Importance of Concrete Pavement Smoothness

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

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

<table>
<thead>
<tr>
<th>Reduction in Roughness</th>
<th>HMA</th>
<th>PCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>5.3</td>
<td>7.3</td>
</tr>
<tr>
<td>25%</td>
<td>13.3</td>
<td>18</td>
</tr>
<tr>
<td>50%</td>
<td>26.7</td>
<td>36</td>
</tr>
</tbody>
</table>

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

   \[
   \text{IRI}(t) = \text{IRI}_0 + a_i D(t)_i + b_j M_j + c_i SF
   \]

   \(\text{IRI}(t)\) = pavement smoothness
   \(\text{IRI}_0\) = initial IRI
   \(D(t)_i\) = distress
   \(M\) = maintenance activities
   \(SF\) = site factors (Fl, P_{200}, etc)
   \(a, b, c\) = regression constants

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

   Smoother Pavement = Less Vehicle Maintenance

Concrete Pavement Smoothness Specifications

- Current (2019) Specifications for PCCP: Smoothness Index

<table>
<thead>
<tr>
<th>Smoothness Specifications</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoothness Index</td>
<td>10%-40%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Smoothness Specifications</th>
<th>Incentive</th>
<th>Full Pay</th>
<th>Disincentive</th>
<th>Threshold for Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Limit</td>
<td>Lower Limit</td>
<td>Upper Limit</td>
<td>Lower Limit</td>
<td>Upper Limit</td>
</tr>
<tr>
<td>Max</td>
<td>68.0</td>
<td>68.1</td>
<td>93.0</td>
<td>93.1</td>
</tr>
<tr>
<td>Avg</td>
<td>56.8</td>
<td>57.1</td>
<td>72.3</td>
<td>71.8</td>
</tr>
</tbody>
</table>

- Localized Roughness Provisions (22 states)

<table>
<thead>
<tr>
<th>Smoothness Specifications</th>
<th>Number of States</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>14</td>
<td>69-102,102-134</td>
</tr>
<tr>
<td>Transition</td>
<td>4</td>
<td>25-40, 50-90</td>
</tr>
<tr>
<td>Discontinuous Transition</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>Specified Standard</td>
<td>2</td>
<td>0.3</td>
</tr>
</tbody>
</table>

- 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?
  - IMQ - 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)
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

- 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

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.)

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