
SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD
Using Real-time Smoothness Measurements to Achieve Pavement Smoothness
Plymouth, Michigan
Feb, 20, 2019
U.S. Department of Transportation
Federal Highway Administration
AASHTO
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES


Circa 1950
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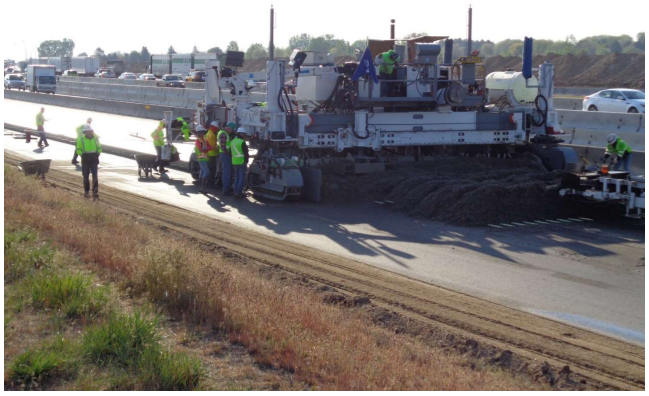
2018



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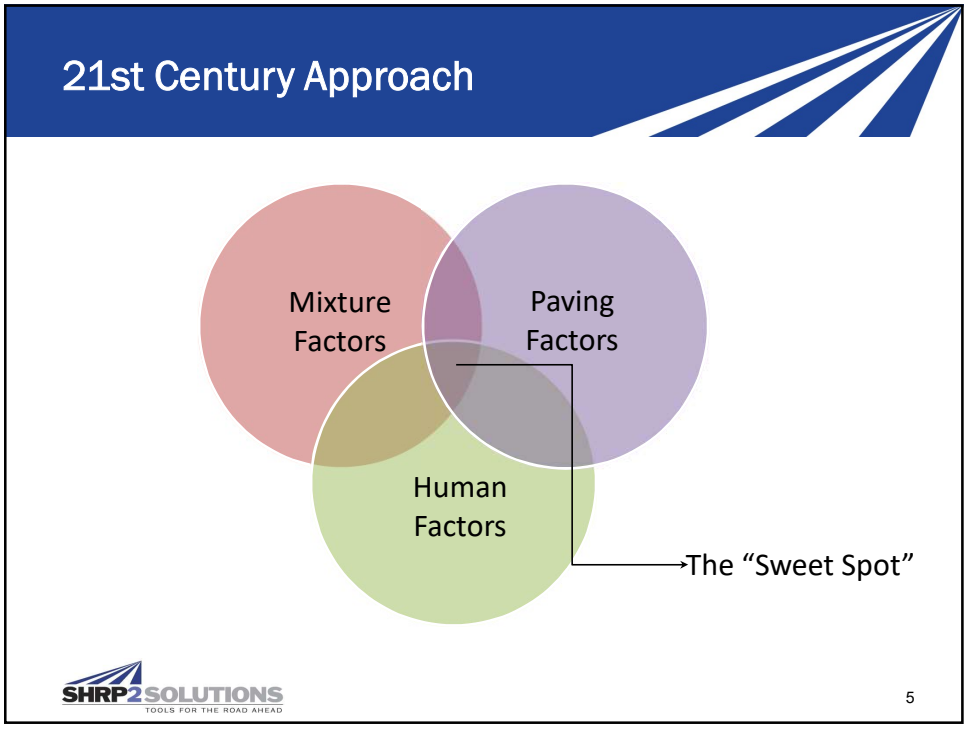
Ten Commandments of Concrete Pavement Smoothness (1988)

1. Develop a smoothness plan for the project.
2. Develop an accurate field survey for stringline/stringless controls.
3. Properly prepare the grade, providing a stable form or track line.
4. Set up proper forms properly for fixed-formed paving.
5. Use a consistent concrete mixture appropriate for the paving method.
6. Deliver and place concrete consistently.
7. Set-up and operate the paver steadily.
8. Fasten dowels/reinforcing securely and use "bump-free" construction joints (headers).
9. Use only necessary and appropriate finishing techniques.
10. Apply texturing and curing with care.

Source: Chapin Cipherd, CMI Corp.


21st Century Approach
Mixture Factors
Paving Factors
Human Factors
The "Sweet Spot"
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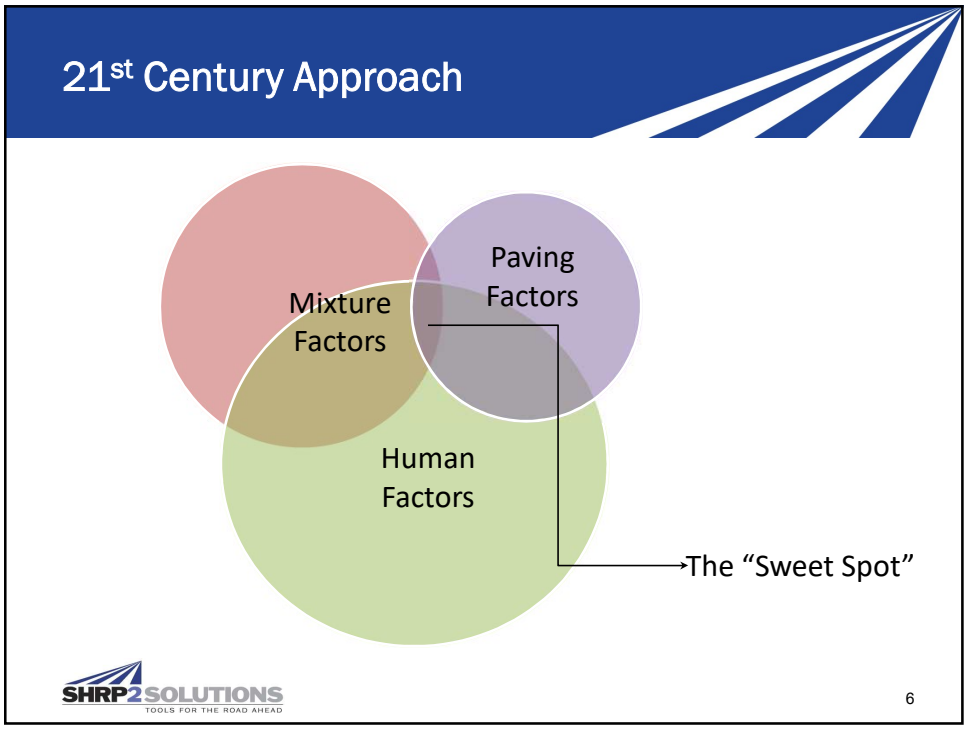
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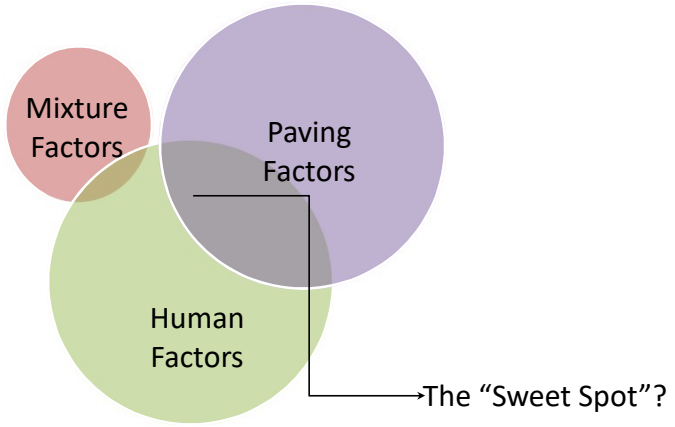
21st Century Approach



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Mixture Factors

- Combined gradation
- Between batch uniformity
- Uniform delivery of concrete

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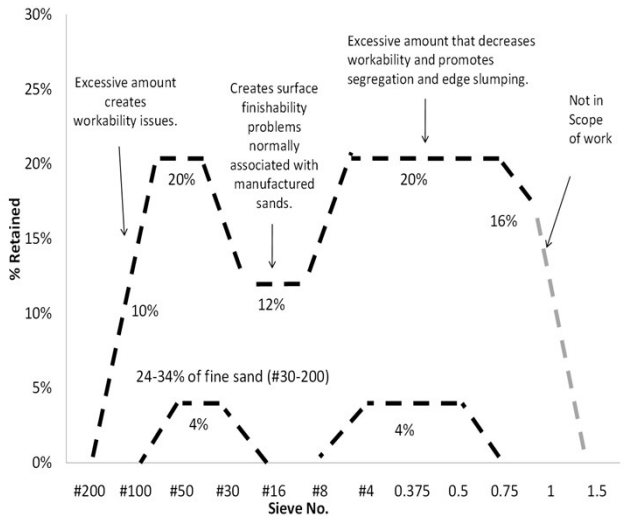
Combined Gradation: The Tarantula curve

Circa 2013
Ley, et al



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Combined Gradation: Best Practices

- The distribution of fine sand can vary largely without affecting the workability.
- An aggregate volume between 24% to 34% is recommended for #30 - #200.
  - This range was similar for multiple gradations and aggregate sources.
- More than 20% retained on the #30 sieve size created finishing issues.

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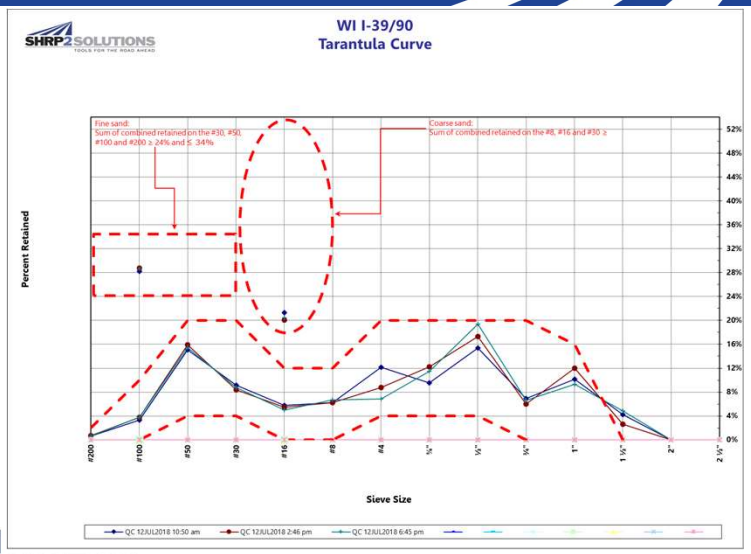
Combined Gradation: The Tarantula curve



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2/25/2019

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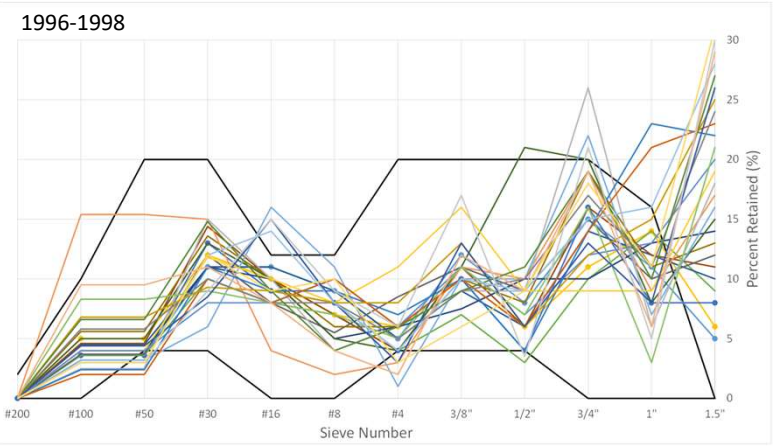
Combined Gradation: Tarantula Curve Validation

Minnesota DOT implements a combined gradation specification in the late 1990s (data from Maria Masten, MnDOT).



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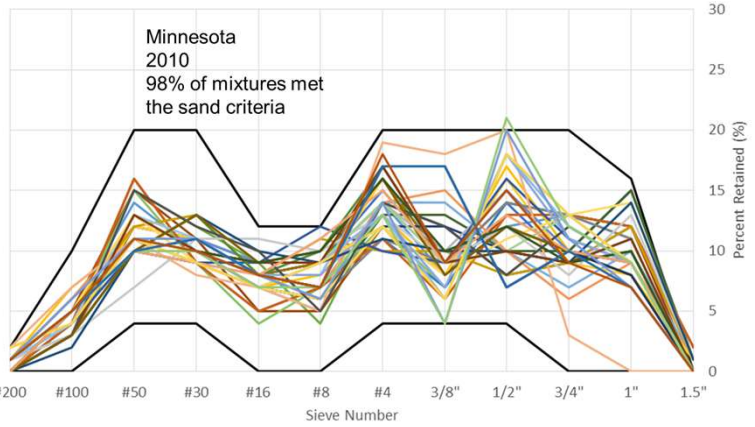
Combined Gradation: Tarantula Curve Validation

With added experience, the field mixtures continue to be refined and further reflect the Tarantula Curve recommendations .



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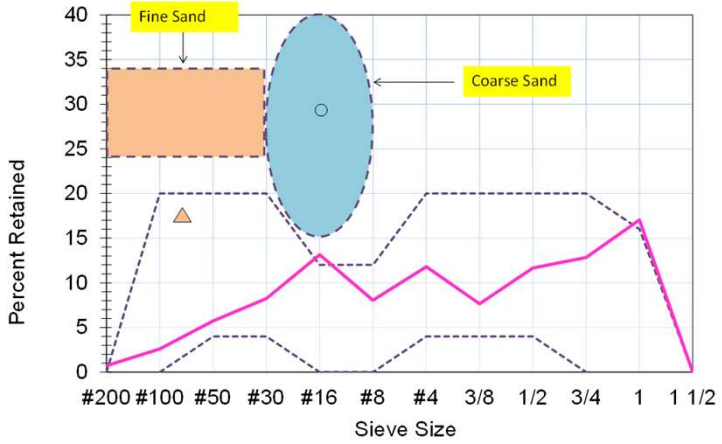
Combined Gradation Tarantula Curve Example

FHWA mobile lab – project A



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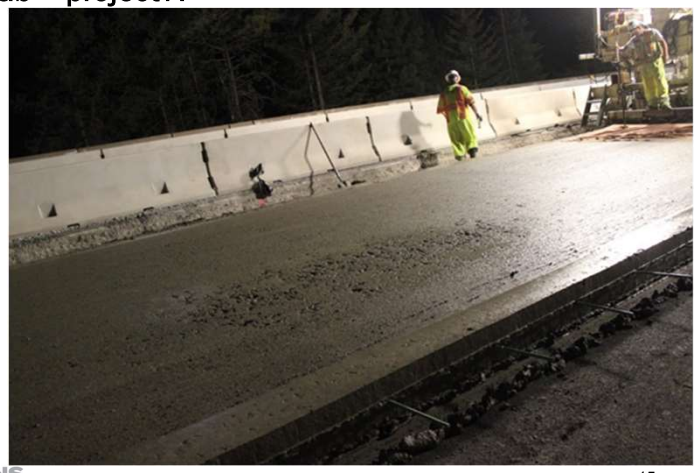
Images from Jagan Gudimettla 14

Combined Gradation Tarantula Curve Example

FHWA mobile lab – project A



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Images from Jagan Gudimettla

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Between Batch Uniformity

Consistent combined gradation and water content

- **Scales in tolerance**
- **Uniform stockpile moistures**
- **Eliminate stockpile segregation**

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Uniform Delivery of Concrete

Translates to minimizing paver stops

- **Plant production capacity must be able to feed the paver**

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Paving Factors

- Track line
- Stringline/Stringless model
- Paver setup
  - Draft/Lead
  - Sensitivities
  - Vibrator frequency
  - Vibrator height
  - Float pan
- Concrete head
- Curing and texturing

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Track Line

Minimize extreme leg barrel movements:

- Profile – trimmed or stabilized base placed with grade control
- Stability – non-yielding and non-pumping
- Width – full width of track supported

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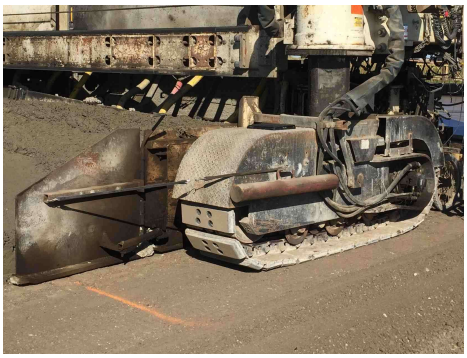
Track Line



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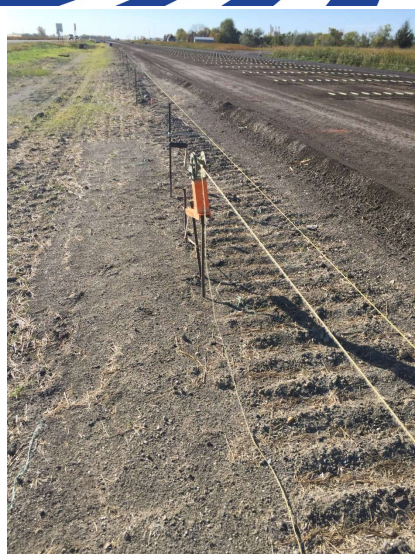
Stringline

- Adjusted for smoothness
- Properly and uniformly tensioned
- Pin spacing



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Stringless Model

- Smooth transitions
- Point spacing or true curves
- Control points

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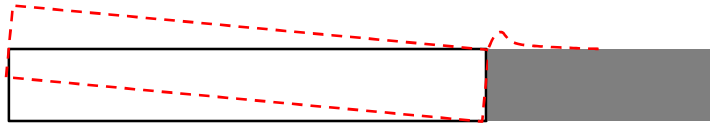
Paver Setup

- Draft/Lead – paver should be as flat as you can get it



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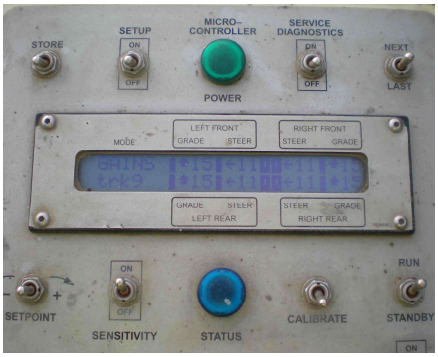
Paver Setup

- Sensitivities
  - Sensors
  - Stringless



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Paver Setup

- Vibrator frequency
  - Adjust for paving speed
  - Adjust for mixture
  - Slower at edges

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Paver Setup

- Vibrator height – adjust for base stiffness and optimize for smoothness

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Concrete Head

- Starts with subbase uniformity (grade control)
- Maintain a uniform head pressure

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Concrete Head

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Curing and Texturing

- Cure before any surface evaporation occurs to reduce warping.
- Texture
  - Minimize positive texture
  - Uniform texture depth

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Hand Finishing?

- Is it necessary?

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Hand Finishing?

- Does it improve the pavement smoothness?

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Human Factors

- Training
- Experience
- Communication
- Empowerment

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Human Factors

- Training
  - Everyone on the project contributes to smoothness
  - Each crew member should understand how their tasks impact smoothness – the "**BIG PICTURE**"

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Human Factors

- Experience
  - "The only source of knowledge is experience." (Einstein)
  - Crew retention and continuity is essential

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Human Factors

- Communication
  - "The single biggest problem in communication is the illusion that it has taken place." (George Bernard Shaw)
  - Establish clear lines of communication, so that everyone is on the same page
  - Radios, phones, hand signals, etc.
  - Listen to crew members

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Human Factors

- Empowerment
  - Encourage innovation
  - Enable decision making

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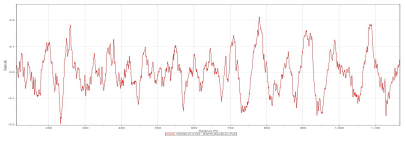
Implementation of Real-Time Smoothness

- Smoothness is the "heartbeat" of the paving operation.
  - An EKG indicates that something is abnormal with the heart, but does not diagnose the underlying cause(s).

  - RTS is similar to an EKG. The profile feedback indicates if there are issues with the paving operation, but doesn't diagnose the root cause.
  - Process adjustments are then made to improve the RTS results.



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Reasons for Using RTS Equipment

- Reduce disincentives
- Increase incentives
- Anticipated change in smoothness acceptance requirements
  - PrI to IRI
  - Change in localized roughness specification limits

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What is RTS Measurement?

Real-time Smoothness refers to measuring and evaluating the concrete pavement surface profile during construction, somewhere along the paving train while the concrete surface is still wet (plastic).

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RTS Measurements: Benefits

- Innovative tools for evaluating concrete pavement smoothness in real time.
- Tools that can be used for quality control.
- Process improvements as a result of timely feedback.
- Improved understanding about how construction artifacts can affect smoothness.

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RTS Measurements: Limitations

- Not a replacement for conventional profiling for acceptance.
- Not a replacement for better practices to construct smoother pavements.

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RTS Profilers

Paver-Mounted GOMACO Smoothness Indicator (GSI)

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RTS Profilers

Ames Engineering Real Time Profiler (RTP)

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RTS Mounting Locations

- Typically center of each driving lane
- Adjust this for special situations, when tuning the paver:
  - Tie bar insertion issues
  - One side of the paver is consistently rougher

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RTS Systems: Daily Setup and Shutdown

- Start-up - approximately 5 minutes
  - Install sensors and DMI
  - Connect cables
  - Input starting station and direction
  - Start the system
- Shut-down – approximately 5 minutes
  - Stop the system
  - Download data to a USB drive
  - Disconnect cables
  - Remove sensors and DMI

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Using RTS Systems

- Step 1 – Establish a baseline
  - Monitor results for 1 to 2 days.
  - Keep processes static, but make ordinary adjustments.
  - Observe typical responses to the ordinary adjustments and make notes or add event markers in the RTS.
    - Mixture
    - Vibrators
    - Speed
    - Head
    - Paver stops
    - Etc.

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Using RTS Systems

- The RTS results are higher than the QC hardened profiles – what's up with that?
  - Don't panic
  - Just focus on making the RTS results better (lower IRI)
  - QC profiles will improve as well

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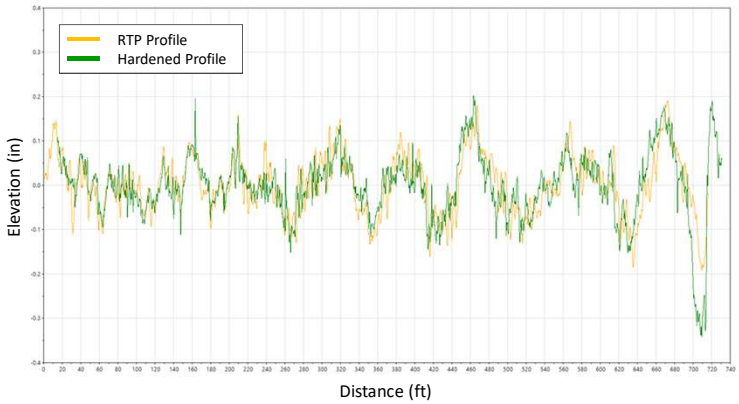
Pennsylvania, I-81

- Real-time and hardened profiles parallel each other
- 20 in/mi difference



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Using RTS Systems

- Step 2 – Pick the low hanging fruit
- Eliminate large events that cause excessive localized roughness.
  - Stringline/stringless interference
  - Paver stops
  - Padline issues
  - Etc.

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Localized Roughness Events

- Running the paver out of concrete

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Using RTS Systems

- **Step 3 – Adjust the paving process to improve overall smoothness**
  - Maintain a consistent head
  - Lead/draft to get the paver as flat as possible
  - Sensitivities
  - Vibrators (height and frequency)
  - Mixture
  - Paver operation
  - Paving speed

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Overall Smoothness

- **Eliminating big events gives you a new "baseline" to adjust from.**
  - Systematically make changes in small increments.
  - Get a minimum of 0.1 mile with consistent paving (no big events) and then evaluate if the adjustment made things smoother.
  - Continue adjusting in small increments and evaluating every 0.1 mile.

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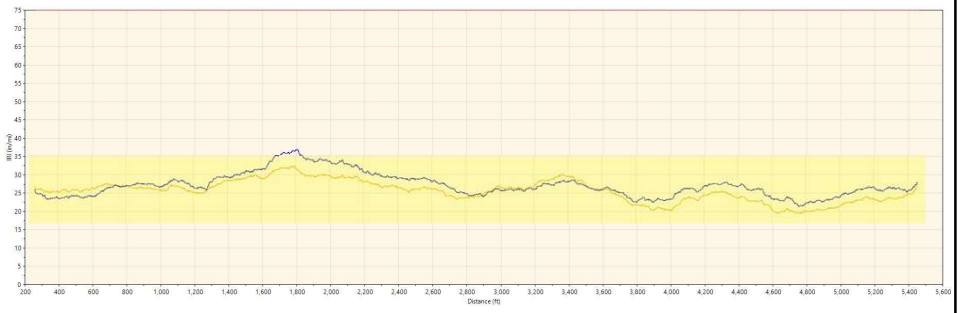
Overall Smoothness

- Stay focused and incredible things can happen

Over a mile paved per day – average IRI = 28 in/mi:



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Using RTS Systems

- Step 4 – Identify repeating features using a ProVAL PSD plot and adjust processes when possible.
  - Joints
  - Dumping/Spreading loads
  - CRCP bar supports

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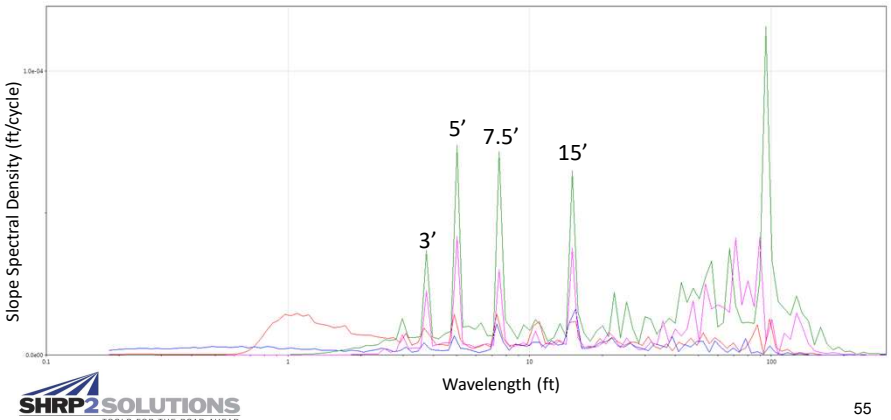
Repeating Features

- What repeating feature shows up here?
- What can you do to mitigate this feature?



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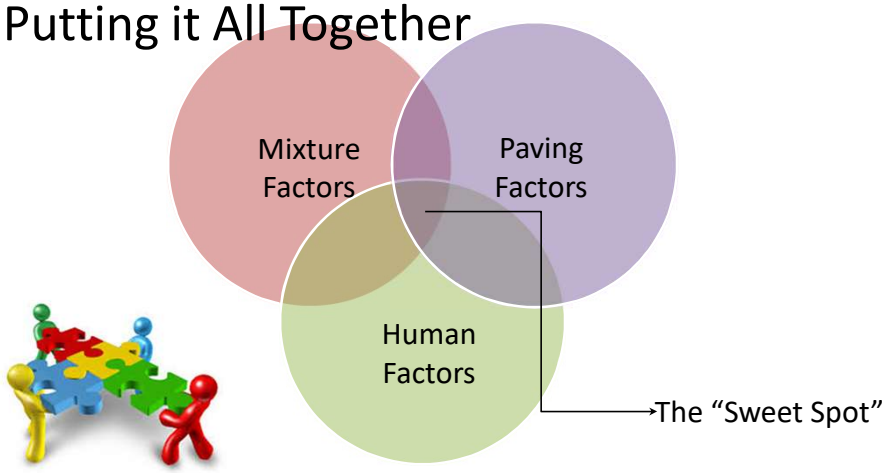
Summary of Best Practices

Putting it All Together



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