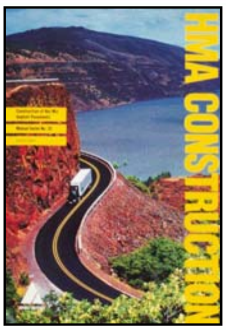
Compaction

"Victorious warriors win first and then go to war, while defeated warriors go to war first and then seek to win." —Sun-tzu



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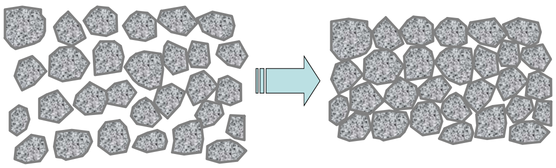
MS-22

Chapter 6-Compaction

What is Compaction?

The process of reducing the volume of a given mass of material.

Compaction Illustrated



Compaction

- Vital for Good Performance
- Compaction Goal
  - 4-8% Air Voids (Conventional Mixes)
  - 3-6% Air Voids (Coarse or Gap Graded Mixes)
- Requirements for Compaction
  - Compactive Effort
    - Use the right rollers
  - Good Mix Temperatures (Workable)
    - Haul length
    - Ambient conditions
  - Mixture Confinement
    - Lift thickness
    - Base support

Compaction Goals

- Increase stability
- Reduce air voids
- Provide a smooth surface

Factors Affecting Compaction

- Mixture properties
- Ambient conditions
- Lift thickness
- Base/subgrade support (confinement)
- Compactive effort

Factors Affecting Compaction

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Mixture Properties

- Materials characteristics
  - Asphalt binder
  - Aggregates
- Mix design
  - Aggregate structure
  - Volumetric properties
- Production variables
  - Moisture content
  - Temperature

Asphalt Binder Properties

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- Binder grade
  - Increase high temperature grade ➔ stiffer binder
  - Neat or modified?
    - PG grades with 92°C or more temperature difference are usually polymer modified
- Temperature
  - Must complete compaction while mix temperature exceeds:
    - 85°C (185°F) for neat binders
    - 100°C (212°F) for modified binders
    - 70°C (155°F) for warm mix binders?

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Polymer-Modified Asphalt

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- Stiffen at much higher temperatures than neat asphalt
  - Reduce time available for compaction by half
- When specifying binders that will likely be polymer-modified (PG 70-28, PG 76-22, etc.)
  - Avoid requiring compacted lift thickness less than two inches

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Aggregate Properties

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- Physical properties
  - Gradation
  - Angularity

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Contrasting Stone Skeletons

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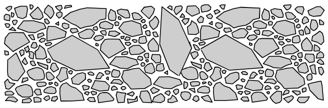
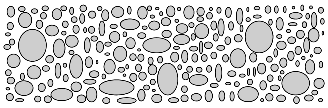


Angular Aggregate



Rounded Aggregate

Mixtures designed to resist rutting will also resist compaction!!!

Compaction

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- Moisture Content
  - Lubricants → tenderness
  - Most common with:
    - Drum plants
    - Mixes with RAP
    - Absorptive aggregates
    - Stockpiles that have been sitting

Compaction

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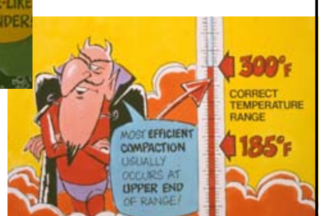

Factors Affecting Compaction

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- Mixture properties
- Ambient conditions
- Lift thickness
- Base/subgrade support (confinement)
- Compactive effort

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Ambient Conditions

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Mat Thickness	Base Temperatures (Minimum)	
	Degrees F	Degrees C
3 inches or greater	40	4
1-3 inches	45	7
Less than 1 inch	50	10

AK specs—40°F and rising

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Factors Affecting Compaction

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- Mixture properties
- Ambient conditions
- Lift thickness
- Base/subgrade support (confinement)
- Compactive effort

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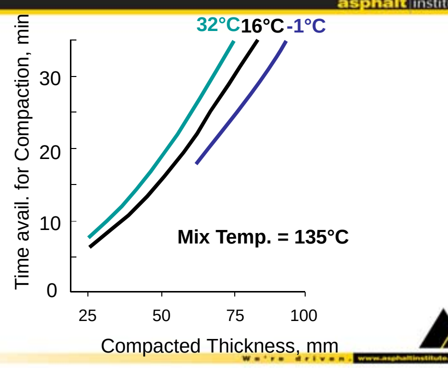
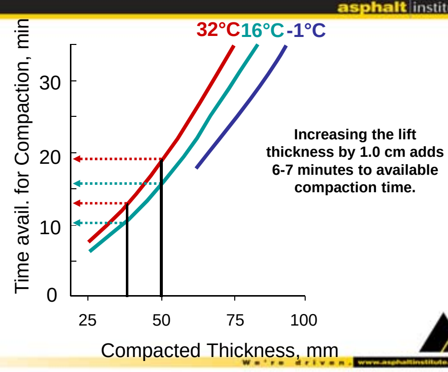
Compaction

- Temperature
  - Generally – hotter is better
  - But – heat ages the mixture
  - Thicker lift holds heat better
    - An extra 1.0 cm gains 6-7 minutes of compaction time
    - Generally – lift should be three times the nominal maximum aggregate size

MS-22, Table 6.03



MS-22, Table 6.03



Suggested Lift Thickness Ranges, P-401 (FAA)

Max. Aggregate Size	Suggested Lift Thickness, in minimum	maximum
1¼ inch	3	6
1 inch	2½	4
¾ inch	1¾	3
½ inch	1½	2½

Do not specify lifts thinner than 1½ inch (40 mm)

AK Specs??

Factors Affecting Compaction

- Mixture properties
- Ambient conditions
- Lift thickness
- Base/subgrade support (confinement)
- Compactive effort

Confinement

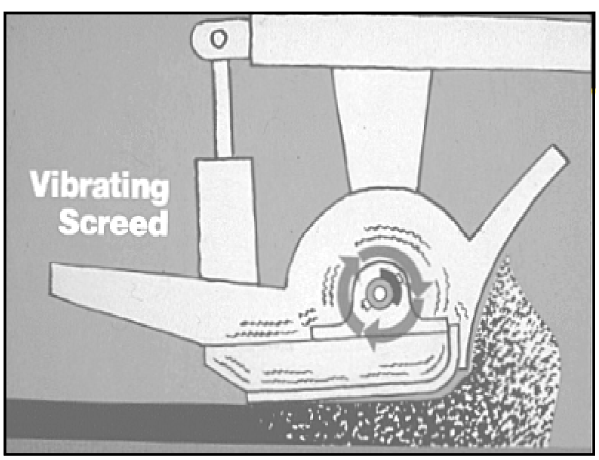
- Stable platform
- Good grip on underlying surface
  – Clean surface
  – Properly tacked
- Use temperature to confine edges
  – Delay rolling unsupported edge to allow "internal confinement" to develop

Factors Affecting Compaction

- Mixture properties
- Ambient conditions
- Lift thickness
- Base/subgrade support (confinement)
- Compactive effort

Compaction Equipment

- Screed
  - Screed weight
  - Screed vibration
  - Tamper bar
- Rollers
  - Vibratory steel
  - Pneumatic
  - Static steel
  - Combination



Tamper Bar


Moves up and down tamping mix under the screed

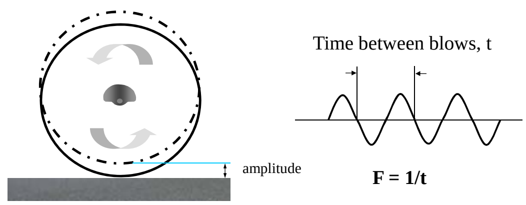
Rolling Procedures

- Breakdown rolling
  - Provides nearly all needed density
- Intermediate rolling
  - Provides final density level
  - Seals surface
- Finish rolling
  - Removes roller marks

Rollers

- Vibratory
  - Used for breakdown (initial) compaction
  - Offers greatest compactive effort
  - Speed of roller needs to match its frequency

Amplitude & Frequency



Amplitude = f (drum weight, eccentric moment, frequency)
Amplitude is calculated, not measured value.

Checking Frequency

Contractors and Inspectors should have a Reed Tachometer available

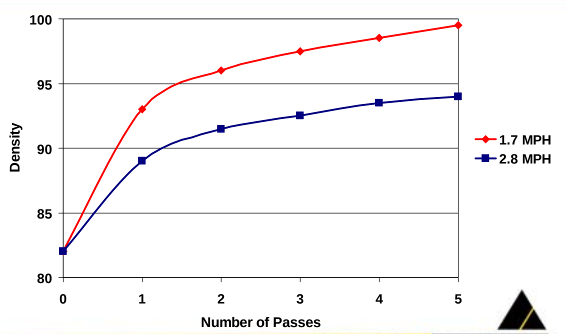
Vibratory Rollers

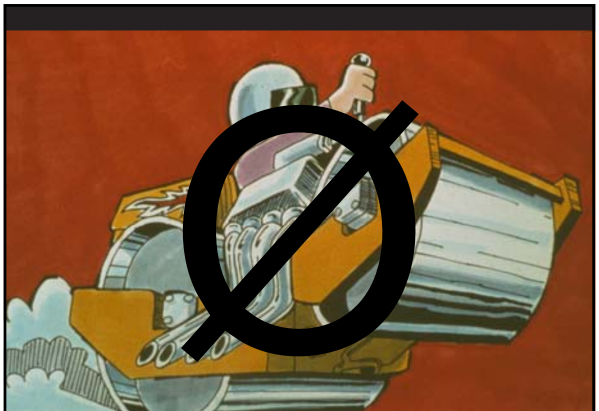
- Commonly used for initial (breakdown) rolling
- 8-18.5 tons, 57-84 in wide ("heavy" rollers)
  - 50-200 lbs/linear inch (PLI)
- Frequency: 2700 - 4200 impacts/min.
  - Trend to increase frequency
- Amplitude: 0.4 - 0.8 mm
  - For thin overlays (< 150 mm) use lowest amplitude setting or static mode
- Operate to attain at least 30 impacts/meter
  - 3-6.5 km/hr

Why are vibratory rollers more effective?

- Movement of drum initiates particle motion
- Resistance to deformation is much less when particles are moving than when static (inertia)
- Force applied by weight of drum has greater effect, thus achieving more compaction per pass than other roller types

Roller Speed Comparison





Frequency vs. Travel Speed

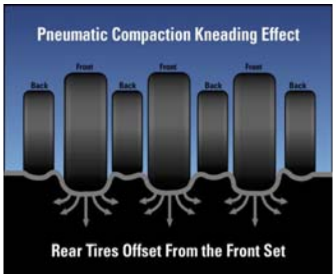
VPM	2 mph	2.5 mph	3 mph	3.5 mph	4 mph
2000	11.4	---	---	---	---
2500	14.2	11.4	---	---	---
3000	17.0	13.3	11.4	---	---
3500	19.9	15.9	13.3	11.4	10.0
4000	22.7	18.2	15.2	13.3	11.4

What happens if you operate the roller too fast?

- < 10 impacts per foot causes separated impacts
- Result is a washboard/rippling pattern that can't be rolled out
- Most easily seen with low-angle light
  - Early or late in day
  - Headlights from vehicles

Pneumatic Roller

Rubber Tire Manipulation



- Overlap manipulates mat under and between tire
- Tight finish resists moisture penetration
- Manipulation increased by lowering tire pressure
- Static force increased by high tire pressure

Pneumatic Roller

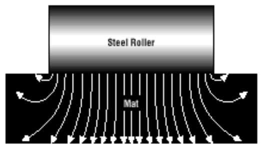
- Generally used as intermediate roller
- Reorients particles through kneading action
- Load/tire: 1050 – 6730 #/tire depending on model/ballast
- Tire pressure of ~70 psi—must be consistent
- Be sure to ballast
- Tires must be hot to avoid pickup
- Use skirts

Compaction Issues - Tire Pick-up

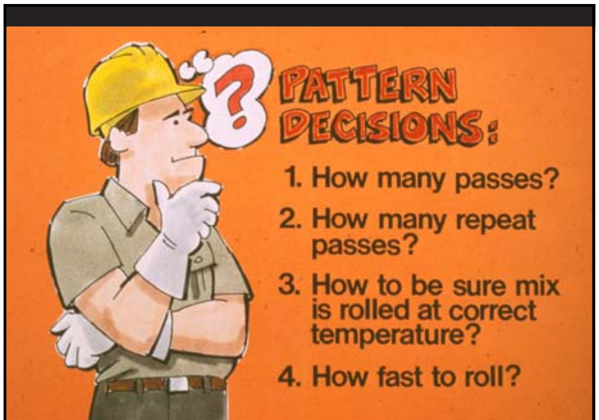
- Once tires hot - keep them hot
- Develop good rolling pattern - never stop rolling
- If waiting for trucks, roll on previously compacted mat

Static Steel-Wheeled Rollers

- 10-14 ton rollers normally used for HMA compaction
  - Commonly use vibratory rollers operated in static mode
- Lighter rollers used for finish rolling
- Drums must be smooth and clean
- For initial compaction, drive wheel must face paver



AI MS-22, Figure 6.05



Test (Control) Strip

- At least 300 feet long, two "pulls" wide
- Closely Simulate Paving Conditions
  - Base conditions
  - Haul times
  - Mixture storage
  - Paver speed
  - Joint construction
- Monitor Compaction After Each Pass
  - Density will climb, then peak, then fall

Establishing Rolling Pattern

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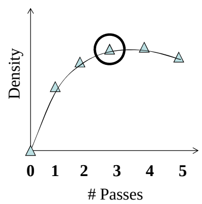

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Rolling Pattern

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- Speed & lap pattern for each roller
- Number of passes for each roller
  - One trip across a point on the mat
- Minimum temperature by which each roller must complete pattern

IMPORTANT:

Paver speed must not exceed that of the compaction operation!!!

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General Rules

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- Avoid Stopping and Sitting on Hot Mat
- Never Turn a Stopper Roller
- Angle all Stops

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Improving Quality Control with Intelligent Compaction

Build a better mousetrap and the world will beat a path to your door.- Ralph Waldo Emerson

How Does IC Help with QC?

- "Real-Time" Feedback to Roller Operator
  - On-Board, Color-Coded Mapping
    - Improved roller patterns
    - Improved temperature control
    - Ability to make adjustments "on-the-fly"
- Permanent Records of Compaction Data
- "Mapping" of Underlying Materials
  - RMV (Roller Measurement Values) readings
    - Locates "soft spots"
    - Identifies irregular support for compaction

Why Intelligent Compaction?

Why Do We Need IC?

- Proper in-place density is vital for good performance
- Conventional compaction equipment and procedures have shortcomings and too often produce poor results
- **Intelligent compaction technology appears to offer *"a better way"***

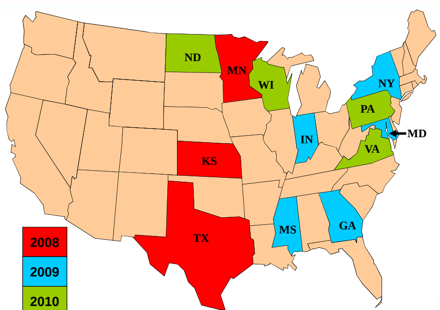
Improving QC with IC

- Shortcomings in Density Acceptance Process…

Limited Number of Locations

After Compaction is Complete

IC Pooled Fund (ICPF)



ICPF States / Year

What is Intelligent Compaction?

Vibratory Single Drum Soil Roller

Vibratory Tandem Drum Asphalt Roller

IC Roller Requirements

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- IC Roller Requirements
  - Roller Measurement Value (RMV)
  - GPS-Based documentation system
  - Color-coded display (on-board)
  - Surface temperature measurement system
  - Optional: automatic feedback system

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Color-Coded On Board Display

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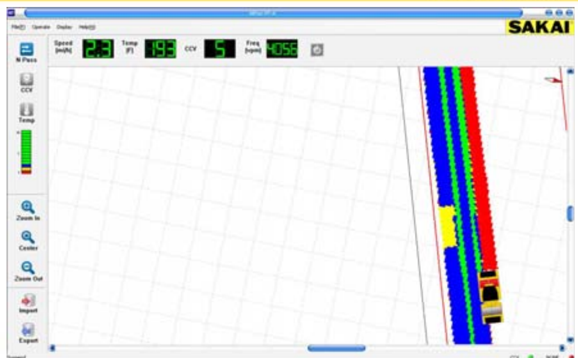

Global Positioning System (GPS)

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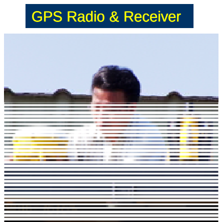
GPS Base Station

GPS Radio & Receiver



GPS Rover

Real Time Kinematic (RTK) GPS Precision

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Mat Surface Temperature Measurement

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Infrared Thermal Gauge

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Improving QC using IC

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"Real-Time" Feedback to Roller Operator

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Sakai Project - CA

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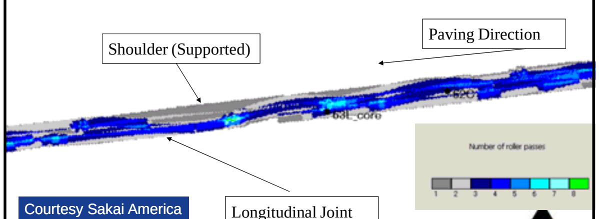
- Roller Passes



Courtesy Sakai America

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Roller Operator Training

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Improved **Rolling** Patterns

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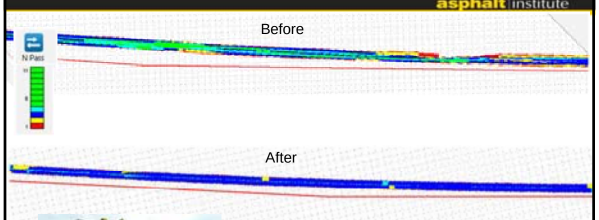

Sakai IC roller

Indiana ICPF Project

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Improving QC using IC

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Permanent Records of Compaction Related Data and Data Analysis

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Improving QC using IC

"Mapping of Underlying Layers Prior to Paving

"Mapping" of Underlying Materials

- Use of RMV color-coded mapping to measure support prior to paving of:
  - Subgrade soil materials
  - Stabilized subbase materials
  - Aggregate base materials
  - Existing asphalt pavements
  - Rubblized concrete pavements
- Underlying Support affects compatibility of subsequent layers

"Mapping" of underling layers

Mapping of the subgrade / agg. base layer

Minnesota ICPF Project

Future Research Needs - IC

- Improve correlation of Density vs. RMV
- Standardization of RMV
- Explore GPS Technology
  - Use of advanced, high prec. GPS technology
  - "Stand-Alone" (non RTK) GPS Technology
- IC Data Management
  - Improvements in on-board roller software
  - Data collection/storage
  - Data analysis/reporting

Summary

- Intelligent Compaction is a major innovation in compaction technology
- Research/field projects show that IC can offer a valuable tool to improve QC of the compaction process
- IC technology is now readily available in U.S.
- More work is need to address various issues
- Stay tuned!

We've Come a Long Way

1924 Buffalo Springfield Steam Roller


Questions?