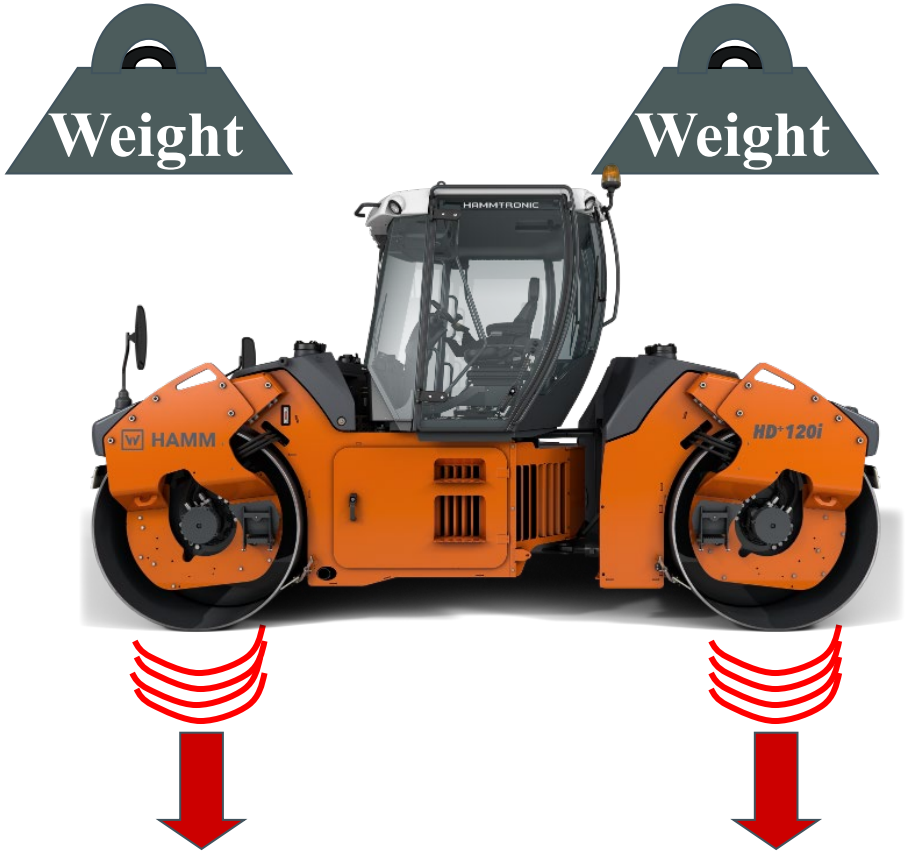
Tandem steel drums (vibration)



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

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

Roller Types?

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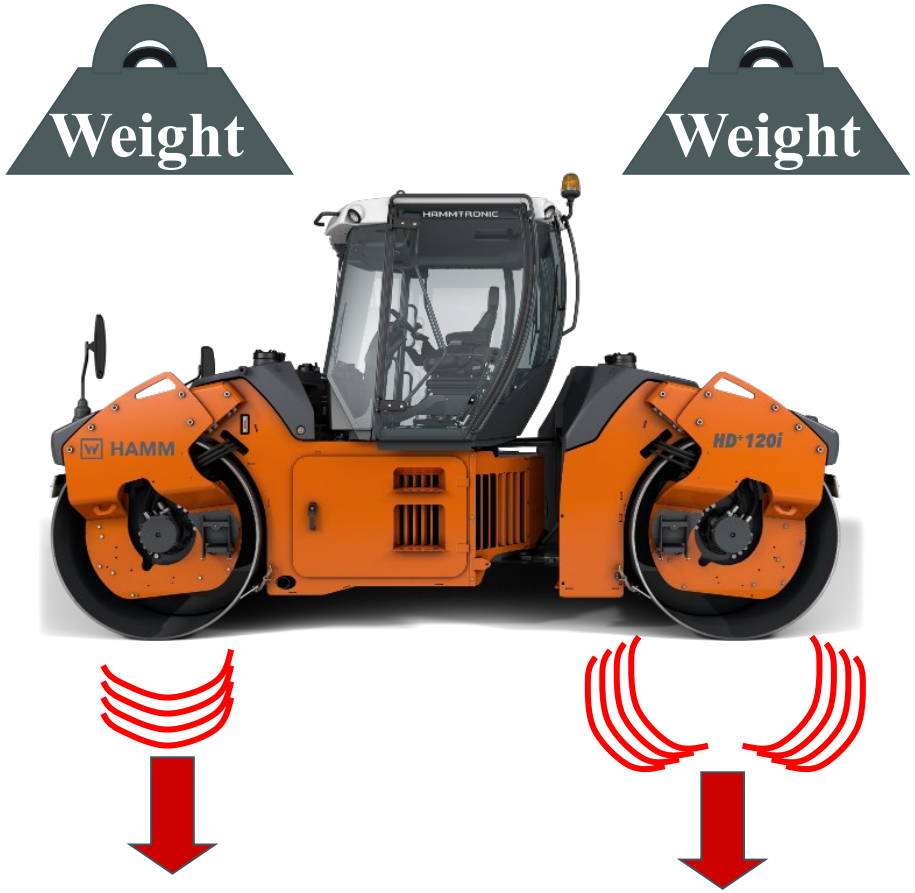
Tandem steel drums (OZZY)



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

Application(s): **All roller train positions**
(Extended rolling time, no crushing, smoothness, joints)

Key Roller Design Specifications Affecting Compaction

Design Specifications

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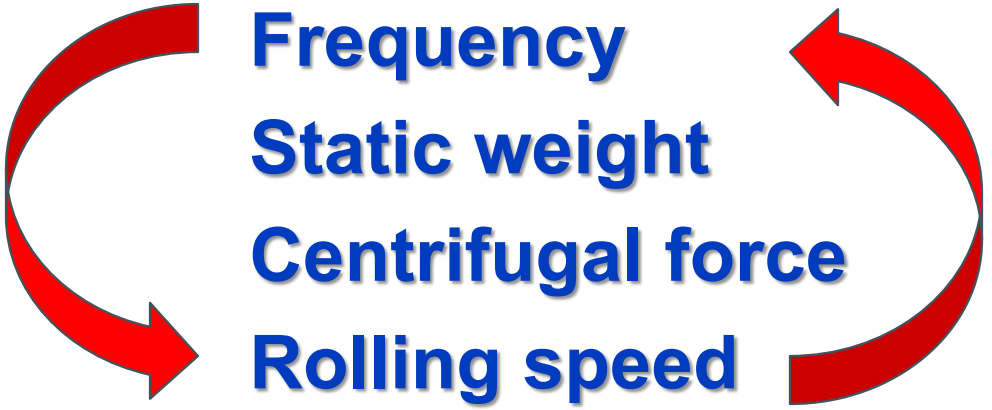
Key roller design specifications affecting compaction

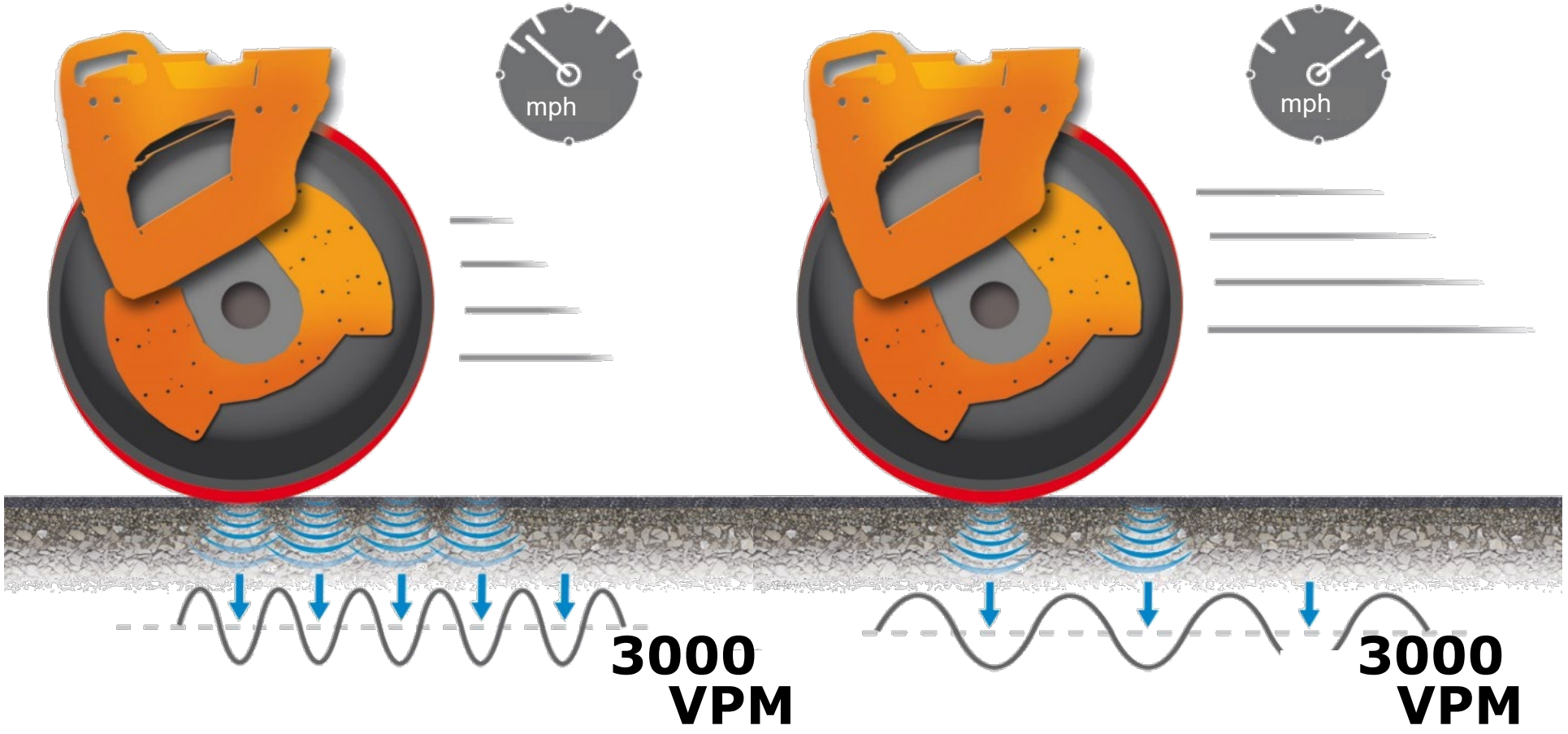


Amplitude
Frequency
Static weight
Centrifugal force
Rolling speed
Drum diameter
Drum activation controls
Drum water & scrapers
Drum offset

Frequency vs. Speed

HAMM

Speed can kill



Centrifugal Force

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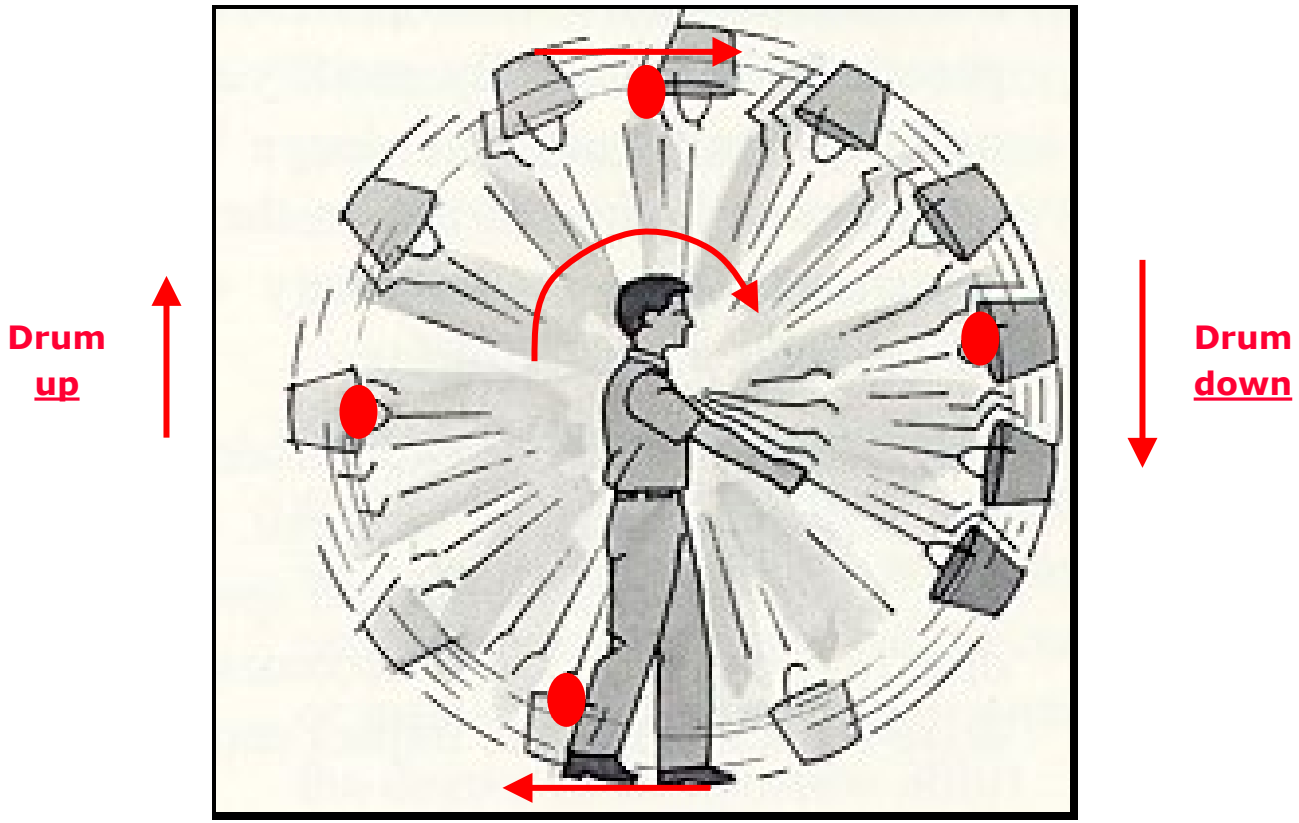
Centrifugal force principle

Centrifugal forces are generated by eccentrics in rotation

Heavier the eccentric weight – greater the generated force

Faster the eccentric rotation – greater the generated force

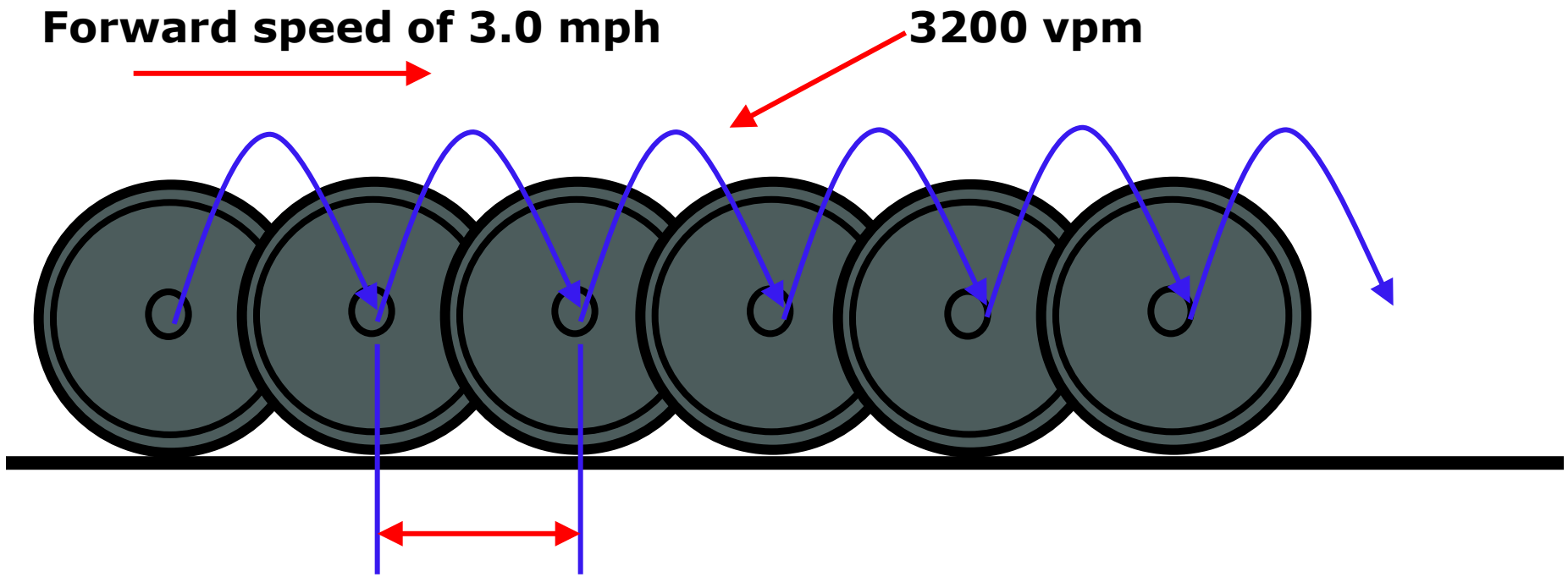


Frequency & Rolling Speed

HAMM

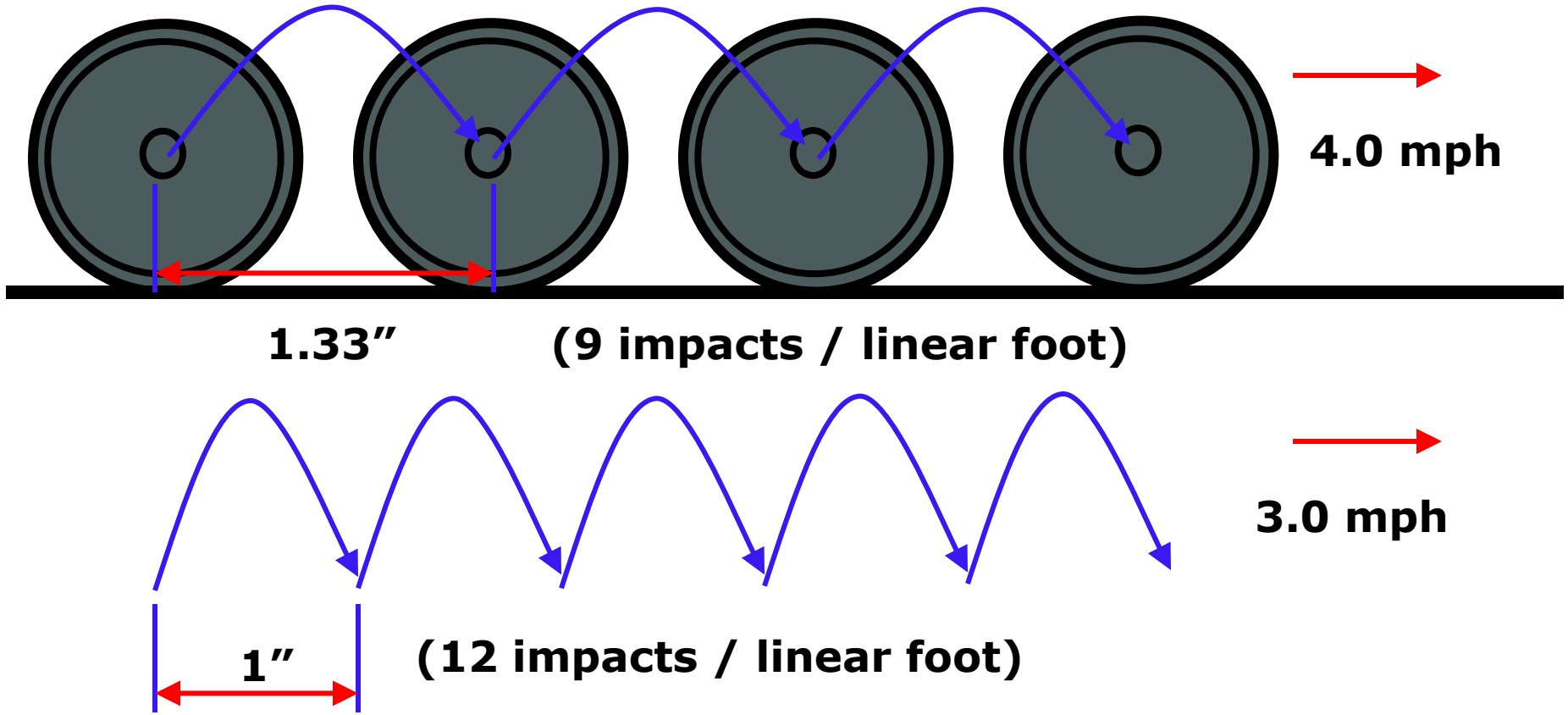
Frequency + forward speed = (impact spacing)

The animation will show the relation between
Eccentric frequency – roller travel speed – impact spacing



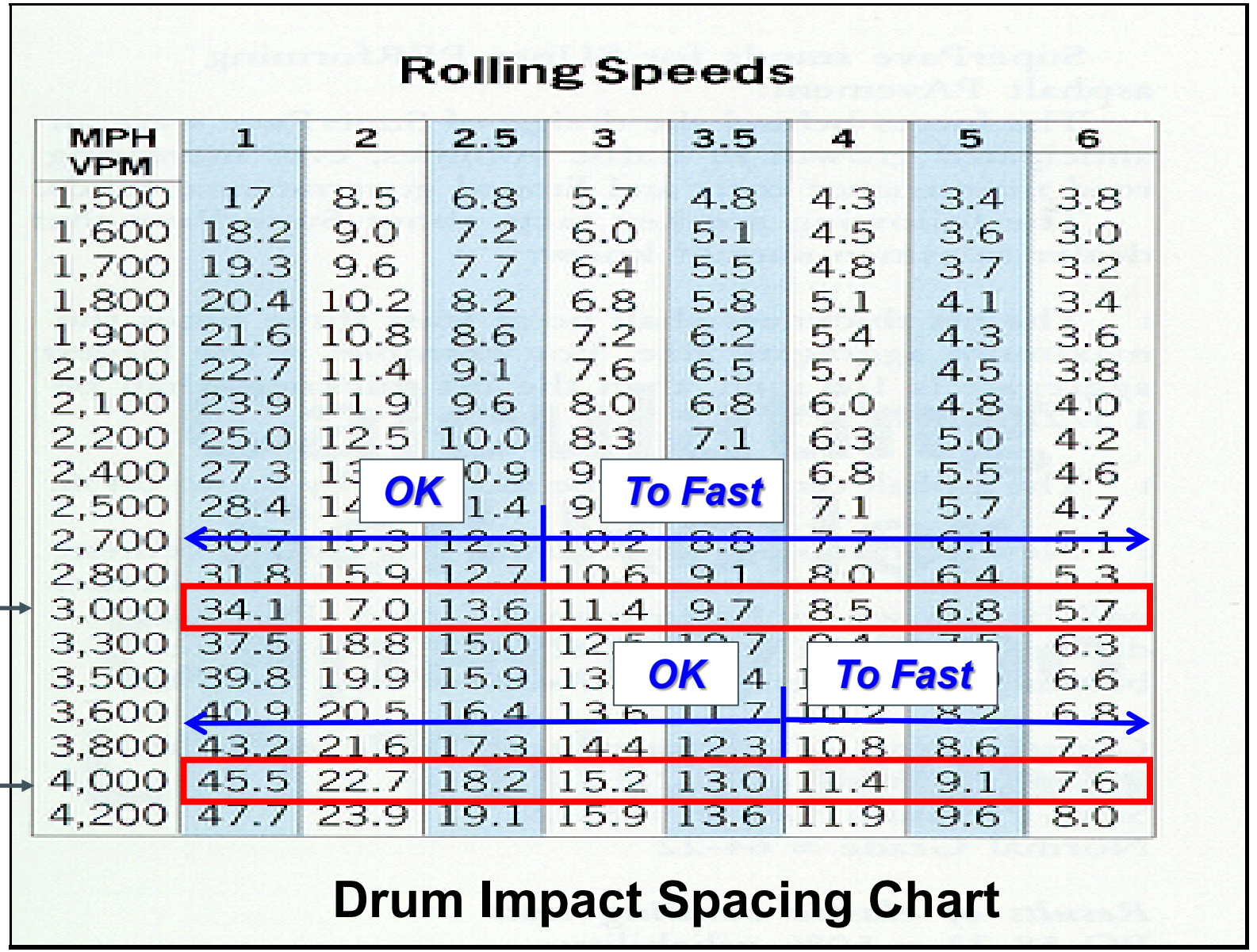
Frequency & Rolling Speed

For the SAME eccentric rotation of 3200 vpm, if I ACCELERATE to 4.0mph the IMPACT SPACING will now INCREASE to …



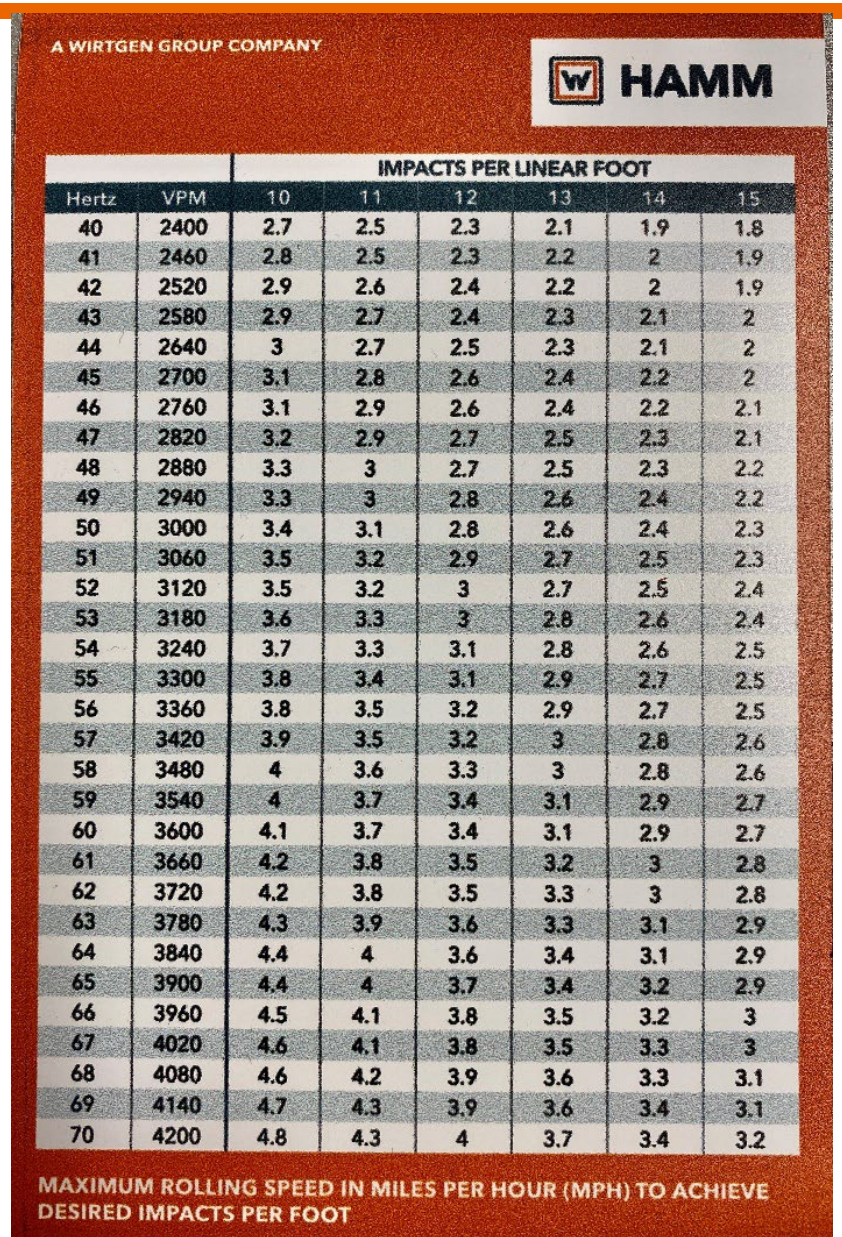
Frequency & Rolling Speed

HAMM



Frequency & Rolling Speed

HAMM



A WIRTGEN GROUP COMPANY

HAMM

		IMPACTS PER LINEAR FOOT					
Hertz	VPM	10	11	12	13	14	15
40	2400	2.7	2.5	2.3	2.1	1.9	1.8
41	2460	2.8	2.5	2.3	2.2	2	1.9
42	2520	2.9	2.6	2.4	2.2	2	1.9
43	2580	2.9	2.7	2.4	2.3	2.1	2
44	2640	3	2.7	2.5	2.3	2.1	2
45	2700	3.1	2.8	2.6	2.4	2.2	2
46	2760	3.1	2.9	2.6	2.4	2.2	2.1
47	2820	3.2	2.9	2.7	2.5	2.3	2.1
48	2880	3.3	3	2.7	2.5	2.3	2.2
49	2940	3.3	3	2.8	2.6	2.4	2.2
50	3000	3.4	3.1	2.8	2.6	2.4	2.3
51	3060	3.5	3.2	2.9	2.7	2.5	2.3
52	3120	3.5	3.2	3	2.7	2.5	2.4
53	3180	3.6	3.3	3	2.8	2.6	2.4
54	3240	3.7	3.3	3.1	2.8	2.6	2.5
55	3300	3.8	3.4	3.1	2.9	2.7	2.5
56	3360	3.8	3.5	3.2	2.9	2.7	2.5
57	3420	3.9	3.5	3.2	3	2.8	2.6
58	3480	4	3.6	3.3	3	2.8	2.6
59	3540	4	3.7	3.4	3.1	2.9	2.7
60	3600	4.1	3.7	3.4	3.1	2.9	2.7
61	3660	4.2	3.8	3.5	3.2	3	2.8
62	3720	4.2	3.8	3.5	3.3	3	2.8
63	3780	4.3	3.9	3.6	3.3	3.1	2.9
64	3840	4.4	4	3.6	3.4	3.1	2.9
65	3900	4.4	4	3.7	3.4	3.2	2.9
66	3960	4.5	4.1	3.8	3.5	3.2	3
67	4020	4.6	4.1	3.8	3.5	3.3	3
68	4080	4.6	4.2	3.9	3.6	3.3	3.1
69	4140	4.7	4.3	3.9	3.6	3.4	3.1
70	4200	4.8	4.3	4	3.7	3.4	3.2

MAXIMUM ROLLING SPEED IN MILES PER HOUR (MPH) TO ACHIEVE DESIRED IMPACTS PER FOOT

Rolling Speed Example

HAMM

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

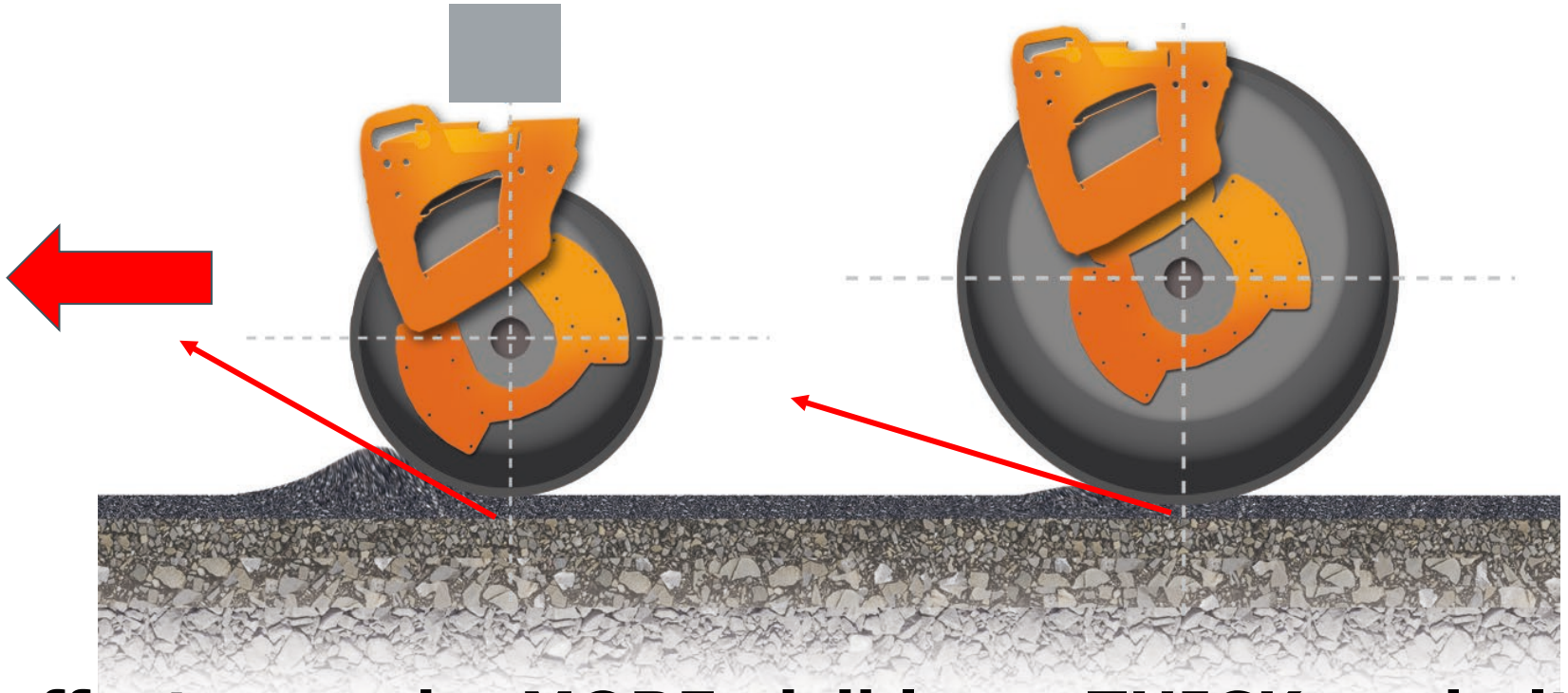
Drum Diameter

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

External Factors Affecting Compaction

External Factors?

Don’t go blaming the roller…

Fact is, it’s rarely the rollers fault!

External Factors?

HAMM

External Factors Affecting Compaction:

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

Asphalt

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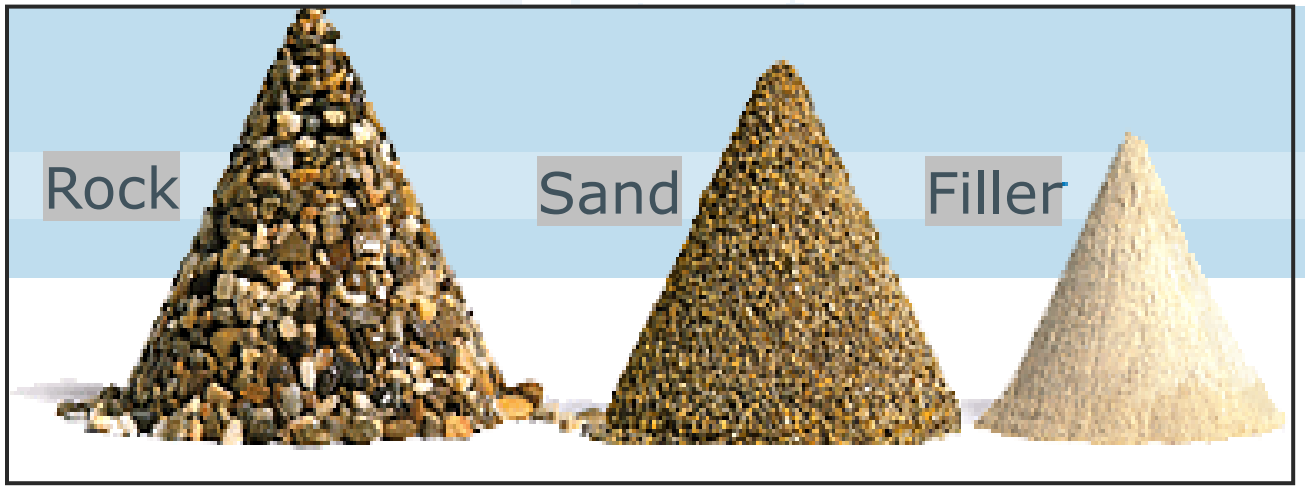
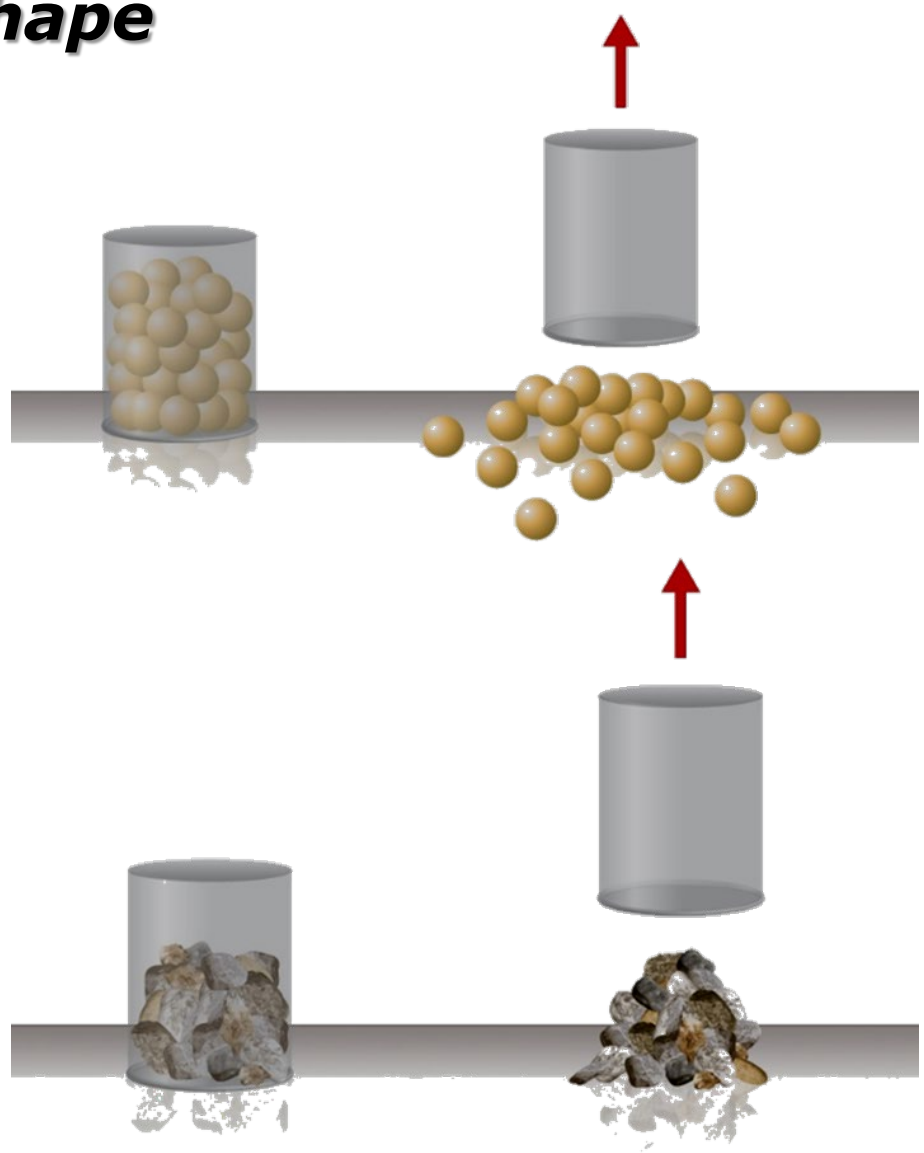
What is asphalt?

Bitumen
+
Aggregates



Mix Design

Particle shape



Mix Type & Design

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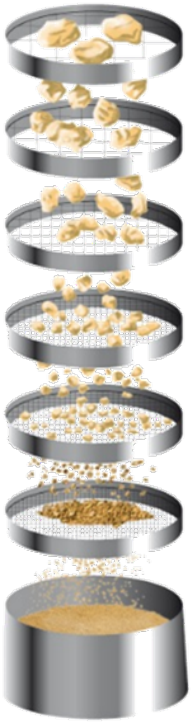
A science of its own

The main components can be summarized as follows:



Gradation of stones & fines

Bitumen

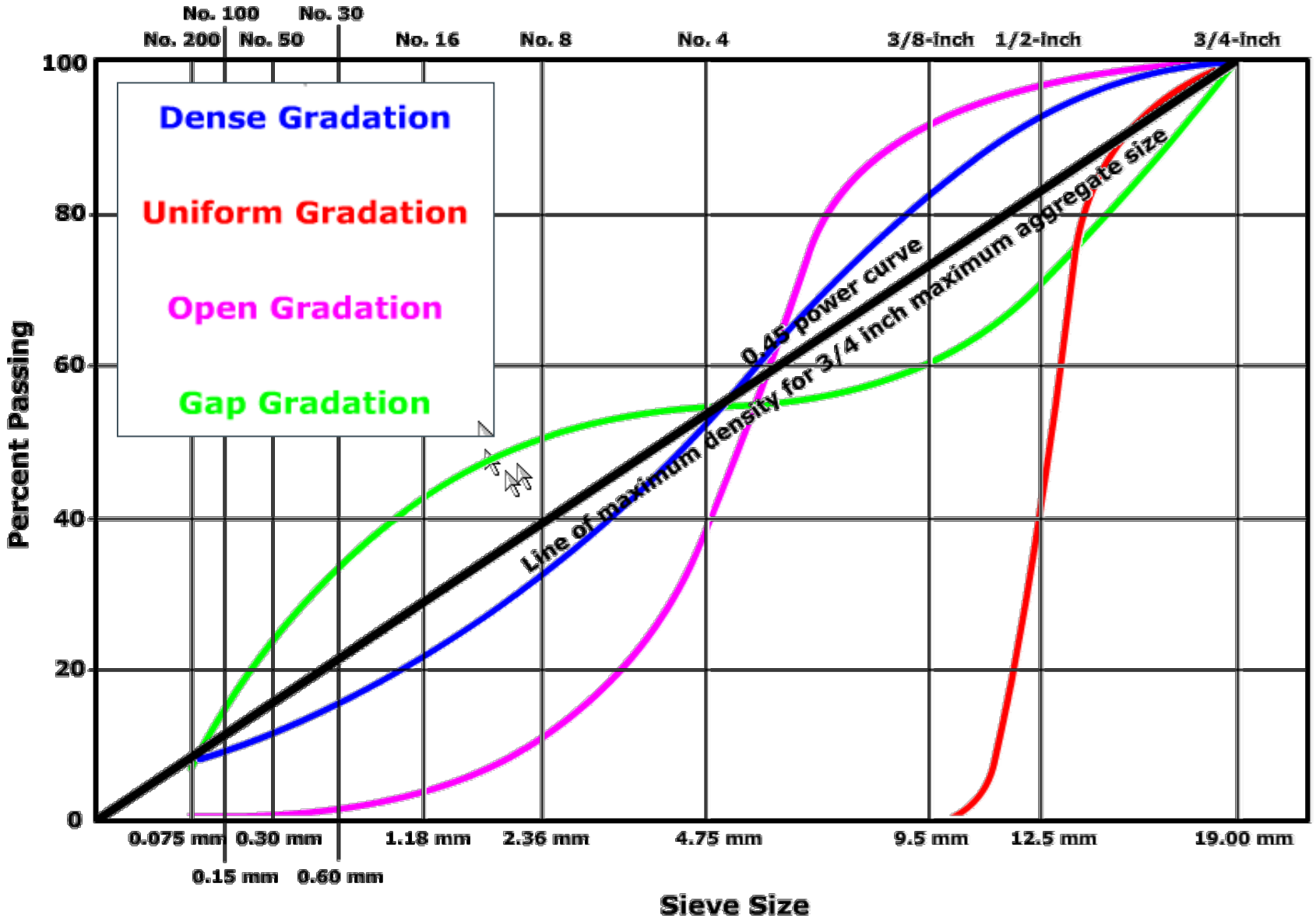
<u>Modifiers</u>

(Polymers, rubber, liquid anti-strip)

<u>Stabilizers</u>

(Fibers, crumb rubber, sulfur, hydrated lime)

Gradation Curve



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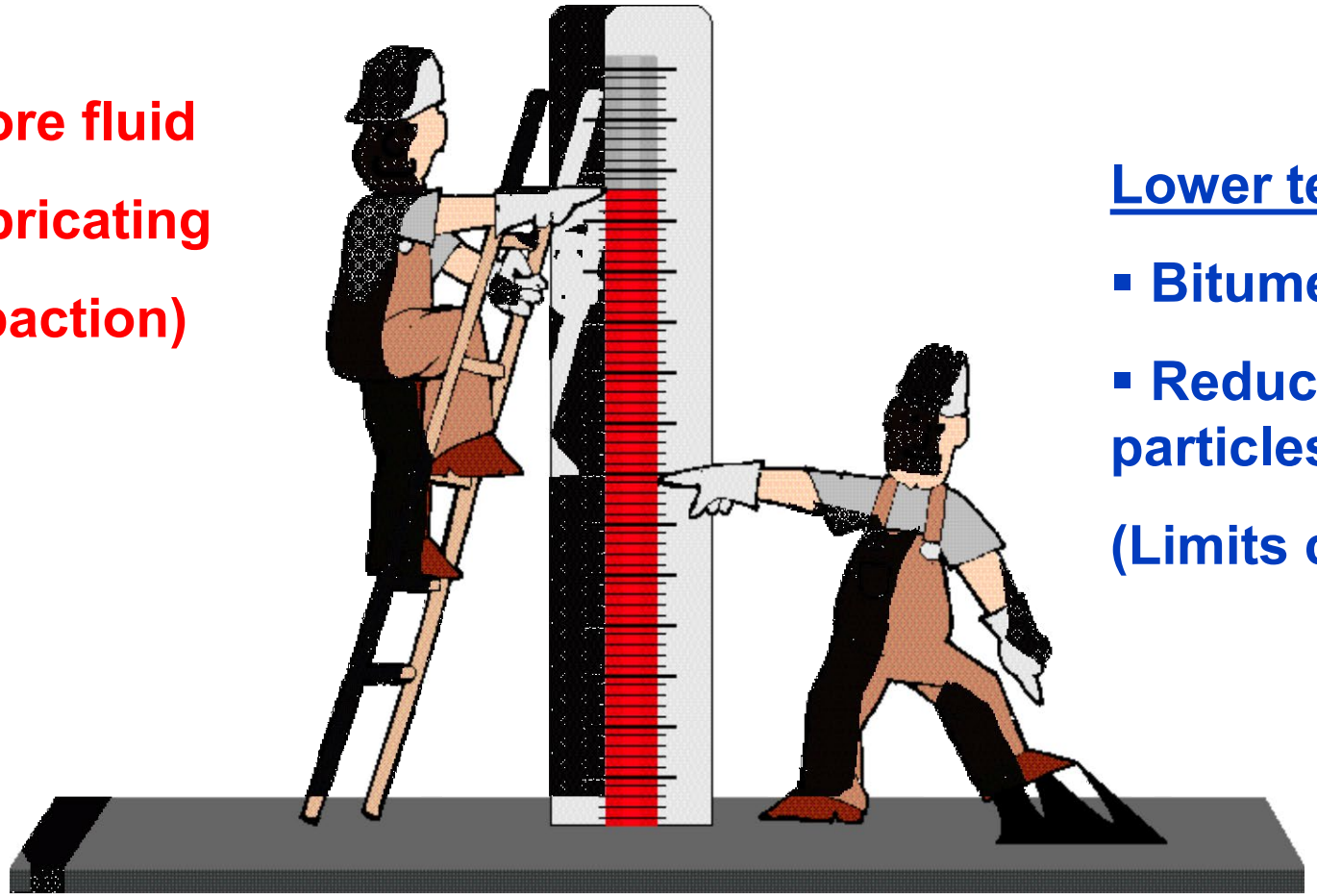
Hot mix & ambient temperature

Higher temp.

- Bitumen is more fluid
- Bitumen is lubricating

(Good for compaction)



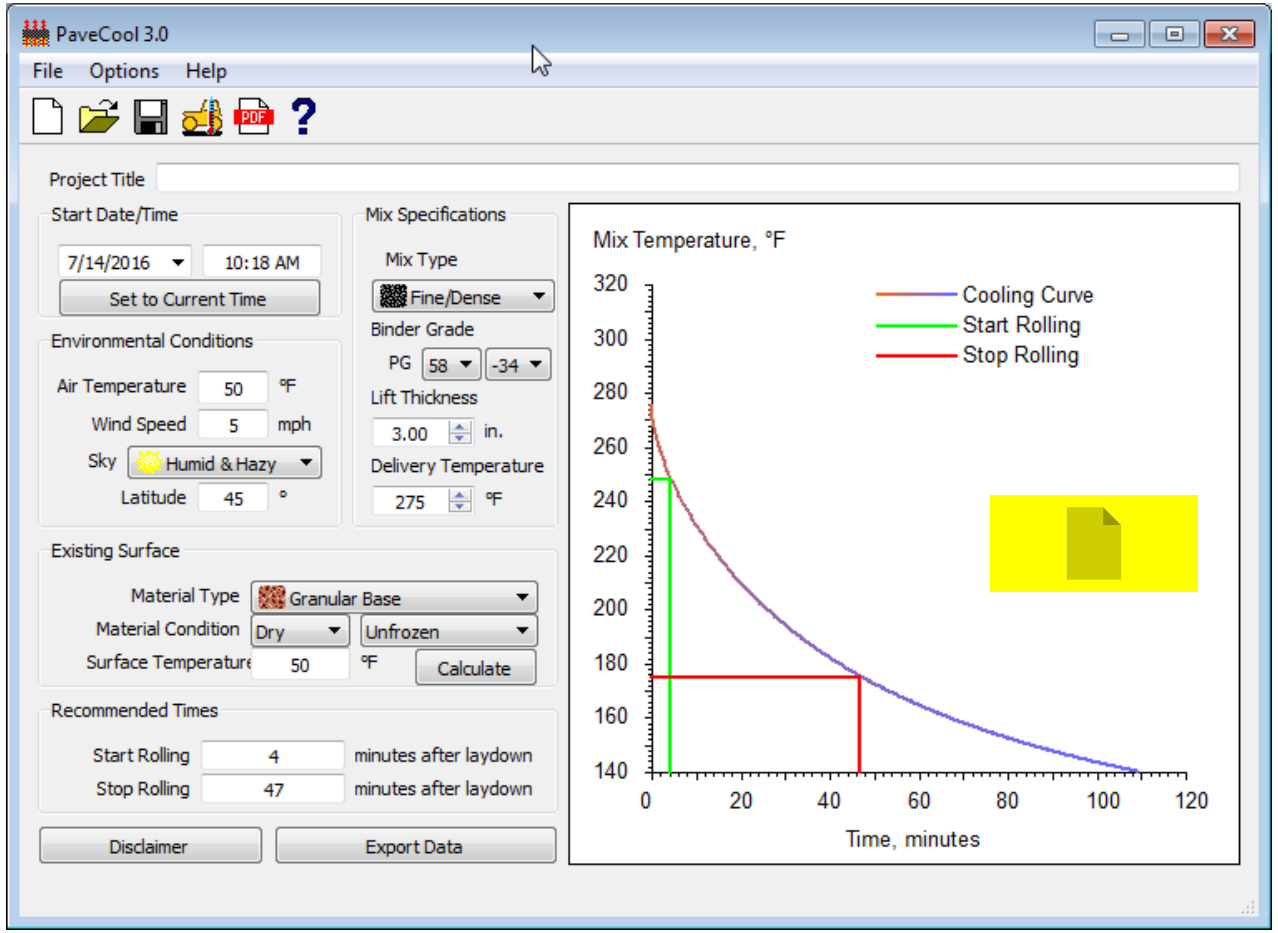
Lower temp.

- Bitumen is more stiff
- Reduces ability to move particles

(Limits compaction)

Temperature

Cooling rate = rolling time



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

OR

HAMM

Hot mix & ambient temperature

Temperature ranges can dictate the "roller train" set up

Temperature

Hot mix & ambient temperature

Cooling rate affected by…

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

Key Factors Affecting Rolling Patterns

Rolling Pattern

HAMM

Key factors affecting pattern

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

Rolling Pattern

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Basic rolling techniques

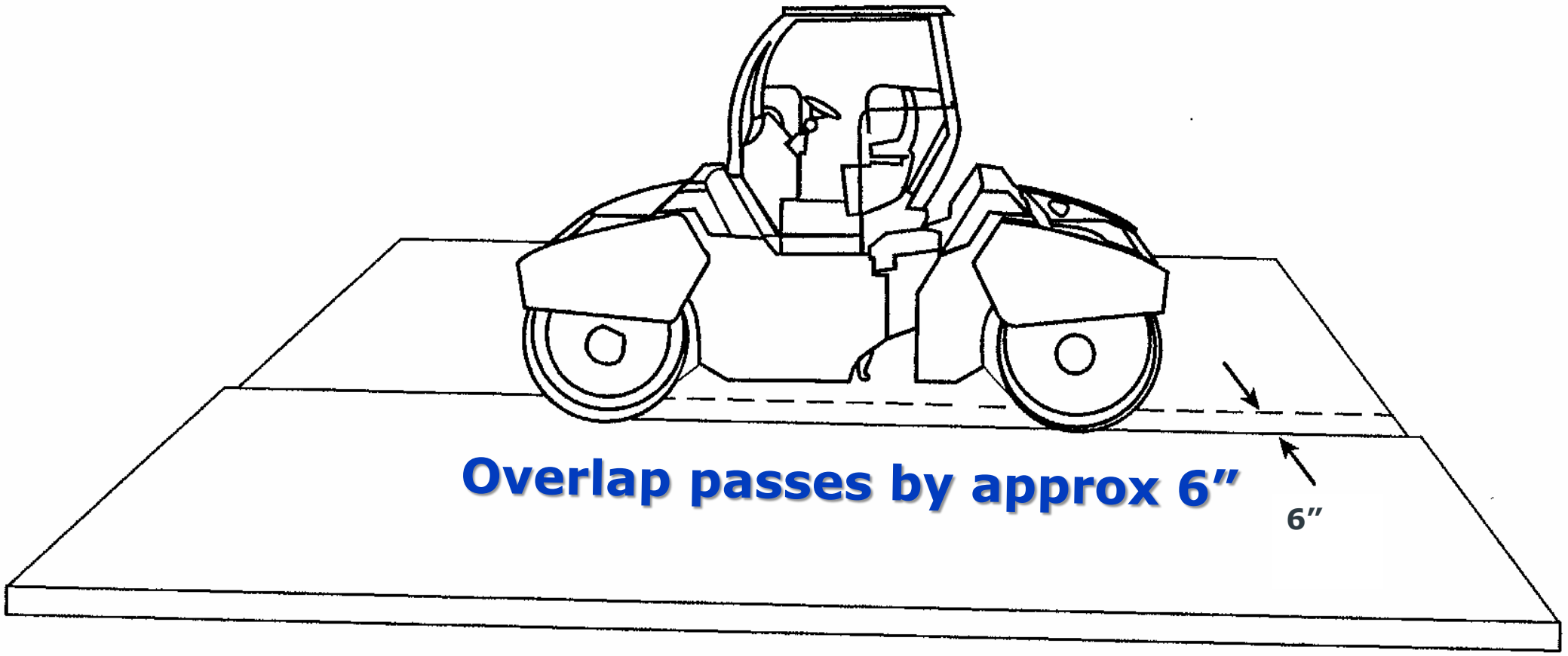
Never STOP on a soft mat

Never VIBRATE standing still

Rolling Pattern

HAMM

Basic rolling techniques



Rolling Pattern

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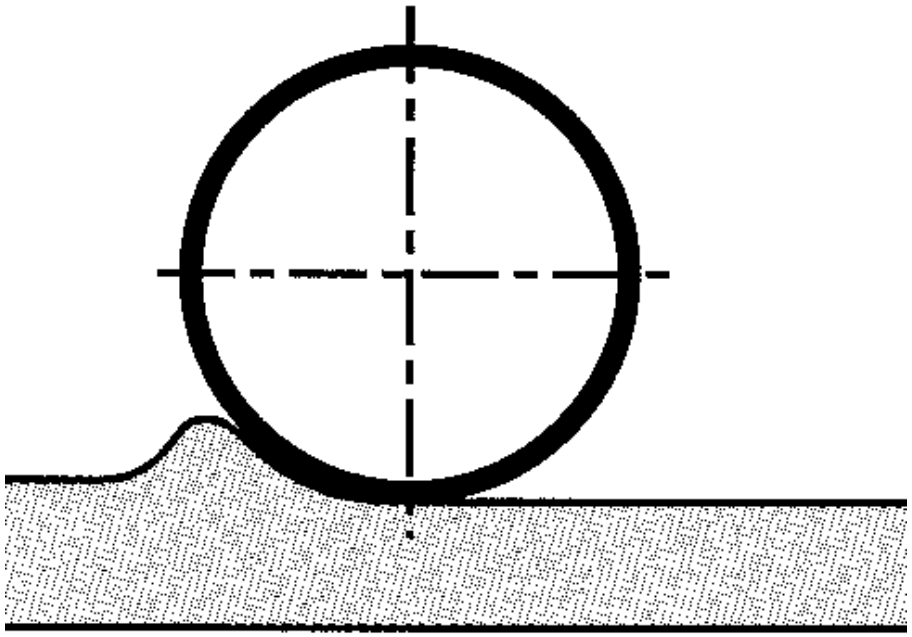
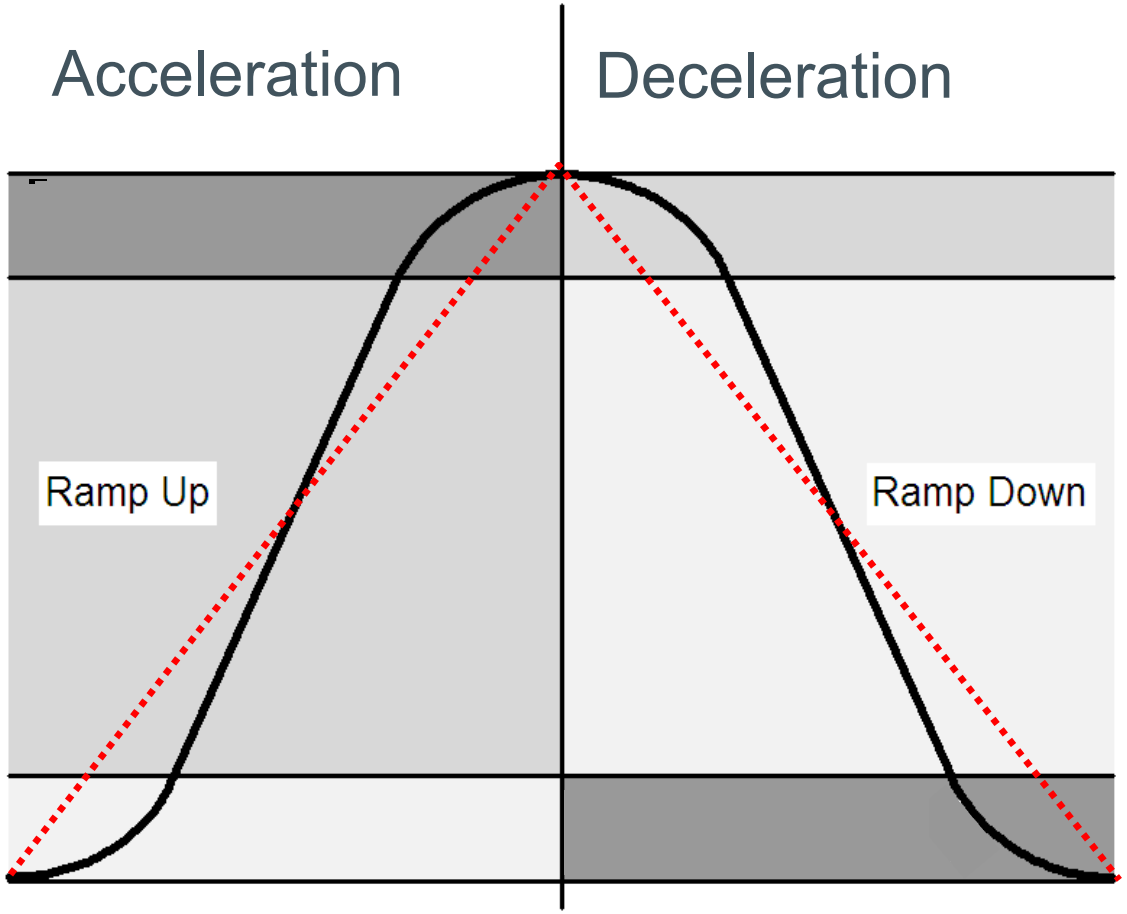
Basic rolling techniques

Need for delicate transitions

- **Smooth start**
- **Smooth stop**



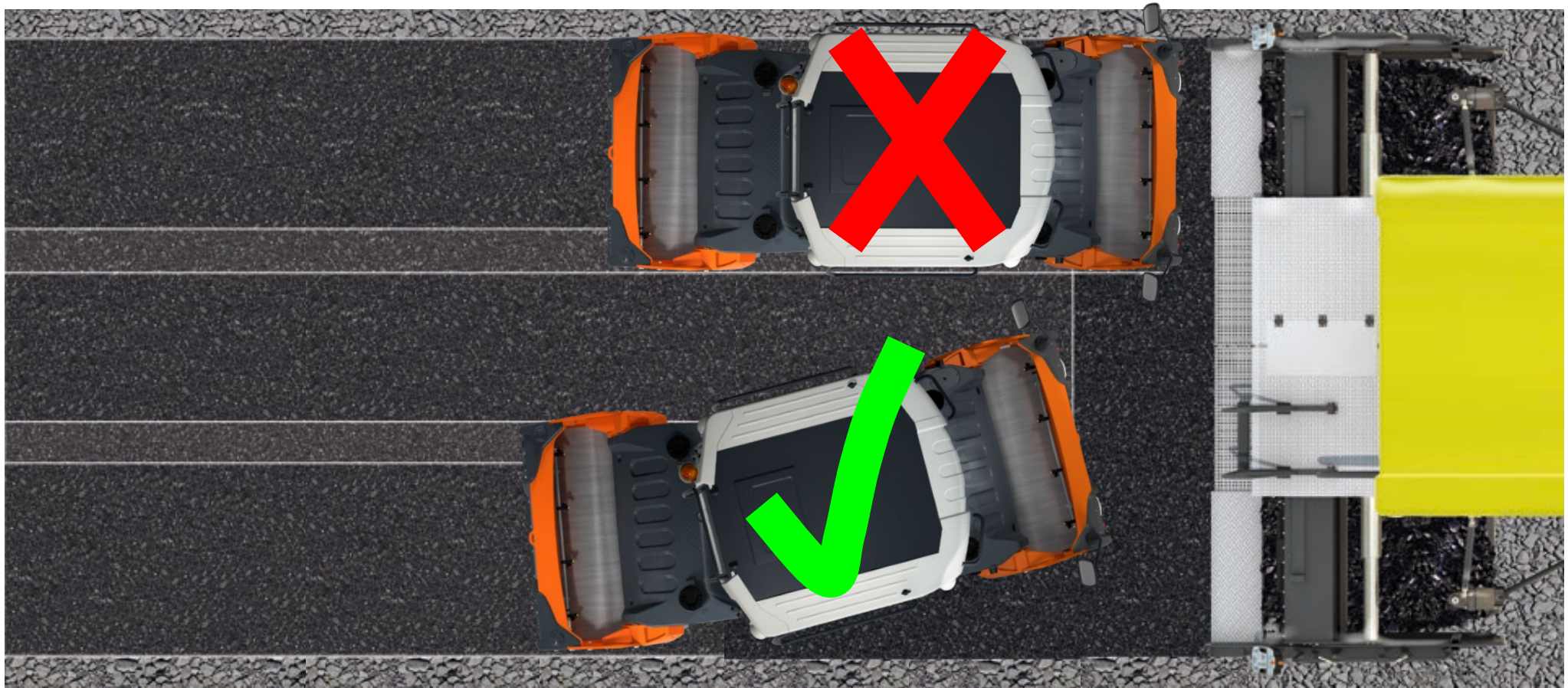


Rolling Pattern (Stopping)

HAMM

Basic rolling techniques

Always stop at an angle

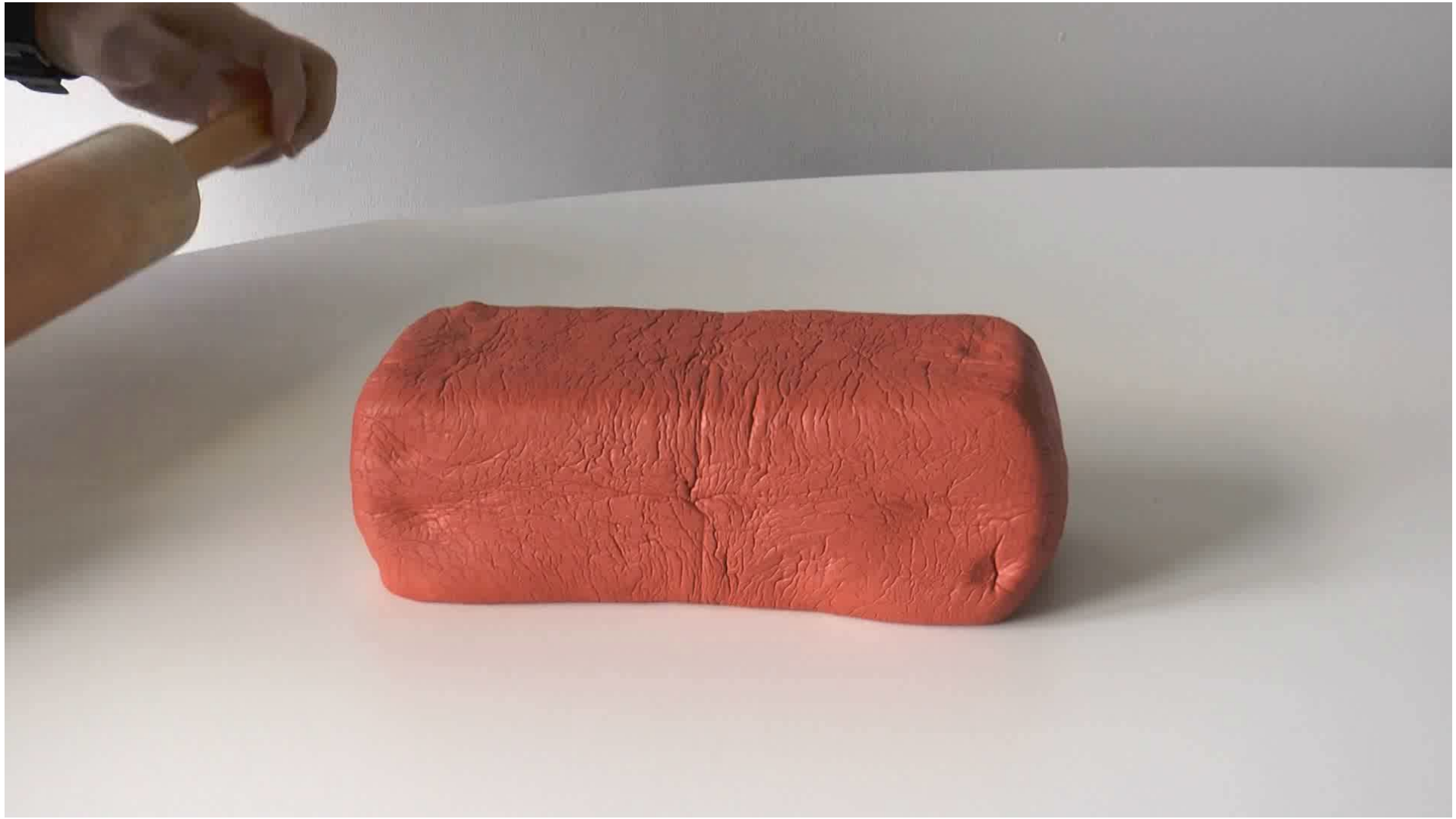


Rolling Pattern

HAMM

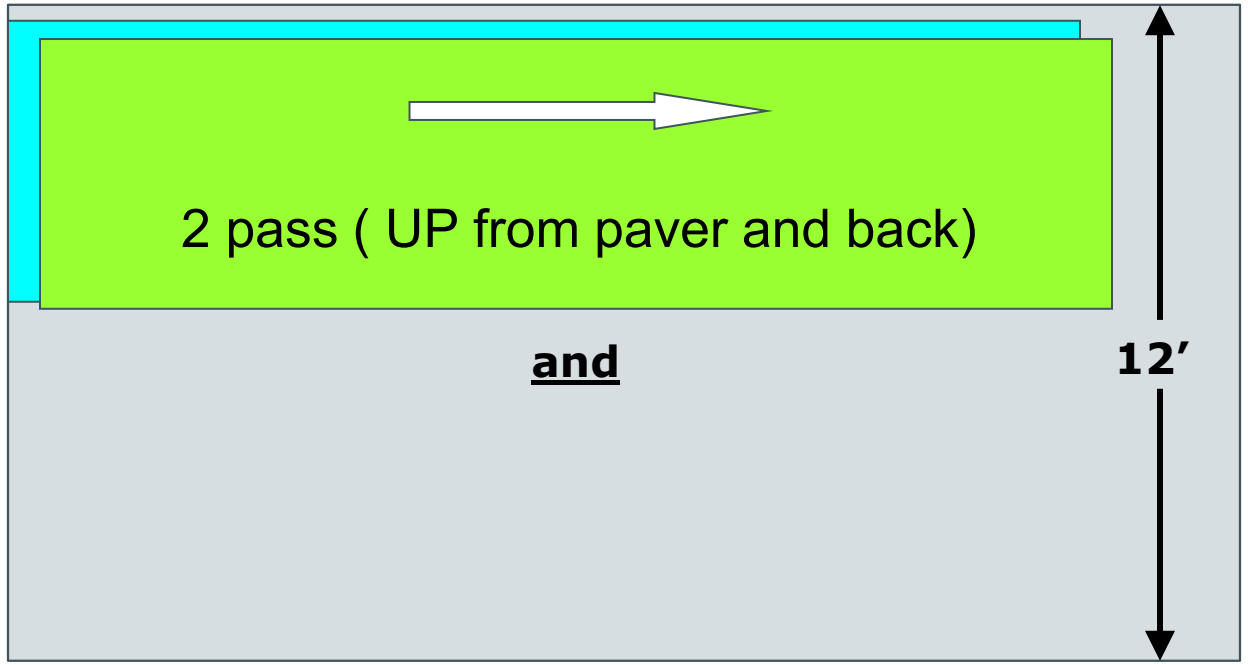
Basic rolling techniques

Always stop at an angle



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**



Rolling Pattern (Number of Coverage's)

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Coverage = Number of passes to cover the mat once

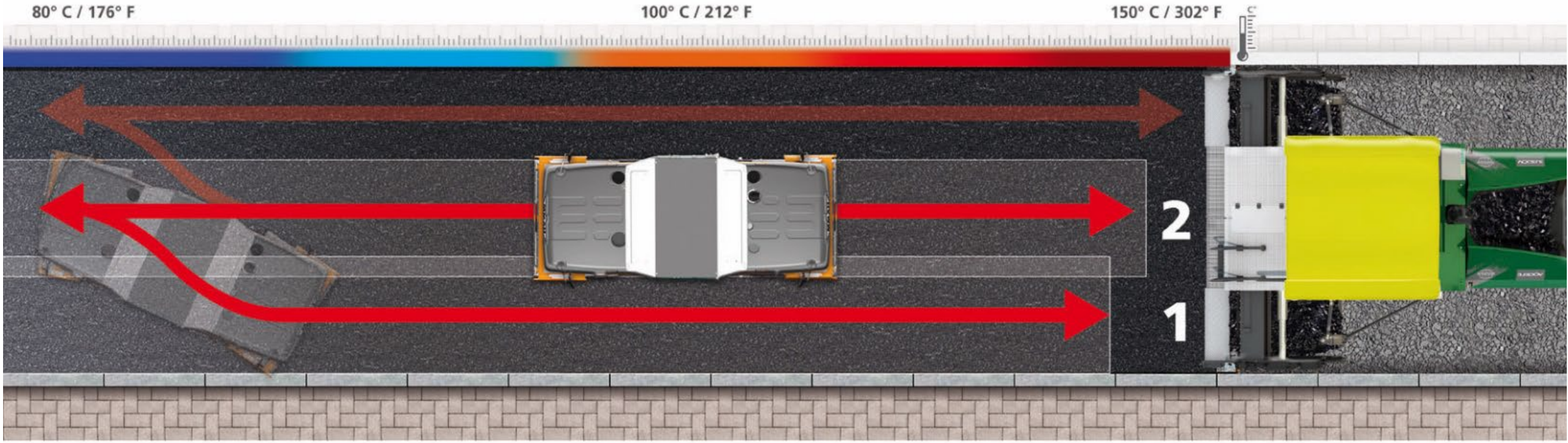
Number of coverages needed to achieve final density

<u>In this example 2 passes are needed to make 1 coverage</u>

Rolling Pattern

HAMM

Basic rolling techniques



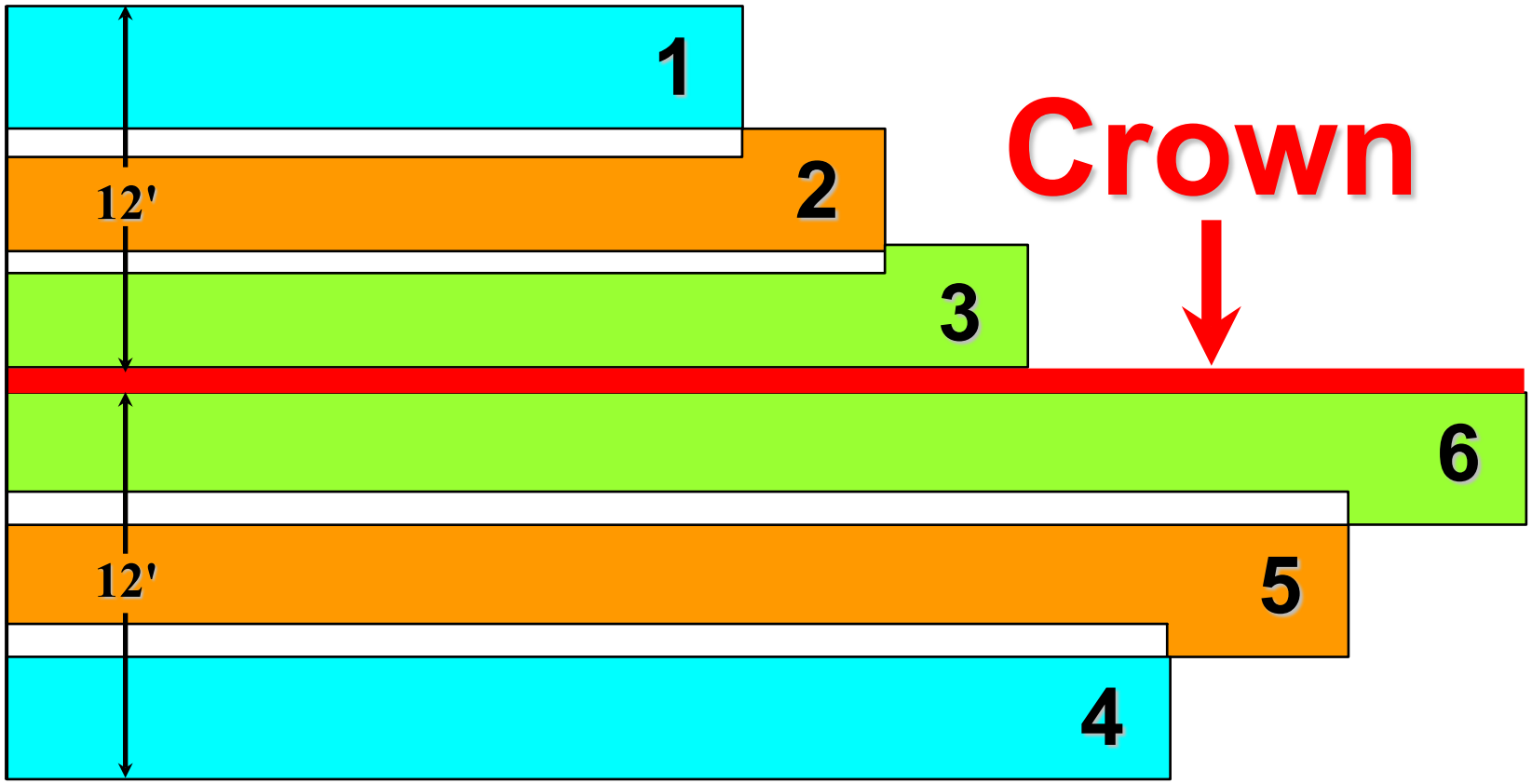
Change tracks on the coolest area of asphalt only

Rolling Pattern

HAMM

Basic rolling techniques

Try not to roll directly on crown line



Rolling Pattern

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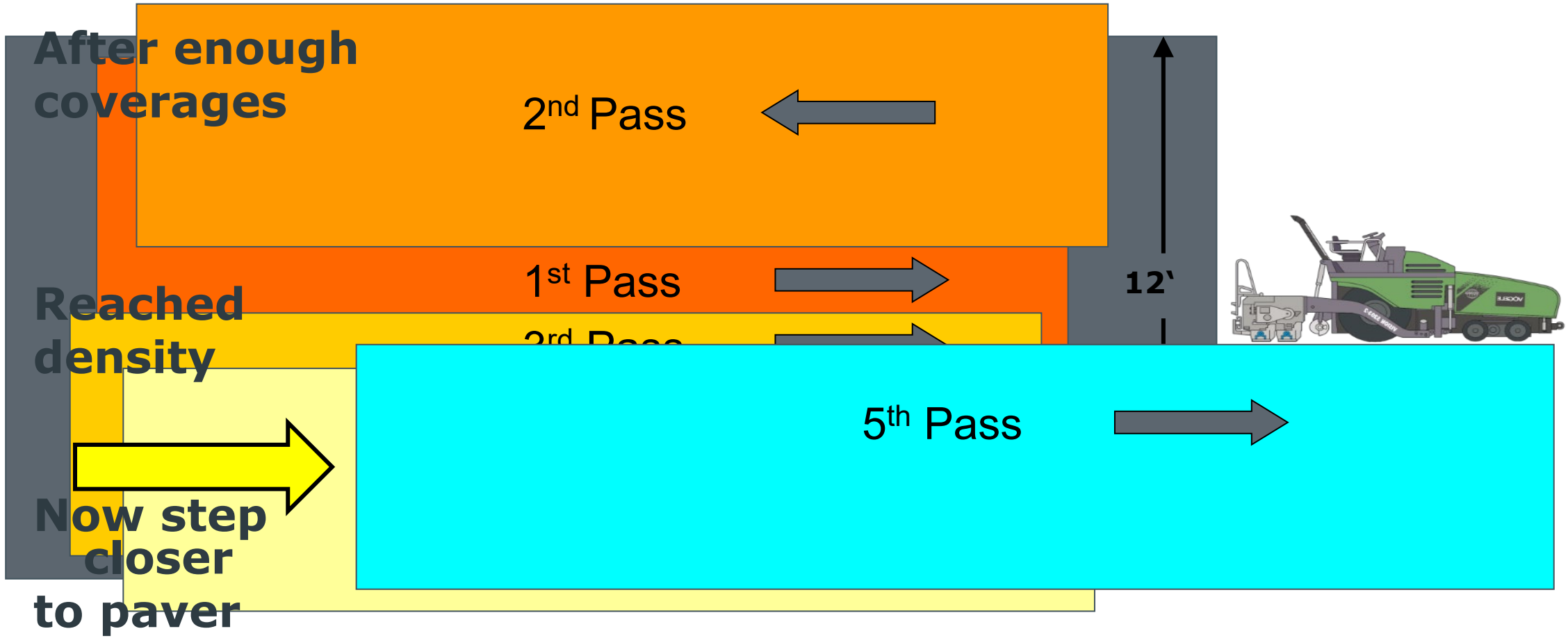
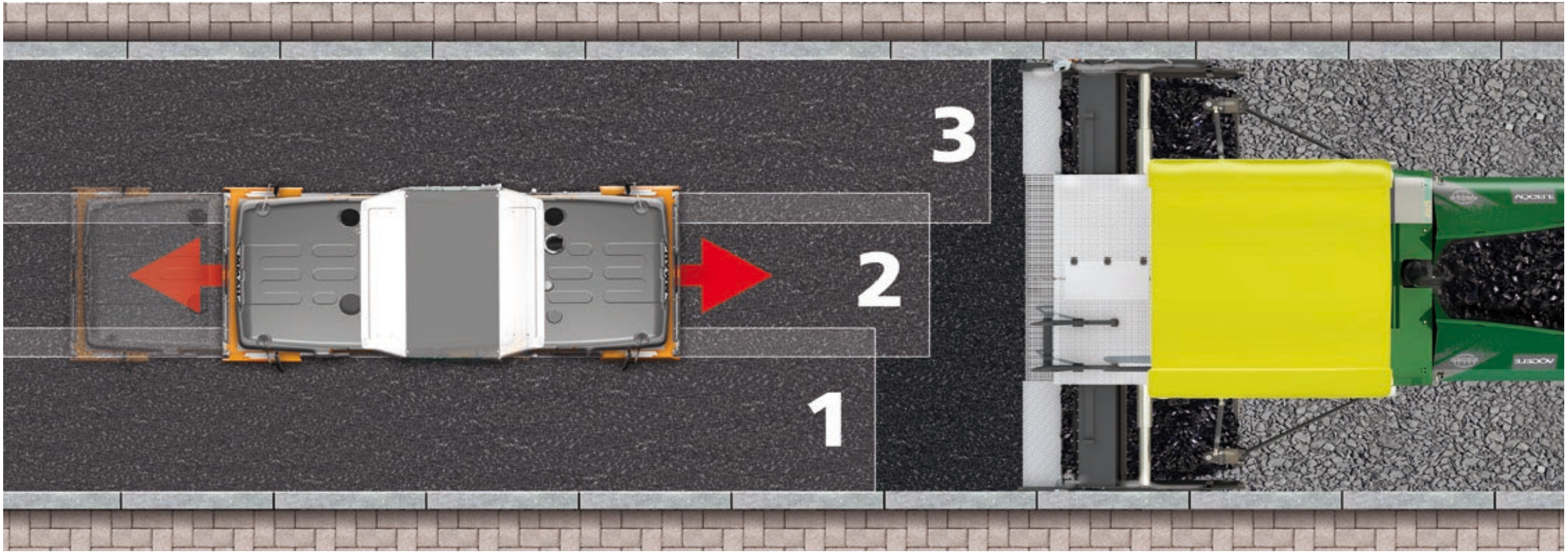
(Example) staggered 5 pass pattern



Rolling Pattern

HAMM

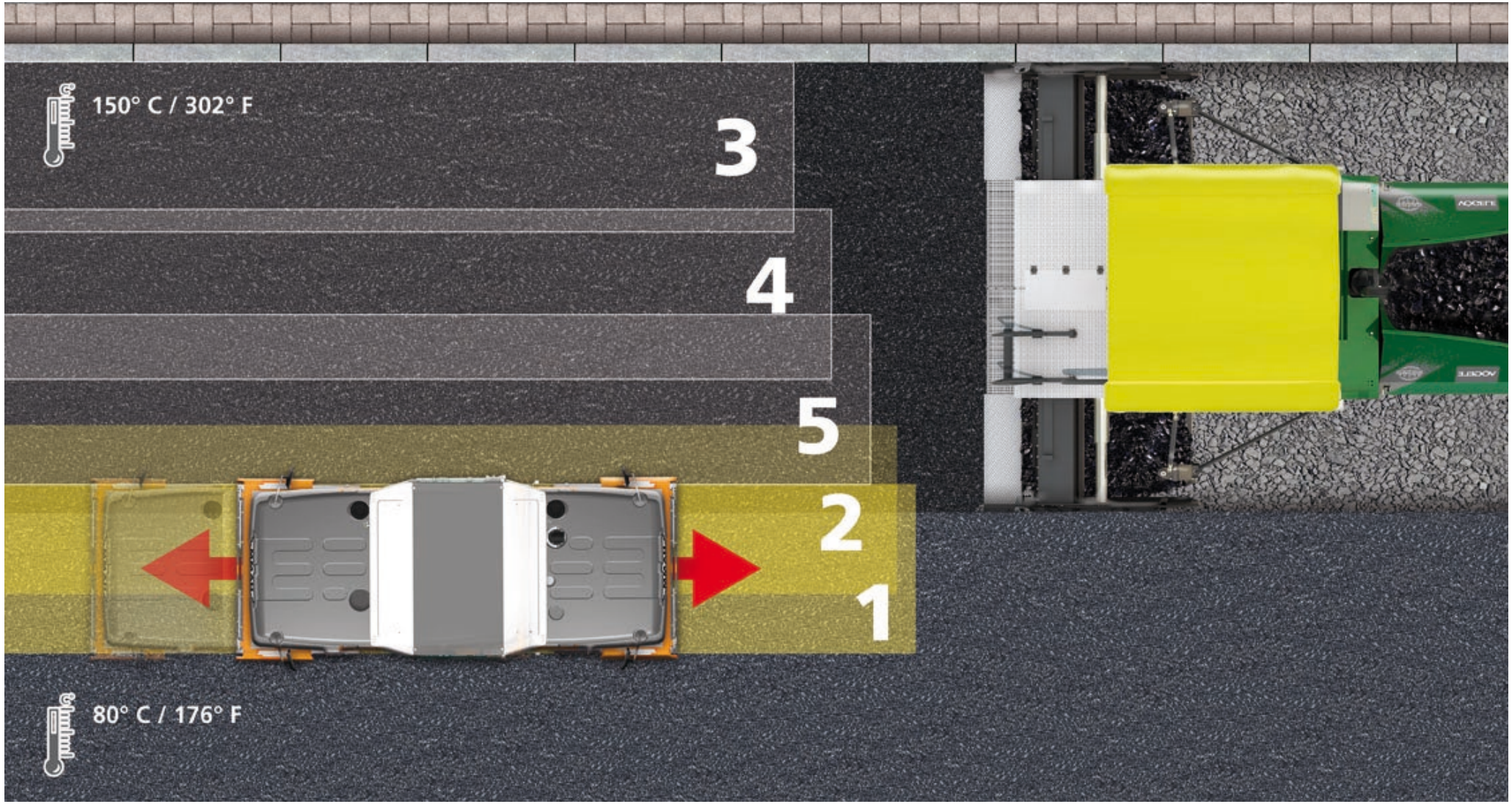
Basic rolling techniques



Compacting with supported edges on both sides

Rolling Pattern

HAMM



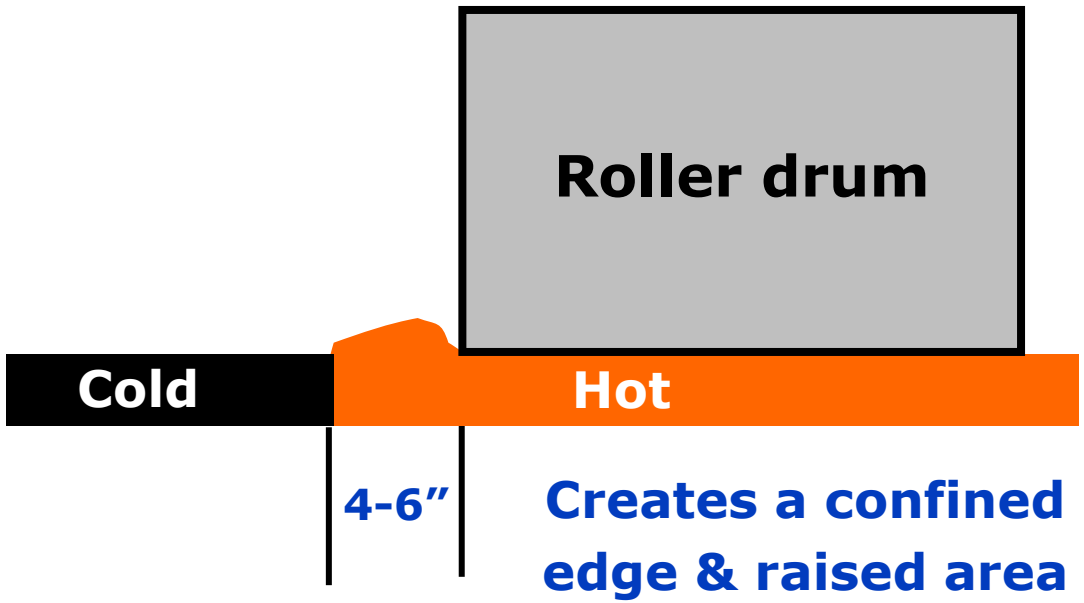
Compacting next to freshly paved lane

Rolling Pattern

HAMM

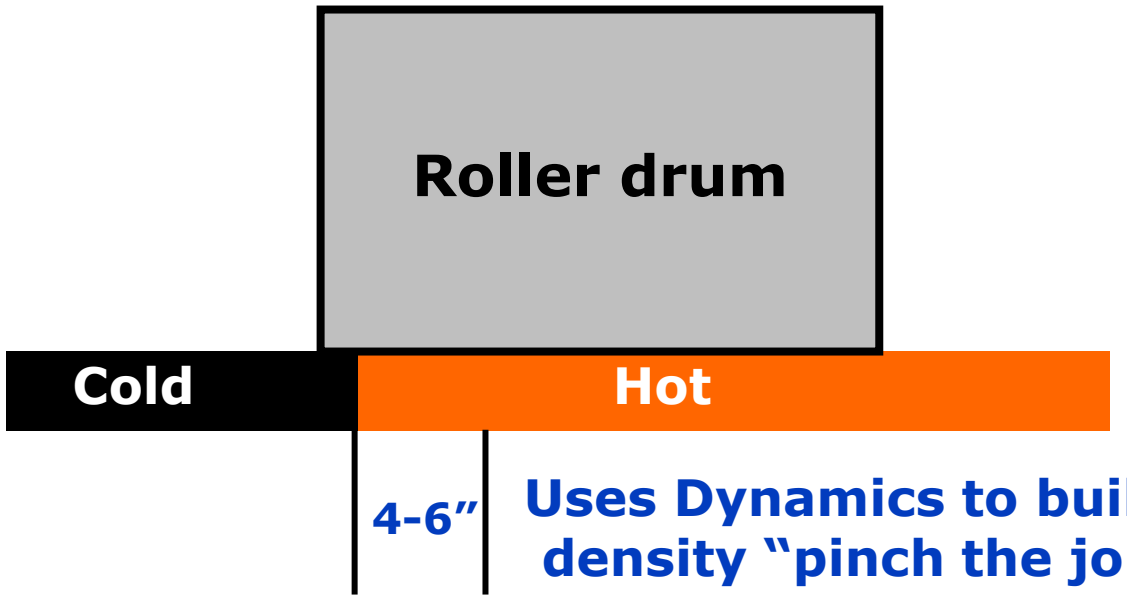
Longitudinal joint (VIBE roller)

1st Pass
off the joint



Creates a confined edge & raised area

2nd Pass
on the joint



Uses Dynamics to build density “pinch the joint”

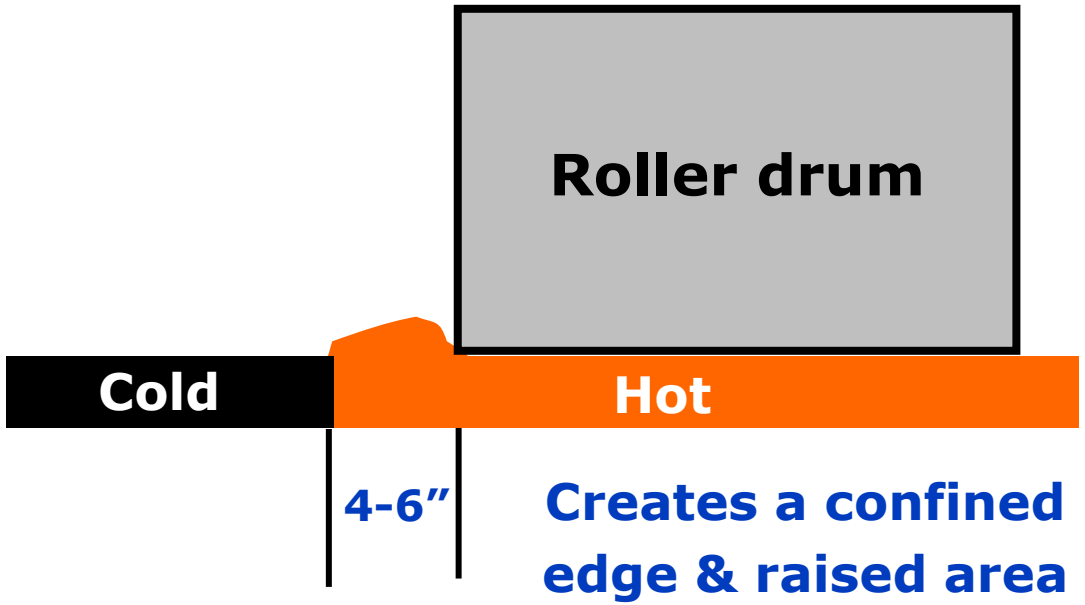
Rolling Pattern (Longitudinal Joint – Vibration)

Rolling Pattern

HAMM

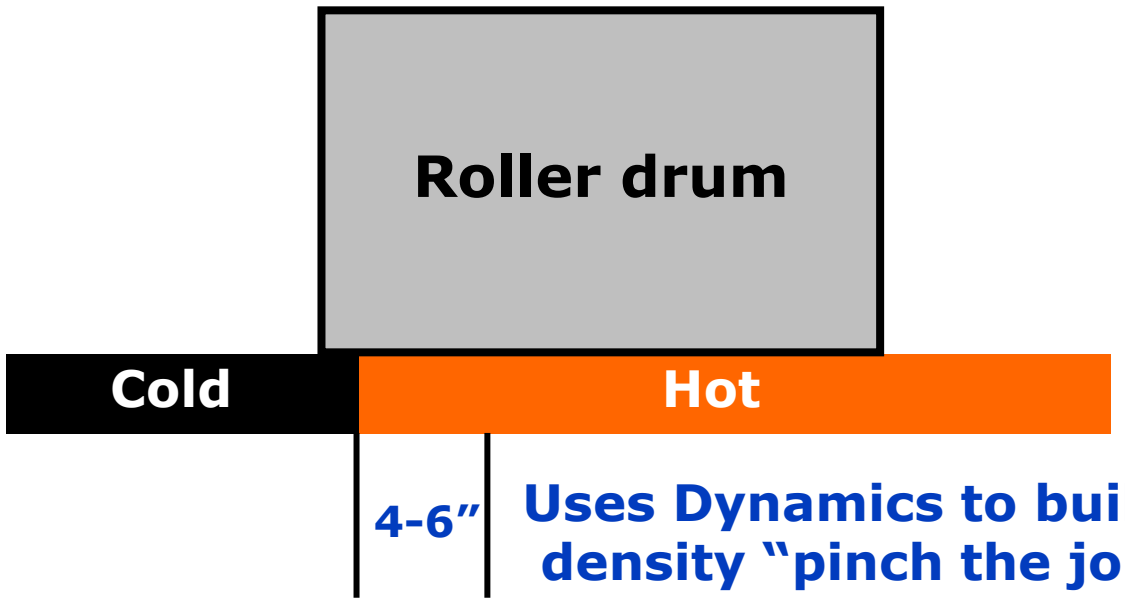
Longitudinal joint (*Ozzie roller*)

1st Pass
off the joint



Creates a confined edge & raised area

2nd Pass
on the joint



Uses Dynamics to build density “pinch the joint”

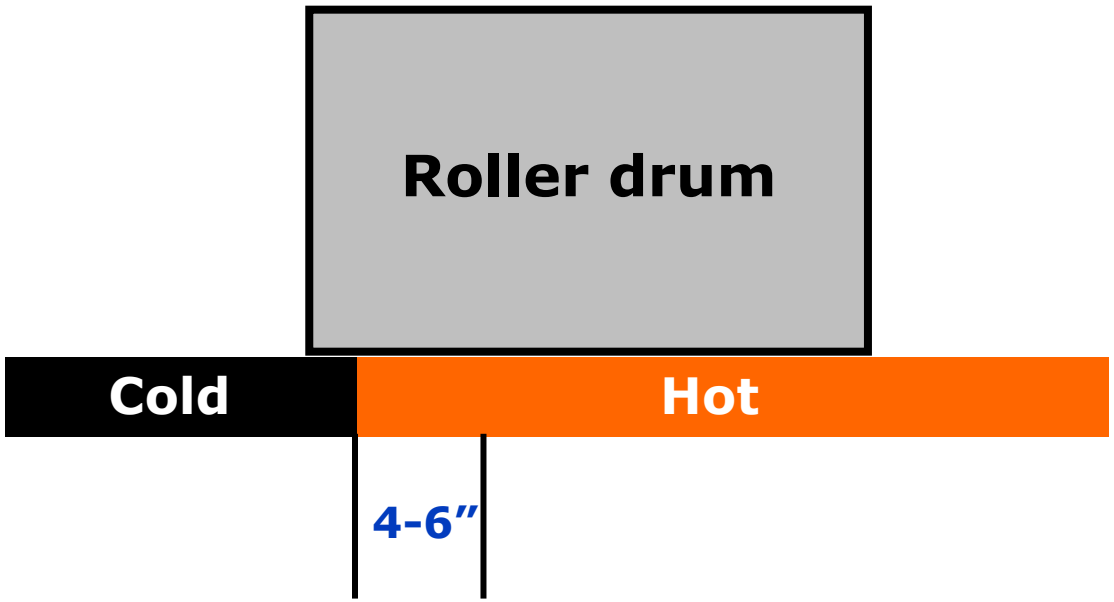
Same as Vibratory Roller

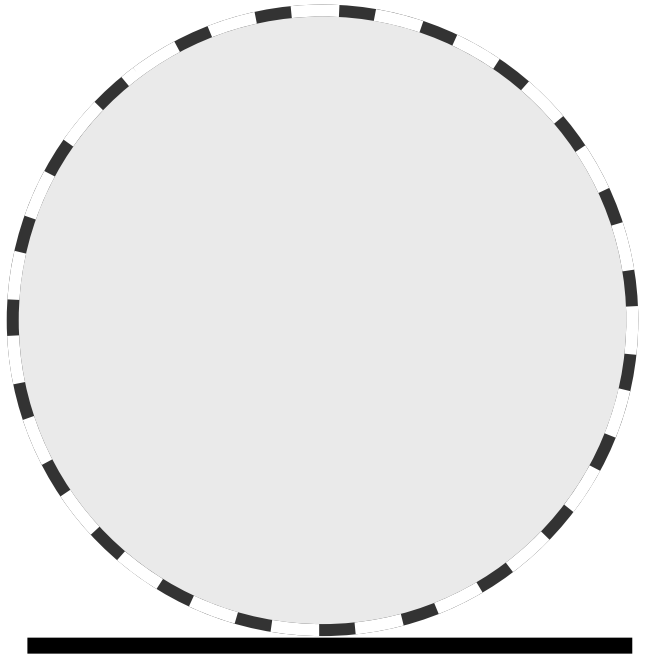
Rolling Pattern

HAMM

Longitudinal joint *(OZZY roller)*

2nd Pass
on the joint





Turn front drum off… Oscillation

allows for much higher joint densities

Rolling Pattern (Longitudinal Joint – Oscillation)

Joint Separation

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Intelligent Compaction

Why do we need IC?

Intelligent

HAMM

Definition

in·tel·li·gent (ĭn-tĕl'ə-jənt)

adj.

1. Having intelligence.
2. Having a high degree of intelligence; mentally acute.
3. Showing sound judgment and rationality: *an intelligent decision; an intelligent solution to the problem.*
4. Appealing to the intellect; intellectual: *a film with witty and intelligent*
5. *Computer Science* Having certain data storage and processing ca
intelligent terminal; intelligent peripherals.

… **sound judgment** and **rationality**

Ultimate Goal for IC

HAMM

- Gain the knowledge needed to develop credible and productive IC Specifications for future projects

- ***Consistency***

Why Intelligent Compaction?

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Shortcomings in the Compaction Process…

Limited "On The Fly" Feedback

Over or Under-Compaction Can Occur

Conventional Spot Testing

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Plate load test	Sampling (i.e. for proctor)	Troxler	Dynamic plate test

Proportion of spot-testings to the quantities placed

1 : 1,000,000

Dis

- **P**
- **Time consuming**
- **Small amount of samples**
- **Samples mostly close to surface**
- **Downtime of the machines**

Example: Counting of Passes

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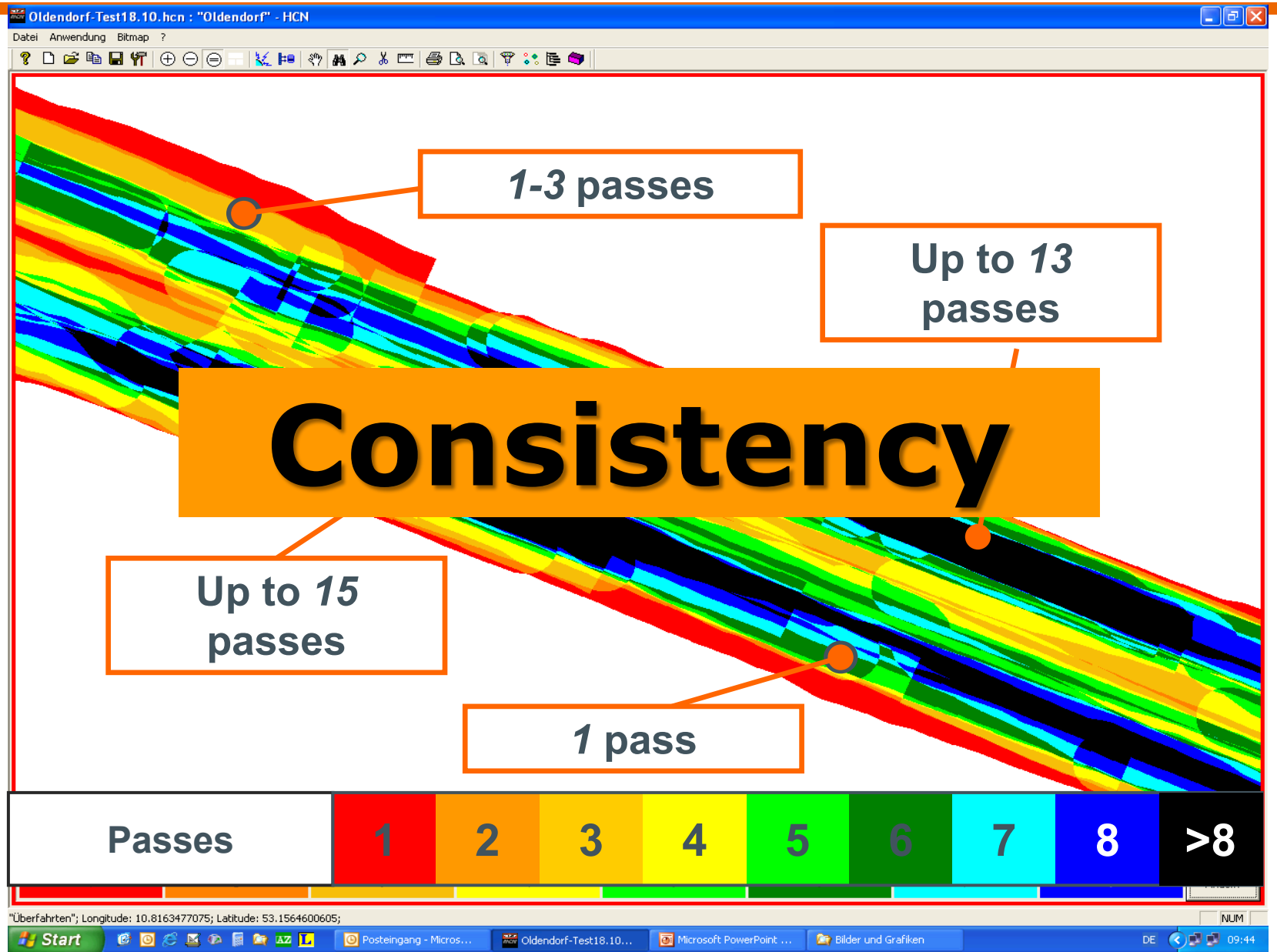

Summary

- Compaction
  - Needed for stability, Load bearing capacity, reducing water permeability
- 4 elements of compaction
  - Static, impact, dynamic, kneading
- Roller trains
  - Vary with location & specifications
- Roller Types
  - Match roller to project
- Roller design specs
  - Impact spacing most important (speed / Frequency)
- External factors affecting Compaction
  - Temp, Temp, Temp
- Intelligent Compaction
  - **Much more to come!!!!**

Thank You

HAMM