Dowel Alignment Considerations and Specification Update

November 8, 2016

Mark B. Snyder, Ph.D., P.E.
American Concrete Pavement Association Staff Consultant
Presentation Overview

- What are the sources of misalignment and mislocation during construction?
- What are the potential impacts of misalignment/mislocation on pavement performance?
- How much misalignment or mislocation is acceptable?
- How do we image dowels in hardened concrete?
- Concepts for dowel alignment specifications.
Introduction
The Goal

- Dowels that are:
  - **Aligned** such that they impose no intolerable restraint on joint opening/closing
  - **Located** such that they provide adequate long-term load transfer
    - Are not so close to the surface or subbase as to cause shear failures
    - Have the required embedment depth
    - Are not too far from (or close to) each other or the pavement edge
Misalignment

- Any deviation in either the horizontal or vertical plane from a true alignment condition (e.g., horizontal skew or vertical tilt).
Mislocation

- Any deviation of a dowel bar from its planned location. DOES NOT LOCK THE JOINT!
Sources of Misalignment and Mislocation
2 Methods of Dowel Placement

Pre-Placement (e.g., baskets)

Insertion (e.g., DBI)

But Dowel Alignment/Location is About More Than Just Initial Placement …
Pre-Placement (e.g., Dowel Baskets)

- Staked to supporting layer
  - Basket height and dowel-to-dowel spacing set; concern for mislocation?
  - If staking sufficient and dowel basket properly aligned and located, concern for misalignment?
  - Misalignment typically due to insufficient staking and/or paving operations
Basket Shifted During Construction
Basket Handling is Key
Dowel Bar Insertion

- Eliminates basket placement & need for separate place/spreader to deliver concrete over baskets

- DBI Advantages: speed of construction, site access (e.g., no adjacent haul road), cost, etc.
The Dowel Bar Insertion Process
The Dowel Bar Insertion Process
Factors Impacting DBI Placement

- Concrete mixture!!!
  - Optimized, well-graded mixture is a must

Aggregate cleanliness, angularity, etc.

Batch-to-batch and in-batch uniformity is key
Factors Impacting DBI Placement

- Accuracy of insertion forks
  - DBI setup is key to get dowels parallel to pavement edge/surface and also spaced properly

- Automated saw cut location indicator
Placement-Specific Factors that Impact Dowel Alignment and Location

- **Baskets**
  - Basket rigidity and design
  - Basket stability – pins, support layer, shipping wires, etc.
  - Concrete placement activities
  - Placed relative to top of base

- **Dowel Bar Insertion (DBI)**
  - Consolidation around dowel bars
  - Concrete mixture too stiff or too soft
  - Equipment problems (e.g., damaged insertion forks)
  - Placed relative to top of concrete
  - “Floating” dowel bars (e.g., FRP dowels)?

**SAWCUT LOCATION!!**
More Placement Concerns

Baskets:
- Basket skew – all dowels misaligned at once
- If basket opens due to cutting of tie wires, dowels fall
- If basket height set, can vertical location be off?
- Anchoring of baskets on concrete overlays is issue

DBI:
- DBI can have systematic error in one or more individual dowel bars due to fork alignment issues
- Dowel feed issues

Saw cut location is a common concern
Issues are Visible in Results

- Typical Joint
- Basket Opened
- Anchoring Issue
- Missing Dowels
Sawcut Mislocation = Dowel Mislocation
Sawcut Not Over Dowel Bar
Avoiding Saw Cut Location Issues

- Locate (verify) edge dowels BEFORE sawing...
Dowels in Construction Joints

- Gang drill produces more uniform alignments than a single drill
Potential Impacts of Misalignment/Mislocation on Pavement Performance
# What’s the Concern?

<table>
<thead>
<tr>
<th></th>
<th>Spalling</th>
<th>Cracking</th>
<th>Load Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal Skew</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Vertical Tilt</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Horizontal Translation</strong></td>
<td>–</td>
<td>–</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Longitudinal Translation</strong></td>
<td>–</td>
<td>–</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Vertical Translation</strong></td>
<td>Yes</td>
<td>–</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Potential Dowel Misalignment Problems
Potential Dowel Misalignment Problems
DowelCAD 2.0

Dowel Comparison Analysis and Design

Analysis Type
- Corner Dowel Spacing
- Center Lane Dowel Leave-Out
- Alternate Dowel Spacings

Dowel Spacing Alternatives
- 12 Dowels, uniform (baseline)
- 11 Dowels (Alternate A)
- 9 Dowels (Alternate B)
- 8 Dowels (Alternate C)

Plot: Peak Dw. Br. Stress
Steel Savings: 33%

Dowel Selection
Dowel Size/Shape: 1.25" Round
Avg. Slab (~9")

Dowel Bearing Stress (psi)
- 12 Dowels (Baseline): 2717
- 8 Dowels (Alt. C): 2657

Steel Savings: 33%
Misalignment and Mislocation Thresholds
Criteria Generally Based on Lab Tests

Some early work from the 1980s:
Most Recent “Big” Study


- Lab testing
- Field testing
- Theoretical analysis
- Recommendations on acceptable dowel alignment levels

NCHRP REPORT 637
Guidelines for Dowel Alignment in Concrete Pavements

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMY

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
NCHRP 10-69 Research Approach

- Field Evaluation
  - MIT Scan – Measurement of dowel alignment
  - Visual distress survey
  - Faulting measurements
  - FWD measurements of load transfer efficiency

- Laboratory Testing
  - Dowel pullout testing
  - Dowel shear testing

- 3-D Finite Element Modeling using ABAQUS
  - Modeling of the laboratory test
  - Modeling of a pavement joint

- Pavement Performance Modeling
  - Use of MEPDG pavement performance models
  - Equivalent dowel diameter concept

- Design and Construction Guidelines Development as Appendix
Field Evaluation

- 35,000 dowels | 2,300 joints | 60 projects | 17 states
- Typical range of misalignment/mislocation with **no significant effect on pavement performance**:
  - Horizontal skew or vertical tilt: < 0.5 in. over 18 in. dowel
  - Longitudinal translation: ± 2 in. over 18 in. dowel
  - Vertical translation: ± 0.5 in. for 12 in. or less in thickness
Laboratory Testing

- 64 single-dowel misalignment/mislocation tests

Two-part test:
- Pull-out to simulate joint opening
- Shear test to simulate loading on damaged system

Results:
- Dowel lubrication significantly affects pullout force
- Dowel rotation as extreme as 2 in. per 18 in. dowel does not affect shear capacity
- Reduction in concrete cover from 3.25 in. to 1.25 in. causes severe reduction in ultimate shear capacity
- Reduction in dowel embedment length to 3 in. and less significantly reduces shear capacity
- Combinations of misalignment and mislocation have a compounding effect on shear performance
Effect of Embedment Length

Initial slope = shear stiffness
Max shear force = shear capacity
Effect of Embedment Length

1 in. dowel
9 in. embedment
Peak bearing stress = 2,465 psi

1 in. dowel
5 in. embedment
Peak bearing stress = 2,751 psi, (11% incr.)

...but what is limit on bearing stress?
Rotated (especially non-uniformly rotated) dowels cause damage to the concrete around dowels due to temperature expansion and contraction, causing a reduction in joint load transfer efficiency.

- Dowel misalignment alone, unless extreme rotation (e.g., > 3 in./18 in. dowel), does not cause joint lockup.

Significant dowel misalignment reduces the effectiveness of dowels.

- Dowel misalignment has the same apparent effect on joint performance as a reduction in dowel diameter.

Dowel-concrete friction and bond overshadows the effect of misalignment on joint lockup.

Reduction in embedment length or cover reduces shear capacity.
Equivalent dowel diameter:

\[ d_{eq} = r_{emb} \times r_{cc} \times r_{vt} \times r_{hs} \times d_0 \]

- \( d_{eq} = \text{equivalent dowel diameter} \)
- \( r_{emb} = \text{correction factor for a reduction in embedment length below 6.9 in.} \)
- \( r_{cc} = \text{correction factor for a reduction in concrete cover due to vertical translation of more than 0.5 in.} \)
- \( r_{vt} = \text{correction factor for vertical tilt higher than 0.5 in. per 18 in. dowel} \)
- \( r_{hs} = \text{correction factor for horizontal skew higher than 0.5 in. per 18 in. dowel} \)
- \( d_0 = \text{nominal dowel diameter} \)
Pavement Performance Modeling

- Compute equivalent dowel diameter for each dowel in a joint
- Applying weighting to dowels in critical area
- Determining equivalent dowel diameter for each joint

Use MEPDG / DARWin-ME / AASHTOWARE M-E to investigate the impact on predicted pavement performance and/or reliability

- Smaller effective dowel diameter will impact faulting and IRI results but not cracking predictions
- Concrete will “cone” before transverse/longitudinal crack happens
Back to Talking about Thresholds...

<table>
<thead>
<tr>
<th></th>
<th>Spalling</th>
<th>Cracking</th>
<th>Load Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Skew</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Vertical Tilt</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Horizontal Translation</td>
<td>–</td>
<td>–</td>
<td>Yes</td>
</tr>
<tr>
<td>Longitudinal Translation</td>
<td>–</td>
<td>–</td>
<td>Yes</td>
</tr>
<tr>
<td>Vertical Translation</td>
<td>Yes</td>
<td>–</td>
<td>Yes</td>
</tr>
</tbody>
</table>
ACPA and PCA Documents

- **ACPA 2006** – SR999P, “Evaluating and Optimizing Dowel Bar Alignment”

- **PCA 2005** – R&D 2894, “Dowel Bar Alignments of Typical In-Service Pavements”
NCPTC 2011 – “Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements”
FHWA Guidance


Longitudinal Translation (18 in. bar)

- **NCHRP 2009**: **Accept**: < 2.1 in.
- **FHWA 2007**:
  - **Accept**: < 2 in.
  - **Reject**: any joints with < three bars with a minimum embedment length of 6 in. in each wheel path
- **CPTech 2011**: Notes that **NCHRP 2009** showed no significant loss of shear capacity until embedment length < 4 in.; embedment length as low as 2 in. provided shear capacity of 5,000 lb, more than sufficient for critical dowels in highways.
MnDOT Experience

Tom Burnham (MnDOT) identified a section with low embedment length due to mislocated saw cut and has monitored field performance, concluding:

“… a minimum dowel bar embedment length of 64 mm (2.5 in.) is needed to prevent significant faulting and maintain reasonable load transfer efficiency across a joint.”

Section is now 15 yrs+ old and still performing adequately

ACPA Guide: Location of Individual Dowel

- **Longitudinal Translation**
  - < 2 in. (50 mm) | Accept
  - > 5 in. (125 mm) | Requires CAP

---

The **Accept** limit:

\[(18 \text{ in. length} - 2 \times 4 \text{ in. of embedment})/2 - 3 \text{ in. safety factor} = 2 \text{ in.}\]

The **Requires Corrective Action** limit:

\[(18 \text{ in. length} - 2 \times 4 \text{ in. of embedment})/2 = 5 \text{ in.}\]

**NOTE:** 4 in. of embedment based on NCHRP 2009 and NCPTC 2011.
Vertical Translation

- **NCHRP 2009:**
  - **Accept:** $\pm 0.5$ in. for $T \leq 12$ in. or 1 in. for $T > 12$ in.
  - **Reject:** concrete cover $\leq 2$ in. or sawcut depth

- **FHWA 2007:**
  - **Accept:** $\pm 1$ in.
  - **Reject:** concrete cover $< 3$ in. or sawcut depth

- **CPTech 2011:** Notes that **NCHRP 2009** showed no difference between dowels at mid-depth and those located more than 1 in. closer to surface
Do Dowels Really Need to be at Mid-Depth?

- **Dowel** requires only adequate cover and to avoid conflict with saw cut.

- **NCC 2011** – provides recommendations for standardization, for example:
  - Dowel diameter: 1.5 in.
  - Height to dowel center: 5 in.
  - Slab Thickness: >10-12 in.
ACPA Guide: Location of Individual Dowel

- Vertical Translation

< 1 in. (25 mm) or >0.5 in. between top of bar and bottom of saw cut | Accept
Cover < 2.5 in. (64 mm) or < 0.25 in. between top of bar and bottom of saw cut | Requires CAP

Do we know if sawcut to correct depth?!?
ACPA Guide: Location of Individual Dowel

- **Vertical Translation**
  - Dowel below mid-depth

  < 1 in. (25 mm) | **Accept**
  Cover < 2.5 in. (64 mm) | **Requires CAP**
Horizontal Translation

- **NCHRP 2009:**
  - *Accept:* ± 1 in.
  - This is fixed with baskets
  - Many documents (e.g., FHWA 2007) identify horizontal translation as a concern but do not provide guidance on allowable magnitude
  - Many state agency specs omit a tolerance
  - **Cover depth with edge of pavement is key**
  - **Dowels @ 12 in. o.c. is VERY conservative**
ACPA Guide: Location of Individual Dowel

- **Horizontal Translation**
  - < 2 in. (50 mm) | Accept
  - > 3 in. (75 mm) | Requires CAP
Alignment of *Individual* Dowel (18 in.)

- **FHWA 2007:**
  - **Accept:** component misalignment < 0.6 in.
  - **Reject:** SDM > 1.5 in.

\[
\text{Single Dowel Misalignment (SDM)} = \sqrt{(\text{Horizontal Skew})^2 + (\text{Vertical Tilt})^2}
\]
Alignment of **Individual Dowel** (18 in.)

- **NCHRP 2009:** Dowel rotations up to 2 in. have a negligible effect on pullout and shear performance
  - **Accept:** component misalign < 0.5 in.
  - **Reject:** SDM > 3 in.
    - Acceptance is slightly less than FHWA recommendation and reject is 2x FHWA
- A combination of low concrete cover and low embedment length has a more adverse effect on dowel performance than either of the two misalignments
ACPA Guide Spec: Alignment of Individual Dowel

Horizontal Skew AND Vertical Tilt $\leq 0.6$ in. (15 mm) | Accept
SDM $> 1.5$ in. (38 mm) | Requires CAP
Considering **All Dowels in a Joint**

**Joint Score (JS)** – Means of assessing locking potential; evaluated for a single transverse joint between adjacent longitudinal joint(s) and/or pavement edge(s):

\[
Joint Score (JS) = 1 + \sum_{i=1}^{n} W_i
\]

where:

- \( n \) = number of dowels in the single joint
- \( W_i \) = weighting factor for dowel \( i \)
Excessive Misalignment = “Lock” Restraint

<table>
<thead>
<tr>
<th>Single Dowel Misalignment (SDM)</th>
<th>W, Weighting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDM ≤ 0.6 in. (15 mm)</td>
<td>0</td>
</tr>
<tr>
<td>0.6 in. (15 mm) &lt; SDM ≤ 0.8 in. (20 mm)</td>
<td>2</td>
</tr>
<tr>
<td>0.8 in. (20 mm) &lt; SDM ≤ 1 in. (25 mm)</td>
<td>4</td>
</tr>
<tr>
<td>1 in. (25 mm) &lt; SDM ≤ 1.5 in. (38 mm)</td>
<td>5</td>
</tr>
<tr>
<td>1.5 in. (38 mm) &lt; SDM</td>
<td>10</td>
</tr>
</tbody>
</table>

The potential for restraining a single joint:

- **JS ≤ 5** | very low risk of joint restraint
- **5 < JS ≤ 10** | low risk of joint restraint
- **10 < JS ≤ 15** | moderate risk of joint restraint; potentially locked
- **JS > 15** | high risk of joint restraint; joint locked

NOTE: Values identical in **FHWA 2007, PCA 2005, ACPA 2006**
Alignment of Single Joint

Joint Score ($JS$) = $1 + \sum_{i=1}^{n} W_i$

JS < JST | Accept
...But More Than 1 Joint Can Lock

- Maximum Allowable Locked Length (MALL) – maximum allowable length of locked-up pavement; 60 ft (18 m), including no more than three consecutive joints with JS > JST.

Hinge Joint Design | Essentially JRCP with steel strategically located beneath joint.

Shrinkage happens over 30 ft | Shrinkage happens over 30 ft

How many lanes can you tie together?
Alignment of Single Joint

Joint Score (JS) = 1 + \sum_{i=1}^{n} W_i

JS < JST | Accept
JS > JST for all joints over MALL | Requires CAP

MISALIGNMENT OF ANY DOWEL WILL CONTRIBUTE TO THE JOINT SCORE
Impact of Joint Score on Pavement Performance (ACPA Study)
Findings from the ACPA Study

- Dowel alignments are generally very good, but
  - Almost all projects contained at least a few significantly misaligned bars
  - None of the sections surveyed exhibited any distress
- Occasional, isolated “locked joints” may have no significant effect on pavement performance
- Poor dowel alignment may cause looseness around dowels, impacting LTE but not cracking
- Dowel alignment achieved using baskets and DBI are comparable
Joint Scores for a Basket Placement in IN
5 years old
Joint Scores for a DBI Placement in KS
KS, NB I-35 – 6 years old
Joint Scores for a 30-year old Section in GA
30-yr old GA section with extremely poor dowel alignment
... but no faulting!

So maybe Joint Score is not the holy grail of dowel bar alignment characterization.
Measuring Dowel (Mis)alignment and (Mis)Location
Measuring (Mis)alignment – the hard way!
Measuring (Mis)alignment – the REALLY hard way!
Initial Attempts in the 1980s w/GPR

- Ground penetrating radar (GPR)
  - Image about 40 joints/day – SLOW
  - Manual interpretation required

**FIGURE 2** Radar test setup at transverse joint.

**FIGURE 3** Typical graphic output of a pass of the radar transducer.
2000s – MIT Introduced

- 2000 – Magnetic imaging tomography (MIT) device developed in Germany specifically for dowel bar imaging in concrete pavements
- 2001 – MIT Scan exhibited at conf in Orlando
- 2002 – Caltrans purchases a unit
- 2005 – FHWA adopts MIT Scan as ready-to-implement technology under CPTP; 3 units available for loan and 1 unit on MCL
- 2008 – FHWA loan program continued under the ACPT program
- … use of GPR evaluation also continued
Quick Adoption of MIT Scan2 - BT

- 2002 – Caltrans – first to evaluate
- 2003 – SC DOT – first to use on a construction project (I-95 reconstruct)
- 2003 – NV DOT – first to use on basket placement
- 2004 – NC DOT – first to specify the documentation of dowel alignment as a condition for allowing the use of DBI
- 2006 – MTO – first dowel alignment PWL spec
- Currently, many agencies require use of MIT Scan2-BT
2010s – Other Devices Introduced

- Hilti – Pulse Radar Imaging
- MIRA – Ultrasonic tomography
  - Utilizes sound waves
  - Like GPR, can also detect other issues, such as delamination
- Hilti & MIRA are time consuming
- ... continued use of GPR and MIT-SCAN
Recent GPR Dowel Imaging

- KY and NM field testing; MO experimenting
### MIT-DOWEL-SCAN

**ADVANTAGES AT A GLANCE**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate and efficient measurement</td>
<td>Specialized system for measuring dowel bar and tie bar positions</td>
</tr>
<tr>
<td></td>
<td>Comprehensive and accurate measurement of dowel positions:</td>
</tr>
<tr>
<td></td>
<td>- Bar depth tolerance of ± 4 mm</td>
</tr>
<tr>
<td></td>
<td>- Bar misalignments tolerance of ± 4 mm</td>
</tr>
<tr>
<td></td>
<td>- Bar side shift tolerance of ± 8 mm</td>
</tr>
<tr>
<td></td>
<td>High production field inspection of joints per day on long road sections (up to 500 joints per day with a single operator)</td>
</tr>
<tr>
<td>Versatile in use</td>
<td>Nondestructive data acquisition, no reference core required</td>
</tr>
<tr>
<td></td>
<td>Measurement independent of the degree of concrete hardening, also on rain-wet road surfaces</td>
</tr>
<tr>
<td></td>
<td>Scanning of cut and un-cut joints (can be used to locate the saw joint)</td>
</tr>
<tr>
<td>User-friendly operation</td>
<td>Simple and intuitive handling: Rail-Free due to automated course correction of measuring device</td>
</tr>
<tr>
<td></td>
<td>Fast and easy transportation from joint to joint to increase productivity</td>
</tr>
<tr>
<td></td>
<td>Easy to transport: Compact, collapsible measuring device</td>
</tr>
<tr>
<td></td>
<td>Testing can be done easily with a single operator</td>
</tr>
<tr>
<td></td>
<td>Comprehensive analysis with evaluation software MIT-MagnProof 5</td>
</tr>
</tbody>
</table>

**MIT-DOWEL-SCAN**

Measuring system for the non-destructive and accurate measurement of dowel bar positions in concrete pavements

---

MIT Mess- und Prüftechnik GmbH
Goslarer Straße 63, D-01177 Dresden
Germany
Phone +49 (0) 351 871 81 25
Fax +49 (0) 351 871 81 27
www.mit-dresden.de
info@mit-dresden.de
Where We Are Now ...

- Imaging technologies are being adopted and improved rapidly
- Guidance on their use is also evolving

**Personal** opinions:

- Can always dig out or core, but not ideal
- MIRA and Hilti devices are too labor intensive (for now)
- GPR can test joints at high speed but predominant viewpoint is that it lacks accuracy (for now)
- MIT Scan2-BT is currently the most widely used device
- Spec tolerances vary between devices!!
FHWA Guidance

- FHWA 2005 – FHWA-IF-06-002, “Use of Magnetic Tomography Technology to Evaluate Dowel Bar Placement” (full report is FHWA-IF-06-006)
ASTM Standards


- Defines sign conventions
- Standardizes operational procedures and equipment requirements
- Provides precision, bias and repeatability
Concepts for Dowel Alignment Specifications
The Goals

- Provide indicators of adequate construction process control (i.e., define unqualified acceptance levels).
  - Consider use of incentives/disincentives (PWL) to encourage good process control.

- Avoid conditions that are likely to result in reduced levels of pavement performance or service life (i.e., define unqualified rejection levels).

- Provide better guidance on when expensive corrective actions (i.e., remove and replace, etc.) are really necessary.

- Simplify measurement/control process.
Basis for Alignment Criteria

- Identify distresses and conditions that may result from each type of misalignment/mislocation.
- Develop acceptance/action/rejection criteria based on measures of misalignment/mislocation for individual dowels or groups of dowels, as appropriate.

Criteria must recognize:

- Target (acceptance) levels (easily achievable with good practices)
- Process correction levels (fails to meet target levels, but no anticipated performance problems)
- Corrective action levels (possible performance problems)
Example: Rotational Misalignment Limits

- **Distress Mechanisms**
  - Dowel Groups: Restraint of Joint Function
    - Development of dominant joints
      - Sealant failure, infiltration of water and incompressibles
    - Load transfer system failure
      - Deep joint spalling, loss of load transfer, higher deflections/stresses, reduced pavement life
    - Possible mid-panel cracking

- **Alignment Criteria**
  - Dowel Groups: Control Restraint of Joint Function
    - PWL on Joint Score
    - Limit consecutive restrained joints (e.g., MARL < 60 ft)
Example: Rotational Misalignment Limits

Distress Mechanisms – Individual Dowels

- Local failure of concrete surrounding dowel, loss of individual dowel LT
- Surface spalling (dowel end near surface due to severe vertical rotation)
- Deep corner spalling (significant rotation of dowel near pavement edge)

Alignment Criteria – Individual Dowels

- PWL spec based on SDM values
- Corrective actions only for critical dowels (wheel paths, edge dowels)
  - Allowable SDM based on distance from edge
Considering Measurement Accuracy of Equipment

Very important to understand measurement accuracy of devices – different measurement accuracy may mean different testing spec limits!

Example:

- Longitudinal Offset (Side Shift) Acceptance = 2 inches
- Longitudinal Offset (Side Shift) Rejection = 5 inches
- Device A accuracy = +/- ¼ inch
  - Accept values less than 2.25 inches, Reject values exceeding 4.75 inches
- Device B accuracy = +/- ½ inch
  - Accept values less than 2.50 inches, Reject values exceeding 4.50 inches
ACPA’s Dowel Alignment Guide Specification

- Version 3.1.1 Aug 1 2016
- Major revision underway incorporating concepts presented today
- Public draft expected in December 2016
Acknowledgments

- Glenn Eder – Dayton Superior (retired)
- Jagan Gudimettla – FHWA
- Ron Guntert – Guntert & Zimmerman
- Lev Khazanovich and Kyle Hoegh, Univ. of MN
- Brad Rister – Univ of KY
- Robert Rodden, PNA (formerly ACPA)
- Shiraz Tayabji – Applied Research Associates (formerly Fugro)
- Jerry Voigt and Eric Ferrebee, ACPA
- Dan Ye – Fugro Consultants
- Tom Yu – FHWA
Discussion/Questions?

Mark B. Snyder, Ph.D., P.E.
ACPA Staff Consultant
msnyder@pavement.com
412.979.8332

Main Website | acpa.org
Free Apps | apps.acpa.org
Resources | resources.acpa.org
Your Local Contact | local.acpa.org