Dowel Alignment: Measurement and Impacts on Pavement Performance

prepared by:
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for:
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Concrete Pavement University
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Presentation Outline

- Descriptions and Definitions of Dowel Misalignment
- Measurement of Dowel Alignment
  - “Old School”
  - 21st Century
    - MIT-SCAN (Magnetic Tomography)
    - Ground Penetrating Radar (HILTI PS-1000 and others)
    - Ultrasonic (MIRA)
- Effects of Misalignment on Pavement Performance
Dowel Bar
Misalignment Categories

**MISALIGNMENT**
- **Plan View**
  - Horizontal Skew

**MISLOCATION**
- **Plan View**
  - Horizontal Translation
- **Section View**
  - Vertical Tilt
- **Section View**
  - Vertical Translation
- **Plan View**
  - Longitudinal Translation
Measuring (Mis)alignment – the hard way!
Measuring (Mis)alignment – the REALLY hard way!
Measurement of Dowel Alignment: MIT Scan-2

Developed for locating dowels and tie bars in plain (unreinforced) concrete pavements.
Principles of Magnetic Induction Tomography

- Transmitter sends a weak, pulsating magnetic signal.
- Transmitted magnetic signal (field) comes induces eddy currents inside of metallic objects it contacts.
- Eddy currents create magnetic response signals, which are measured (and recorded every 20 milliseconds) by receivers inside the testing device.
- Measurements are possible under bad conditions (i.e. in the presence of metallic objects or magnetic aggregates)
The analysis takes less than a minute, dependent on the joint length and the complexity of the dowel positioning. The resulting table (Results Tab) permits a quick determination if a bar position exceeds the specified tolerances or where bars are missing. The table displays the following parameters:
- Position along the measuring path (x)
- Depth (zo)
- Side shift (dy)
- Horizontal misalignment (dx)
- Vertical misalignment (dz)

The information box permits a quick view on different parameters of the current measurement. It includes the name of the measured files, date and time of the measurement, the location of the measurement, and the selected bar type. Two buttons are available in this Tab, Continue and repeat.
The software MagnoProof has been created for a more detailed data evaluation and the creation of reports on a Desktop PC.
MIT Scan-2

- Technology: magnetic pulse-induction and tomography
- Multiple sensors (5) are used and the data are collected continuously over the length of the joint
- Redundant sensors are used to accommodate significant variations in lateral bar positions

Example MIT Scan-2 MagnoProof output
Field Verification

MIT Scan-2 results show severely skewed dowel basket at this joint.
OPERATING LIMITS

LIMITS
- The following are limits for accurate MIT-SCAN2-BT results:
  - a side shift less than 80 mm (3.2 in),
  - horizontal misalignment less than 40 mm (1.6 in),
  - vertical misalignment less than 40 mm (1.6 in)
  - tie bar depth between 110 mm and 190 mm (4.3 in ... 7.5 in),
  - thin bar (0<=25.4mm/1in) depth between 80 mm and 160 mm (3.2 in ... 6.3 in),
  - airport bars depth between 175 mm and 255 mm (6.9 in ... 10.0 in).
TOLERANCES

- Tolerances values:
  - repeatability 2 mm (0.1 in),
  - measuring path (x-direction) +/- (3 mm +0.3% of the distance)
  - bar spacing +/- 4 mm (0.2 in)
  - horizontal misalignment +/- 4 mm (0.2 in)
  - side shift +/- 8 mm (0.3 in)
  - depth (cover) +/- 4 mm (0.2 in)
  - vertical misalignment +/- 4 mm (0.2 in)
MIT SCAN Pros and Cons

Pros:
- Ease-of-use, high production (200+ joints/day)
- Broad Implementation and Acceptance

Cons:
- Calibration for Various Metallic Dowels, Dowel Sizes
- Can’t Detect Nonmagnetic Dowels
  - FRP/GRFP
- Magnetic Interference Can Limit Usefulness
  - Nearby vehicles and other metallic objects
  - Tie bars, steel mesh reinforcing (JRCP)
  - Dowel basket shipping wires
Example of Obvious Tie Bar Influence

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Measurement of Dowel Alignment:
HILTI PS 1000 (GPR)

PS 1000 X-Scan: First easy to use Pulse Radar detection tool

- Localization: Locates objects in multiple layers up to 12” in cured concrete
- Hit Prevention: Helps users to find safe spots to drill, core or saw
- Structural Analysis: provides data analysis, evaluation and report generation
Antenna Array

PS 1000 X-Scan measures with three antennas simultaneously.

Why is three better than one? Three antennas ensure:

- Higher productivity
- Better data quality
- Better vertical resolution
All process steps of data analysis are provided

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<tr>
<th>Step</th>
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<th>Image</th>
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Non-destructive testing, building diagnostics, layers

Safe drilling
Depth measurement accuracy with pulse radar depends on the permittivity of the concrete.

Options to derive the correct value for concrete:

1) Reference value:

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<th>Typical parameter value for &quot;concrete&quot;</th>
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2) Verification:

   - Correct
   - Too low value
   - Too high value

3) Calibration based on known object depth

4) Calibration based on wall / slab thickness

Concrete parameter adjustment until depth value is correct.
Imagescan

- Two dimensional scan
- Two size grids (2ft x 2ft & 4ft x 4ft)
- Depth range: 12 in.
- Immediate results

1. Attach reference grid  
2. Scan  
3. Analyze results  
4. Mark results

2 D view  
3D view
Key application fields for a wide variety of customers

Drilling/coring in concrete structures

Marking layout of embedded objects in structures for drilling e.g. rebar, conduit

Non-destructive inspection of bridges e.g. location of tendons

Locating objects in floor e.g. heating pipes
Dowels are completely in alignment
Side-shifted dowels (Yellow line = joint)
Intersection of transverse and longitudinal joints
Example of horizontal misalignment
## CONCRETE PLACED ON 6-5-12

<table>
<thead>
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<th>Bar</th>
<th>Dist. (in)</th>
<th>Depth (in)</th>
<th>Horizontal Deviation</th>
<th>Vertical Deviation</th>
<th>Misalignment</th>
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### Joint 1 Outside Passing Lane

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Technology limitations

Scanning performance depends on:

- Concrete condition
  - Reduced depth range and depth accuracy if concrete is not cured/wrong concrete setting chosen
  - Amount of aggregates, high density concrete
  - Rough surface (use overlay)

- Multiple layer structure
  - Every additional base material layer gives some reflections and prevents from deeper detection performance

- Rebar layout:
  - Detection range / Multiple layer object detection is reduced when rebar grid is < 5”
Measuring Dowel Alignment with the HILTI PS 1000: Pros and Cons

Pros:

- Able to detect bars of all types and sizes without dowel-specific recalibration
- Not affected by shipping wires on baskets
- Able to detect other flaws (e.g., delamination, poor consolidation)
- PROFIS software (provided) allows viewing in 3 dimensions

Cons:

- Time-consuming (16 scans for 4’ x 4’ area)
- Requires manual extraction of alignment data from images produced
- Lack of application-specific software at this time
Measurement of Dowel Alignment:
MIRA Ultrasonic Tomography Device

40-probe low frequency shear wave (s-wave) ultrasonic pulse-echo device for thickness and flaw detection in concrete

• Self-calibrating
• Can be used with any types of dowel/tie bars/reinforcement
• Evaluates condition of concrete around dowels
• High redundancy of measurements = high accuracy
• Signal Interpretation
  - Detect scatterer by changes in reflection intensity (color coded – blue to red)

Example: Mira B-scan Depth Measurement
Focusing – Spatial Diversity

Potential Flaw Positions

Flaw focused to 1 point by introducing spatially diverse measurements
Field Application – Atlanta Georgia CRCP

Rough Surface

Measurement Point

Lane 3 Shoulder
Longitudinal Joint
28 scan markings

Rough Surface

450 mm

Lane 3
Shoulder
Longitudinal Joint
Measurement Point
18 in.

Field Application – Atlanta Georgia CRCP

Rough Surface

Measurement Point

Lane 3 Shoulder
Longitudinal Joint
28 scan markings

Rough Surface
Field Application – Atlanta Georgia CRCP

http://pavementndt.weebly.com/georgia-crcp-project.html

Depth

left bar

middle bar

“shallowest bar”

right bar

Pointing towards center of lane

Pointing towards longitudinal joint

Department of Civil Engineering
Environmental · Geomechanical · Structures · Transportation · Water Resources
Dowel Location

- Metal or other
- Round or other
Field Application – Atlanta Georgia CRCP: MIRA vs Core Concrete Cover

\[ y = 0.9854x \]
\[ R^2 = 0.9969 \]
Reinforcement Misalignment

Identification of misplaced tie bars

Core Location

Line Parallel to Direction of traffic

Core Showing Misplaced Reinforcement

Dowels

Misplaced Tiebar

Identification of misplaced tie bars
Concrete Damage around Reinforcement

Detection of damage initiated by uncut dowel basket tie wires
Detection of damage initiated by uncut dowel basket tie wires.
Measuring Dowel Alignment with the MIRA Ultrasonic Device: Pros and Cons

Pros:
- Able to detect bars of all types and sizes without dowel-specific recalibration
- Not affected by shipping wires on baskets
- Able to detect other flaws (e.g., delamination, poor consolidation)

Cons:
- Time-consuming
- Requires manual extraction of alignment data from images produced
Effects of Dowel Misalignment: Joint Lockup, Spalling, Mid-panel Cracking
NCHRP Project 10-69: Development of Guidelines for Dowel Alignment in Concrete Pavements

Khazanovich, et al

University of Minnesota
Field Study

Scope:

- 60 pavement sections in 17 states (Arizona, California, Colorado, Georgia, Indiana, Illinois, Kansas, Michigan, Minnesota, Missouri, Nevada, North Carolina, Ohio, South Dakota, Virginia, Washington, and Wisconsin)
- over 2,300 joints
- over 35,000 dowel bars

Climatic regions:
- dry-freeze: 8 sections
- dry-nonfreeze: 24 sections
- wet-freeze: 22 sections
- wet-nonfreeze: 6 sections
Field study sections – dowel placement method

Type of construction

- Basket: 59%
- DBI: 38%
- Retrofit: 3%
Field study sections – dowel diameter

- Dowel diameter
  - 1 or 1.125 in: 3%
  - 1.25 in: 27%
  - 1.5 in: 70%
Field Testing

- MIT Scan-2
- Distress Survey
  - Faulting
  - Cracking
  - Spalling
- FWD
Typical vertical translation: \( \pm 0.5 \text{ in for } D < 12 \text{ inches} \)
Longitudinal Translation Distribution

Typical longitudinal translation:
+ 2 in for 18-in dowel bars
Typical horizontal skew: ± 0.5 in per 18 in
Typical vertical tilt:
± 0.5 in per 18 in
**Field Testing: Misalignment Summary**

- Limits of typical observed misalignment:
  - Vertical translation: ± 0.5 in (for D < 12 inches)
  - Horizontal skew: ± 0.5 in per 18 in
  - Vertical tilt: ± 0.5 in per 18 in
  - Longitudinal translation: ± 2 in for 18-inch dowels

- Levels represent field tolerances that are easily achieved.
- Alignment within these limits does not appear to significantly affect pavement performance.
  - Somewhat higher levels of misalignment also not linked with higher levels of distresses.
- Higher LTE loss at joints with >4 in horizontal skew
- Higher faulting at joints with >0.75 in tilt
SUMMARY AND CONCLUSIONS
Acknowledgments

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