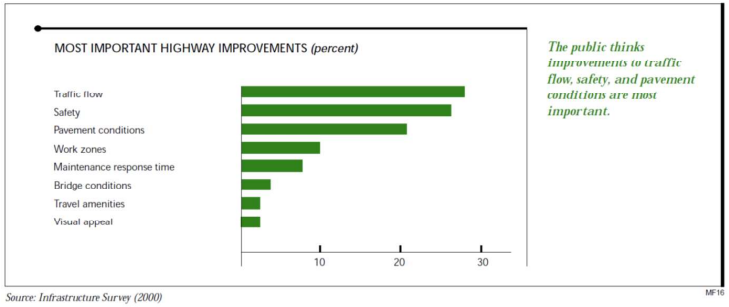
Importance of Concrete Pavement Smoothness

1. It's important to the user (taxpayer).
   - NQI National Highway User Study and Infrastructure Survey



Source: Infrastructure Survey (2000)

Importance of Concrete Pavement Smoothness

2. Smoother roads last longer.
   - NCHRP 1-31 Study

	Average % Increase in Pavement Life		
Reduction in Roughness	10%	25%	50%
HMA	5.3	13.3	26.7
PCC	7.3	18	36

Importance of Concrete Pavement Smoothness

3. Smoother roads stay smoother longer.
   - NCHRP 1-37A ("2002 Design Guide") smoothness model for *Rigid* Pavements:

$$IRI(t) = IRI_0 + a_iD(t)_i + b_jM_j + c_iSF$$

IRI(t) = pavement smoothness
IRI_0 = initial IRI
D(t) = distress
M = maintenance activities
SF = site factors (FI, P_{200}, etc)
a, b, c = regression constants

Source: NHI

Importance of Concrete Pavement Smoothness

4. Smoother roads are safer.
   - Steering wheel angle, driver acceleration, and lateral tire forces are all sensitive to roughness.
   - Rough roads contribute to driver fatigue.
   - Frequency of lost-load accidents was found to be directly related to road roughness.

Importance of Concrete Pavement Smoothness

5. Smoother roads save money.
   - Operating costs to the users of the roadway.

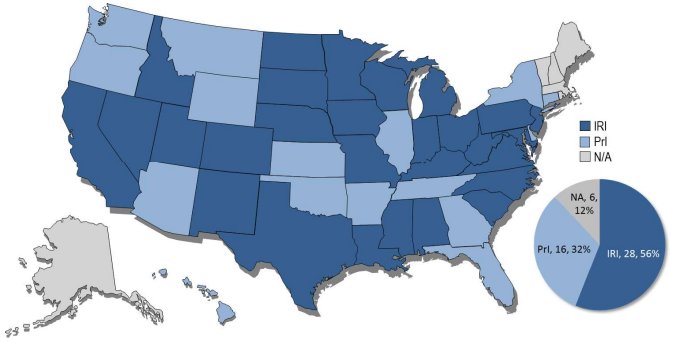
10% Reduction in Roughness = 4.5% Decrease in Fuel Consumption

WesTrack

Smoother Pavement = Less Vehicle Maintenance

Concrete Pavement Smoothness Specifications

- Current (2019) Specifications for PCCP: Smoothness Index



Concrete Pavement Smoothness Specifications

- Summary of IRI-based specification thresholds for concrete pavement (28 states)

	Incentive Upper Limit	Full Pay Lower Limit	Full Pay Upper Limit	Disincentive Lower Limit	Disincentive Upper Limit	Threshold for Correction
Min	39.9	40.0	54.0	54.1	67.5	67.5
Max	68.0	68.1	93.0	93.1	140.0	140.0
Avg	56.8	57.1	72.3	71.8	94.2	93.9

- Localized Roughness Provisions (22 states)

Method	Number of states	Range
Continuous IRI (25 ft baselength)	15	80-200 in/mi (Avg. 148 in/mi)
Fixed Interval IRI	4	25 ft segment: 120-160 in/mi; 0.01 mi (52.8 ft) segment: 100-125 in/mi
Profile Moving Average (25 ft baselength)	1	0.15 inches
Profilograph Simulation (25 ft baselength)	2	0.3 inches in 25 ft.

Smoothness Specifications

- Paving factors includes design elements
  - Vertical curves
  - Superelevation transitions
  - Project phasing (jigsaw puzzle)
  - Blockouts (gaps)
  - Matching existing lanes
  - Equipment clearance and trackline

- **Specification limits should be adjusted for design elements that prohibit conformance with the specification**

Smoothness Specifications for Local Roadways

- Plug and play of the state DOT specification is not always appropriate
- Specification limits should be adjusted to practical limits
  - Tiered approach is recommended by design speed and/or design features (e.g. Class I, Class II or Class III)
  - Measurement limitations of inertial profilers should be recognized
  - Leave-outs for intersections, drainage structures and phased construction
- IRI, profile index or straightedge?
  - IMO - IRI if continuous paving lengths of ½ mile are available
  - Otherwise, profile index or straightedge only
  - Straightedge should be used with both for leave-out areas

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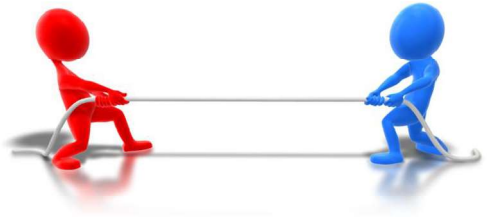
Guidelines for Building Smooth Concrete Pavements

- Materials and Mixtures
  - Performance engineered mixtures (PEM), optimized for:
    - Durability of the mixture
    - Economics
    - Sustainability
    - Utilization of locally available materials
    - Workability of the mixture
    - Other performance objectives



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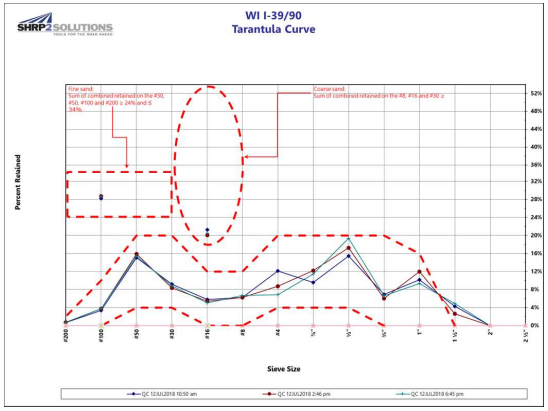
Guidelines for Building Smooth Concrete Pavements

- Materials and Mixtures
  - Tarantula curve



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Guidelines for Building Smooth Concrete Pavements

- Mixture Production
  1. Supply uniform concrete to the paving operation
  2. Produce and deliver the concrete at a rate that will allow the paving operations to maintain a consistent speed with minimal paver stops (consistent delivery)

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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving - Mixture adjustments
  - Subtraction/Addition of water (not to exceed the w/cm of the approved mixture design)
  - Adjustment of admixture dosages
  - Minor reproportioning of aggregates
  - Heating or cooling the mixture

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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Stringline
  - Stringline pins spaced at no greater than 25 ft. c/c
  - Tension the stringline using a winch. Check and re-tension stringline that has been in place for more than five days
  - Raise the stringline where the base course is high (less than design thickness of concrete pavement will be constructed)
  - "Eyeball" adjust the stringline for smoothness

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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – 3D Controls
  - Evaluate IRI of the model
  - Monitor the following:
    - Distance between the robotic total station and the paver
    - Line of sight issues between the robotic total station and the prism mounted on the paver
    - High winds causing movement to the robotic total station and/or the prism mounted on the paver
    - 3-D system errors (radio, software, hardware, wiring, batteries, etc.)

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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Paver Speed
  - Minimize stops
  - Consistent speed
  - Slow down when necessary, but not too much
  - "Rhythm"

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Guidelines for Building Smooth Concrete Pavements

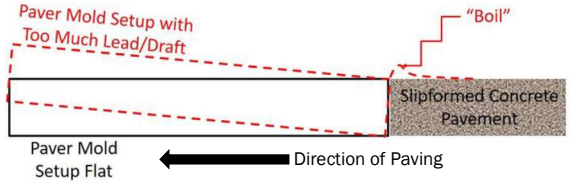
- Maintain a uniform head pressure
- Starts with subbase uniformity (grade control)
- Spreading operation should adjust as needed

Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Vibrators
  - Frequency is speed dependent
  - Rebound from stiff base
  - Adjust height

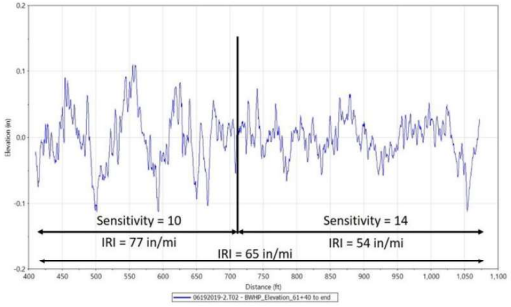
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Paver Attitude (Lead/Draft)
  - Stay as flat as practical
  - One person responsible for adjustments
  - Reduce lead/draft when paving uphill
  - Increase lead/draft when paving downhill



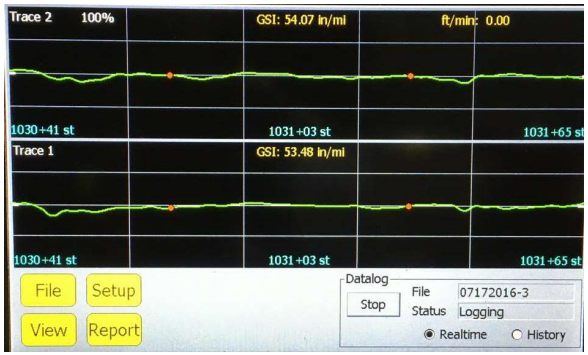
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Hydraulic Response (sensitivity)
  - Slight adjustments can have significant impacts



Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Real-Time Smoothness
  - QC feedback loop reduced from 18 hours to 2 hours
  - Not a replacement for conventional profiling for acceptance
  - Not a replacement for better practices to construct smoother pavements



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