Dowel Basket Anchoring Methods

BEST PRACTICES
WORKSHOP

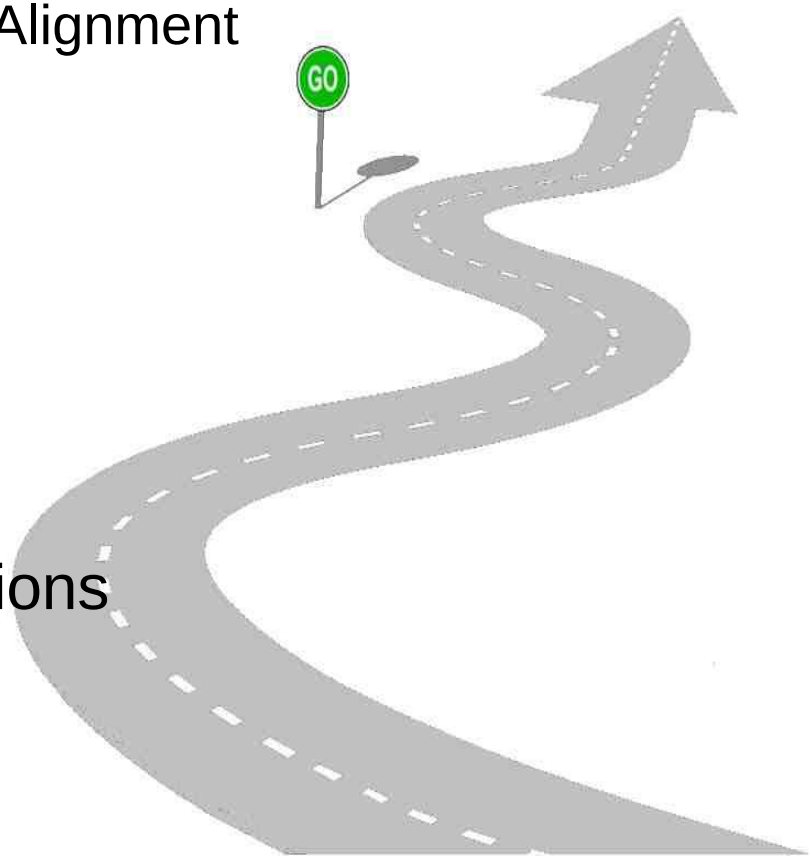
U.S. Department of Transportation
Federal Highway Administration

National Concrete Pavement Technology Center
Tech Center

IOWA STATE UNIVERSITY
Institute for Transportation

Outline

- Dowel Alignment and Placement
  - Dowels 101 – The Basics
  - The Importance of Location and Alignment
  - Placement Methods
- Anchoring Dowel Baskets
  - Basket Stakes
  - Basket Clips
  - Typical Practices
- Additional Support/Bracing Options
- Conclusions



Reference

MAY 2016 FHWA-HIF-16-021

Tech Brief

DOWEL BASKET ANCHORING METHODS

Best Practices for Jointed Concrete Pavements

INTRODUCTION

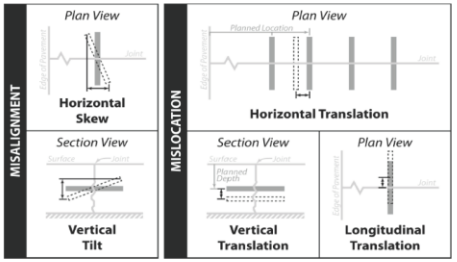
Dowels are the most common form of load transfer in concrete pavements. They come in various sizes, shapes, and materials, but to perform optimally over the course of the pavement life, they need to be oriented appropriately and within tolerable location limits in the slab. Proper placement ensures optimal load transfer with minimal added stress to the pavement. For this reason, attention to dowel placement during paving is important, and ensuring that dowel placement accuracy is maintained through paving is a necessary quality control activity.

Dowel basket fasteners, such as basket clips and stakes, are commonly used to secure dowel baskets for the paving process. This tech brief summarizes the purpose and recommendations for ensuring that dowels placed using baskets maintain their position and elevation through the paving process. Additional details can be found in the *Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements* (Snyder 2011).

DOWEL ALIGNMENT AND PLACEMENT

The location and alignment of dowel bars is important to achieve intended performance. This is true regardless of whether dowels are placed using a mechanical dowel bar inserter (DBI) or placed before paving with baskets, which is the subject of this tech brief.

Pavement specifications typically include placement tolerances. These tolerances call for dowels to be placed reasonably close to parallel with the pavement centerline and the pavement surface. This also results in the dowels being parallel to each other. Specifications also require that dowels be located within mid-depth of the slab. Dowels that are significantly misaligned or mislocated (as illustrated in Figure 1) may not function as intended and, if well out of tolerance, can cause detrimental pavement damage.



Snyder 2012 after Tayabji 1996 and FHWA 2007

Figure 1. Five types of dowel bar misalignment and mislocation

U.S. Department of Transportation
Federal Highway Administration

www.fhwa.dot.gov/pavement/concrete/pubs/hif16021.pdf

DOWELS 101 – THE BASICS

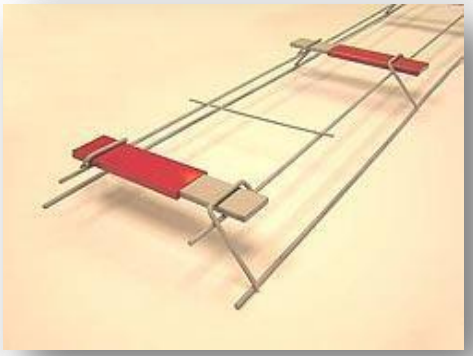
Introduction

- Dowels are the most commonly used means for mechanical load transfer in concrete pavement joints.
- To perform optimally over many years of pavement life dowels need to be:
  - Oriented appropriately
  - Within tolerable location limits
- Proper placement ensures optimal performance.
- Attention to dowel placement and securing dowels is an important quality control activity.

There Are Many Different Types of Dowels





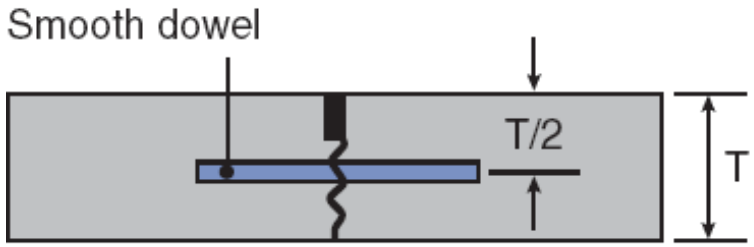
Images: ACPA

Typical Dowel Specifications

- AASHTO M254 - Standard Specification for Corrosion-Resistant Coated Dowel Bars
- ASTM A1078 - Standard Specification for Epoxy-Coated Steel Dowels for Concrete Pavement

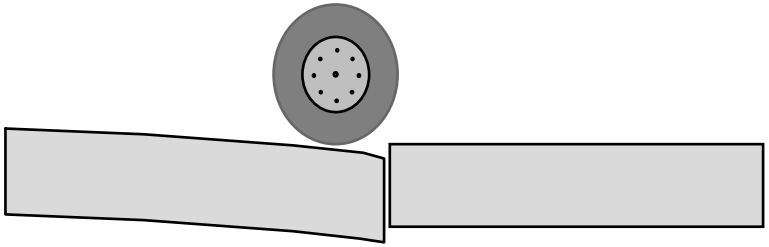
Goal of Dowel Placement

- ***Adequate Alignment*** such that they impose no intolerable restraint on joint opening/closing.
- ***Location within Tolerance*** such that they provide adequate long-term load transfer.

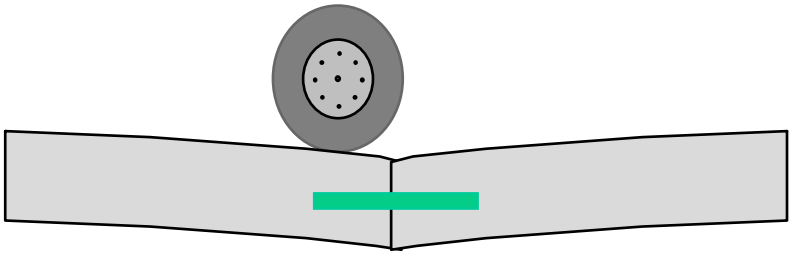


The Purpose of Dowel Bars

0% Load Transfer Efficiency

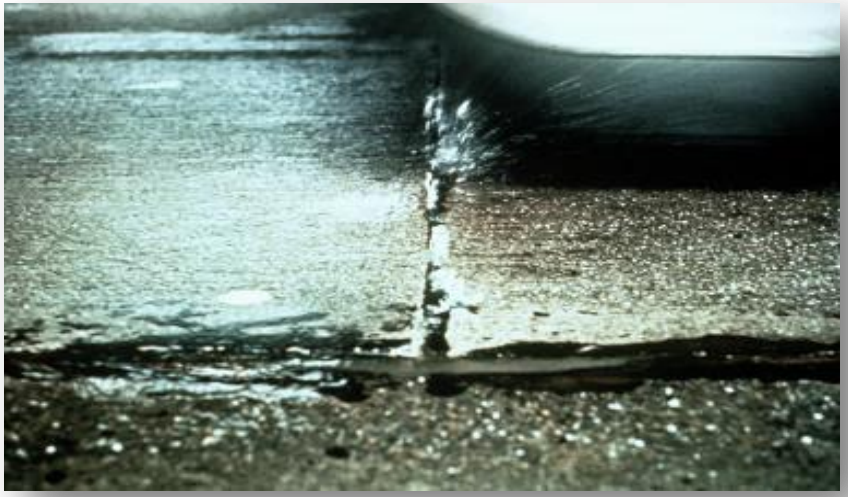


100% Load Transfer Efficiency



Problems From Poor Load Transfer

Pumping of fine-grained materials from beneath the joints.



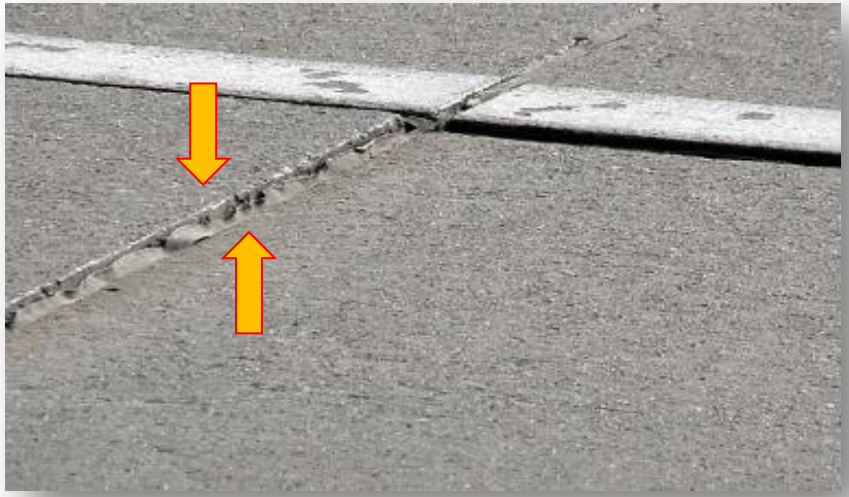
Water expulsion under wheel load

Shoulders stained from fine base materials

Images: ACPA

Problems From Poor Load Transfer

Faulting and corner breaks are common manifestations from pumping



Faulted Joint

Corner Breaks

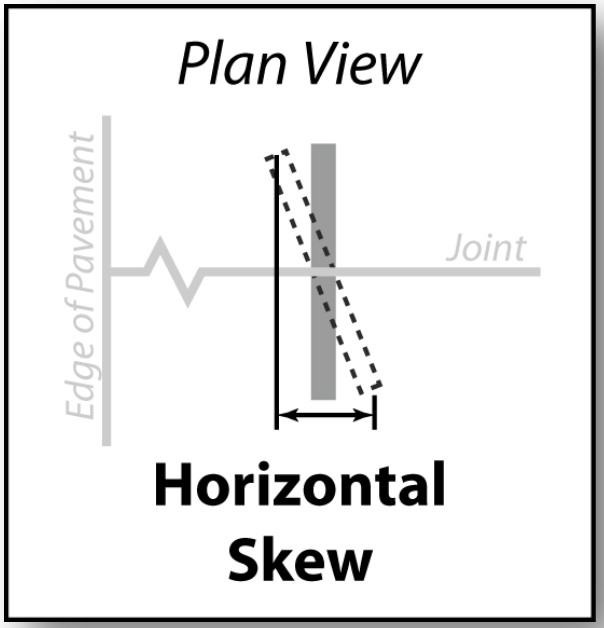
Images: ACPA

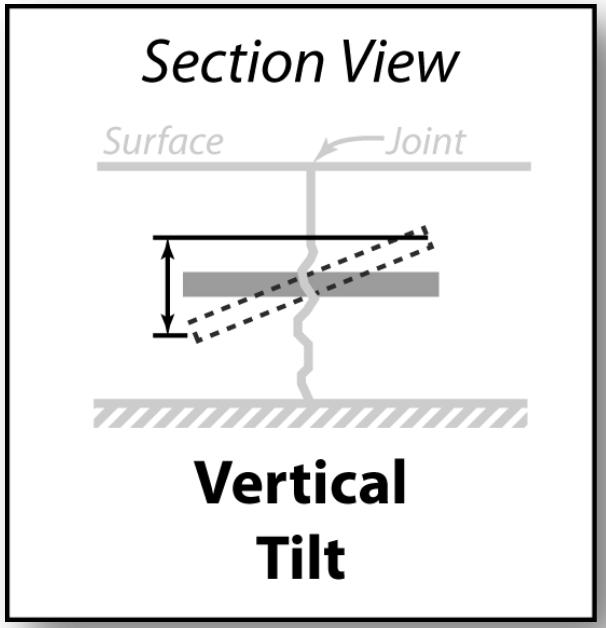
IMPORTANCE OF LOCATION AND ALIGNMENT

Dowel Alignment and Location

- Dowel location and alignment are important to maximizing long-term performance
- Good alignment allows joints to open and close as slabs expand/contract with temperature cycling
- Good location ensures there is enough connection to provide load transfer between slabs
- Dowels baskets need to be positioned and fastened well

Dowel Alignment – Skew and Tilt





Illustrations: Mark B. Snyder (after Shiraz D. Tayabii)

Dowel Alignment - Translation

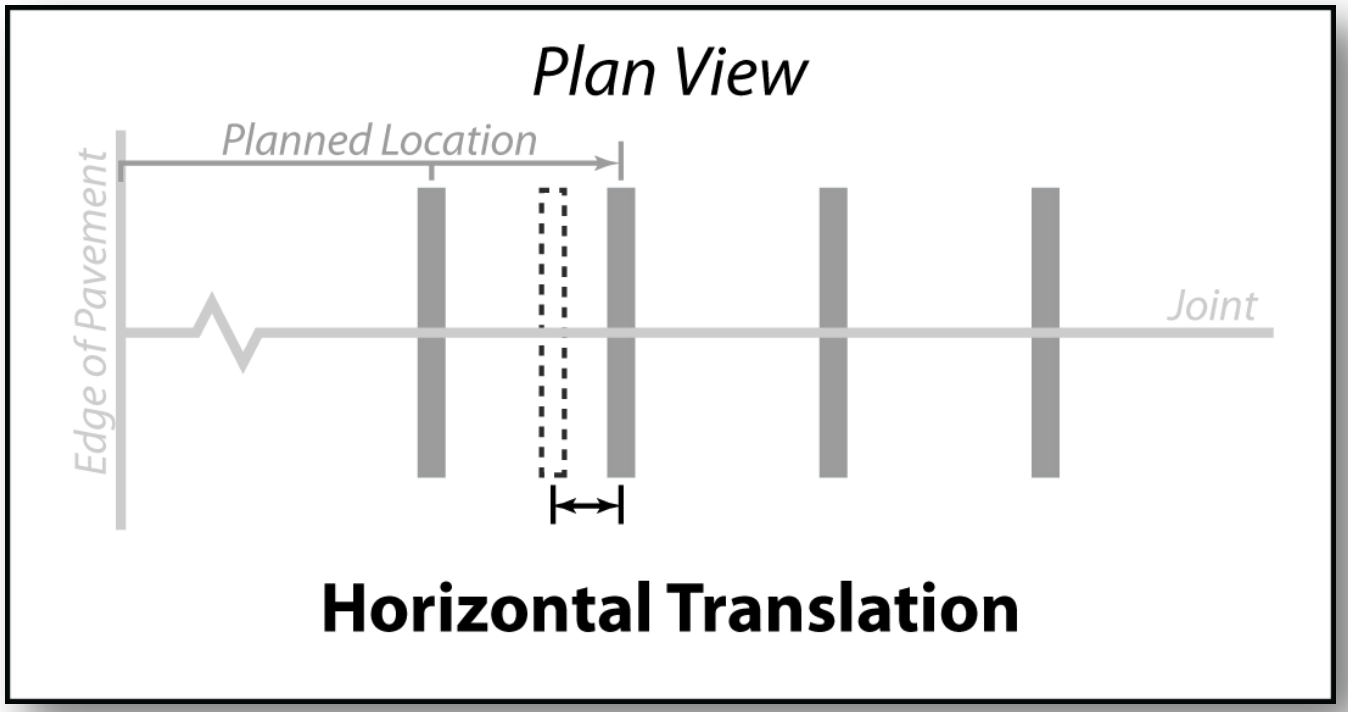
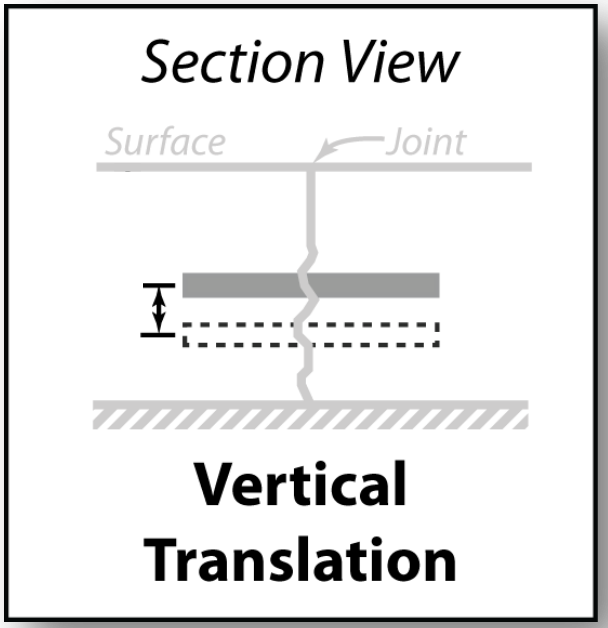
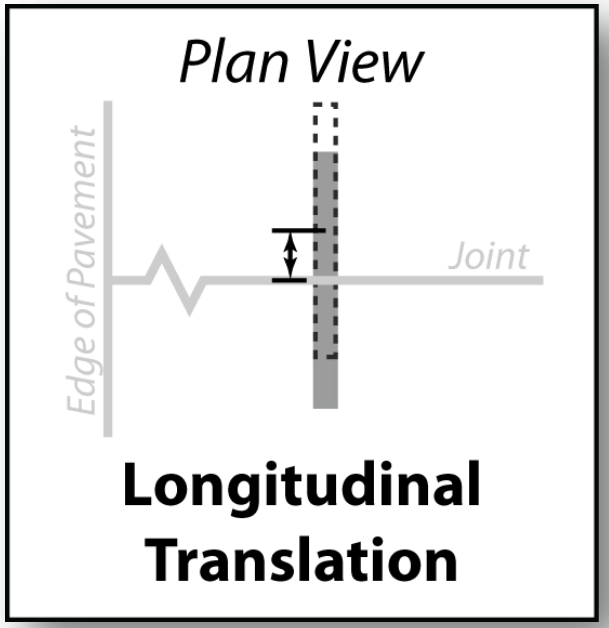


Illustration: Mark B. Snyder (after Shiraz D. Tayabii)

Dowel Alignment - Translation





Illustrations: Mark B. Snyder (after Shiraz D. Tayabii)

Dowels & Dowel Alignment 101

- Typical dowel bar installation results in a combination of skew, tilt and translation of some bars.
- The key is keeping the bars within reasonable tolerances.

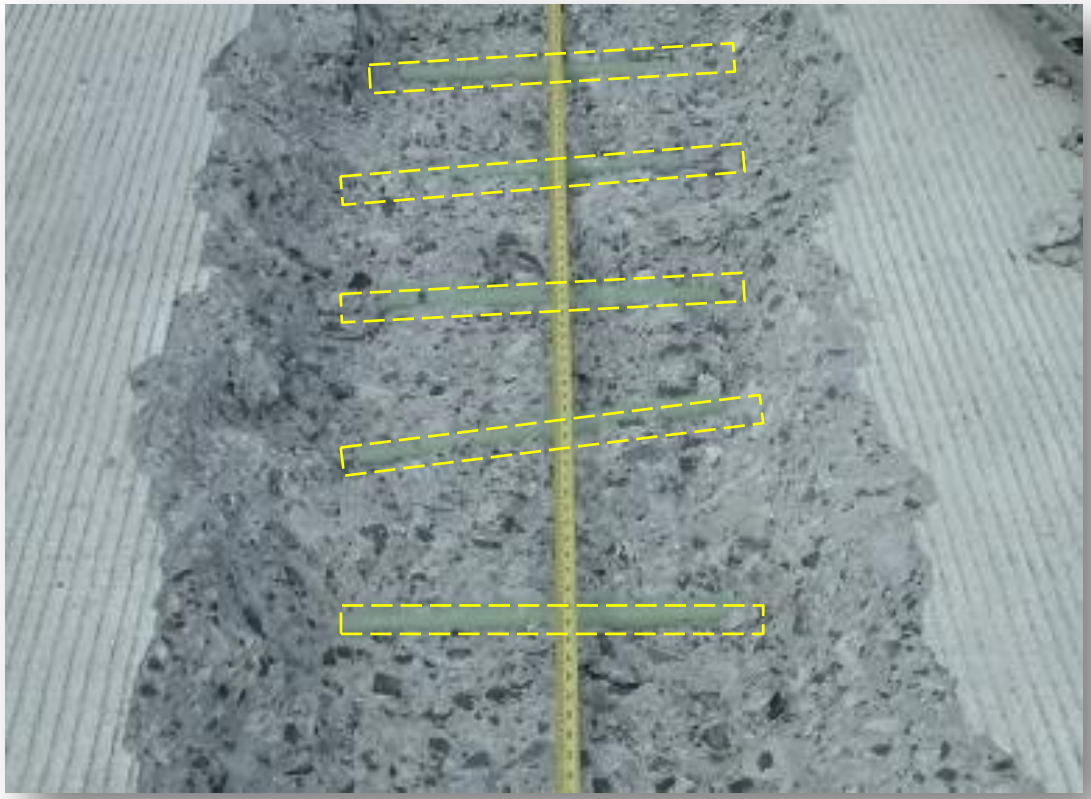
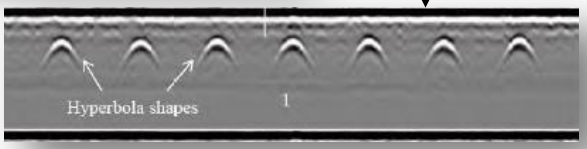


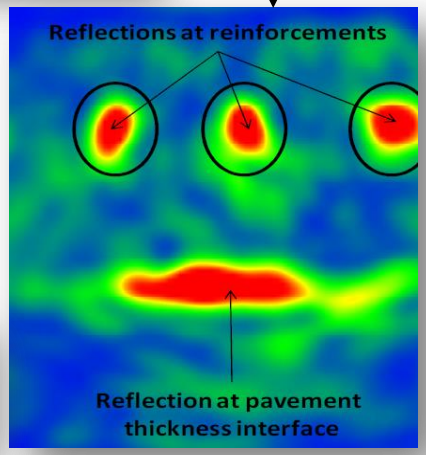
Image: Mark B. Snyder, ACPA


Image: ACI

Dowels & Dowel Alignment 101

- Dowel bar imaging has provided a method to detect bar location and alignment without damaging the slab





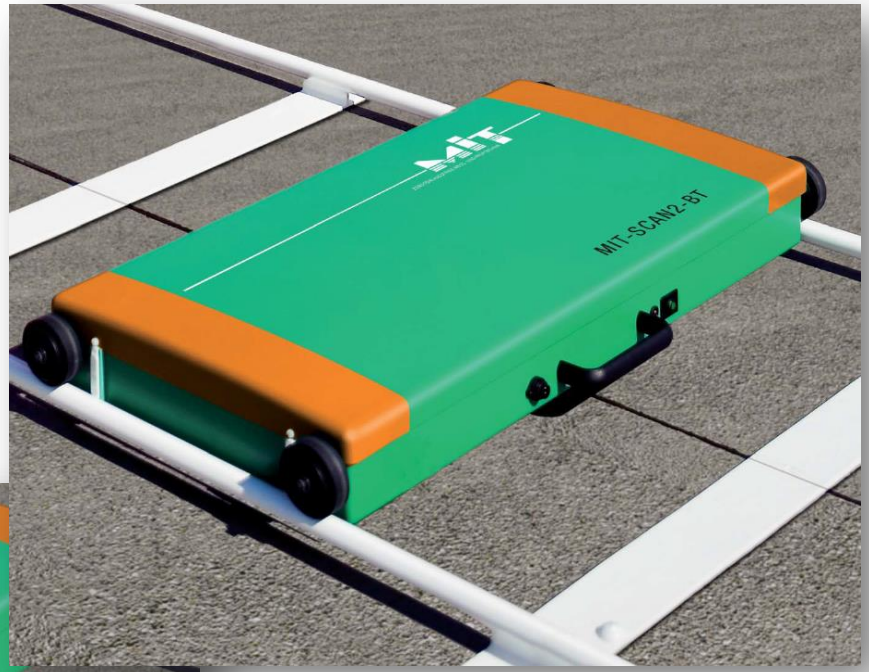
Dowels & Dowel Alignment 101

- MIT Scan2 B.
- Consists of a compact rail-guided measuring device.
- GRP (glass fiber reinforced plastic) rail system.
- Unit is pulled along rails while measuring.

Images: Mark B. Snyder, ACPA and ERES Consultants

Dowels & Dowel Alignment 101

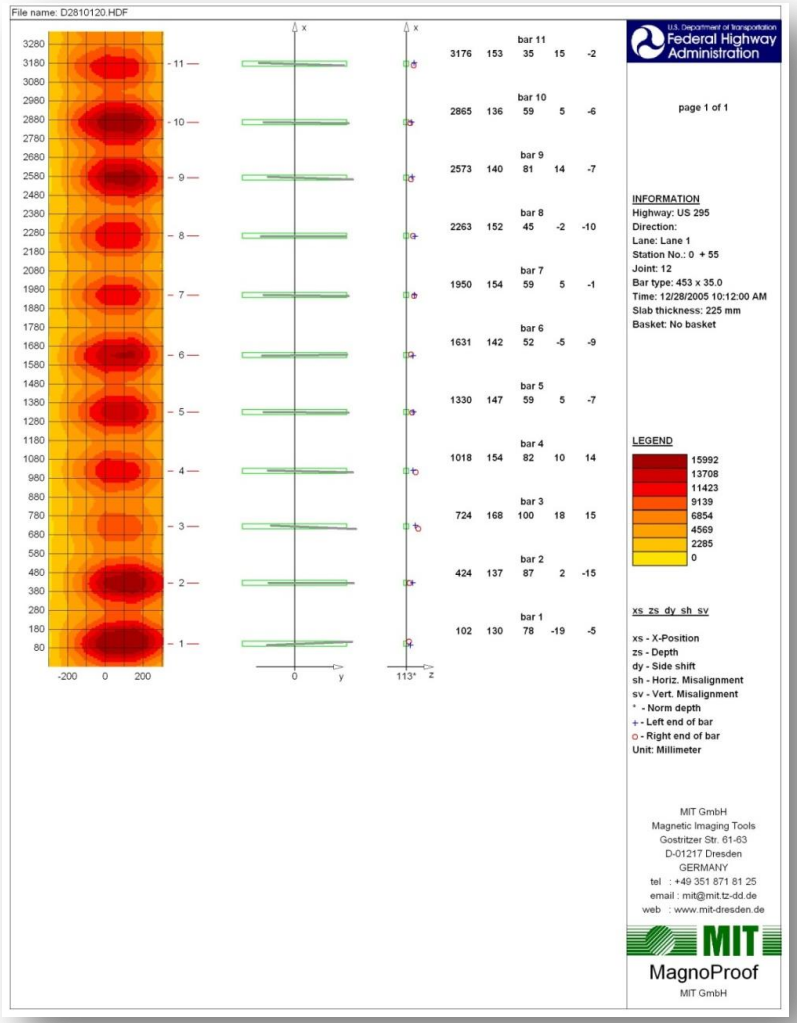
- MIT Scan2 BT requires calibration for accurate results



Images: MIT Mess- und Prüftechnik GmbH, Dresden, Germany

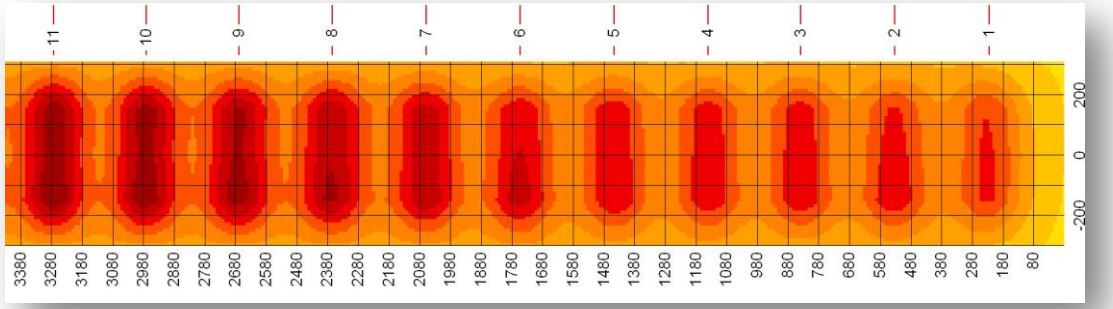
Dowels & Dowel Alignment 101

- MIT-SCAN2 typical output provides:
  - Graphical presentations
  - Numerical data
- Each bar included.
- Easy to interpret.

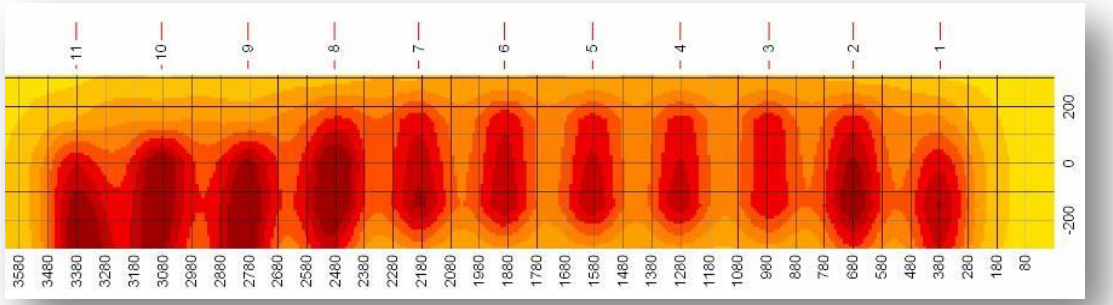


Images: MIT Mess- und Prüftechnik GmbH, Dresden, Germany

Dowels & Dowel Alignment 101



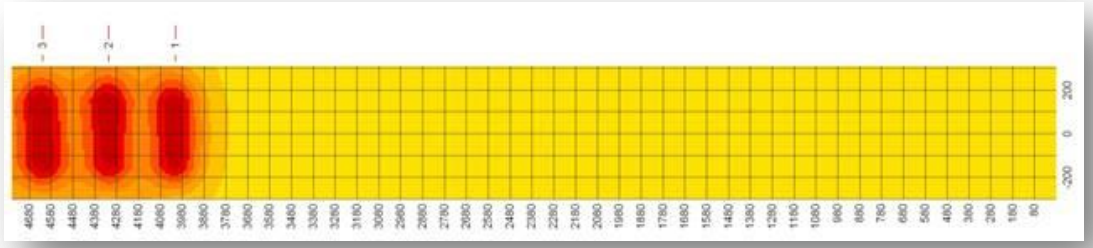
Scan from typical joint showing bars in good position



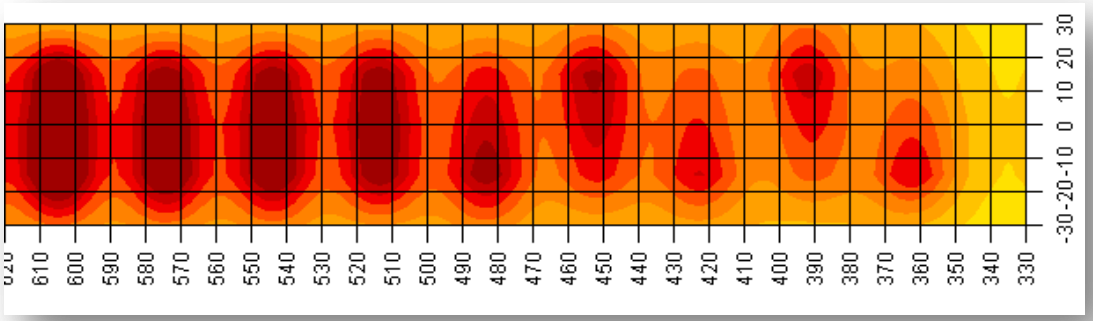
Scan from joint indicating an anchoring Issue

Images: KSE Testing Equipment

Dowels & Dowel Alignment 101



Scan from joint with missing dowel bars



Scan from joint where the basket opened & dowels tilted

Images: MIT Mess- und Prüftechnik GmbH, Dresden, Germany

Dowels & Dowel Alignment 101

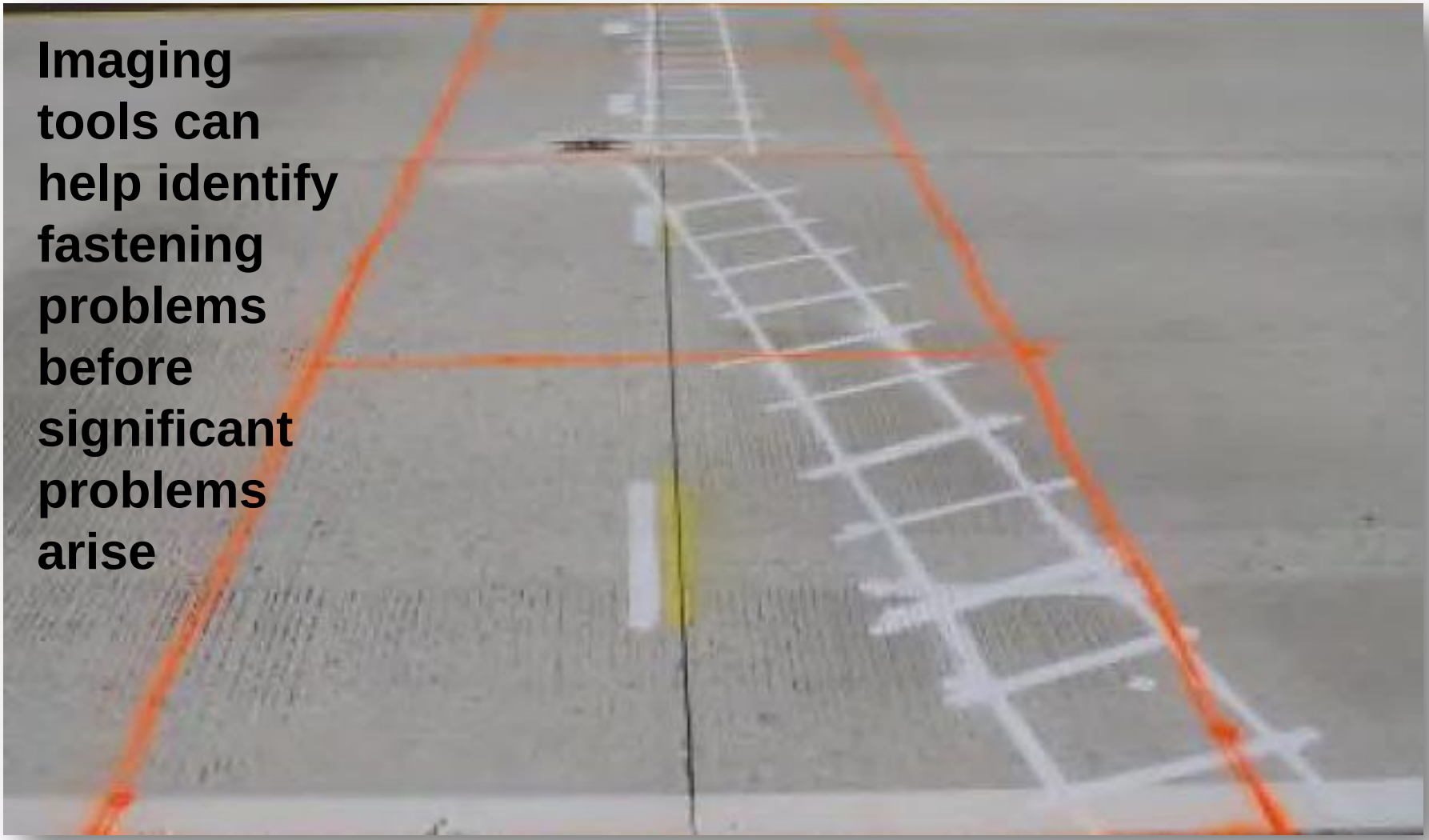


Image: ACPA

Dowels & Dowel Alignment 101

▲ Dowel too close to surface

Dowels tipped and too close to surface ▶

Images: Mark B. Snyder and ACPA

Dowels & Dowel Alignment 101

▲ Dowel too close to corner.

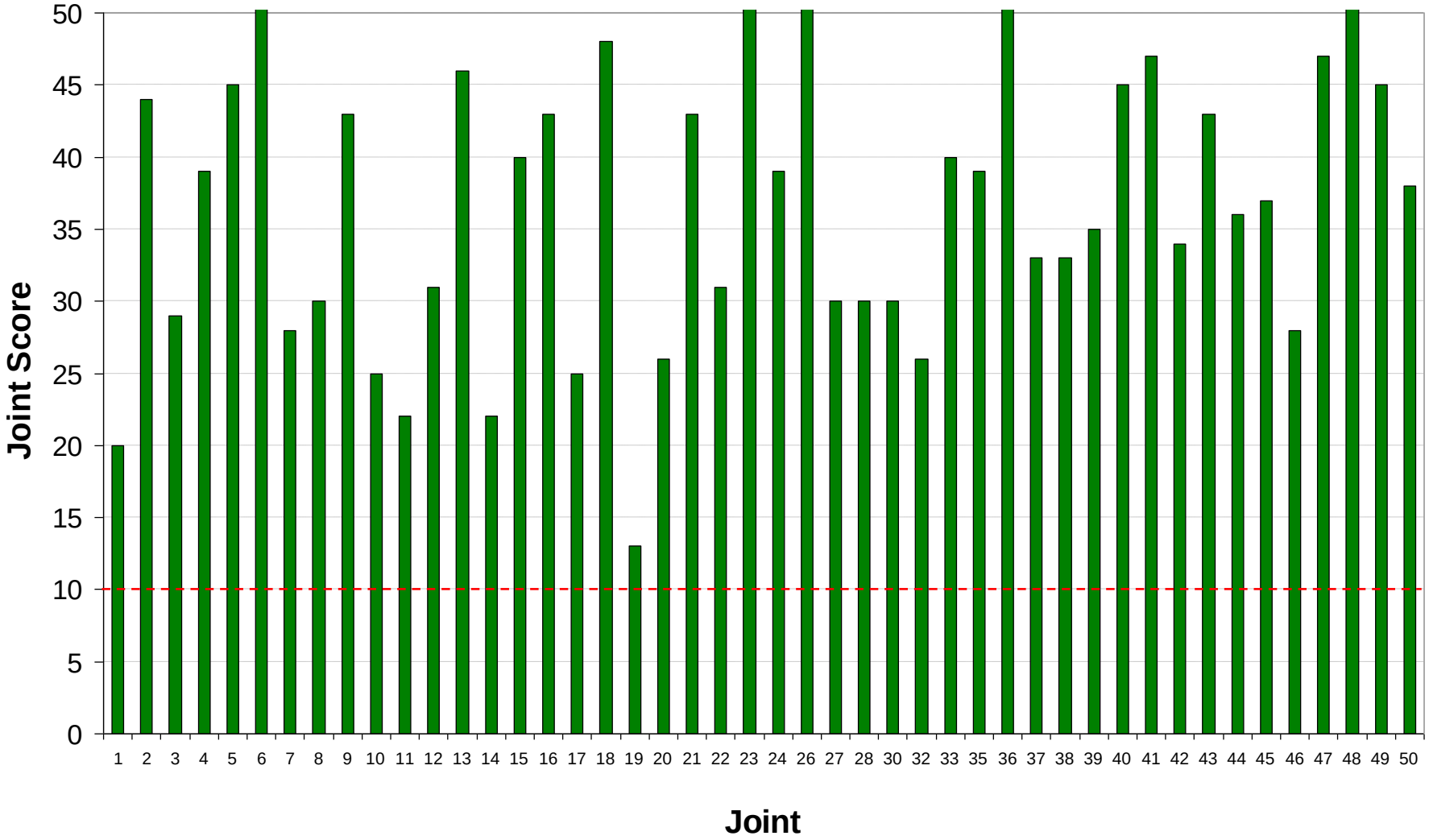
Dowel tipped and too close to surface ▶

Images: Mark B. Snyder and ACPA

Dowels & Dowel Alignment 101

- No perfect measure exists to correlate the degree of misalignment and joint distress or loss of load transfer.
- Engineers are still trying to create a reasonable tolerance and specification measure to take advantage of new measuring devices.
- Joint Score is one approach.

Joint Score for the GA Section



30-yr old pavement section with extremely poor dowel alignment

Image: ACPA

DOWEL PLACEMENT

Dowel Placement

- Two methods:
  - Dowel Bar Insertion
  - Dowel Basket Assemblies

Images: ACPA

Dowel Bar Insertion

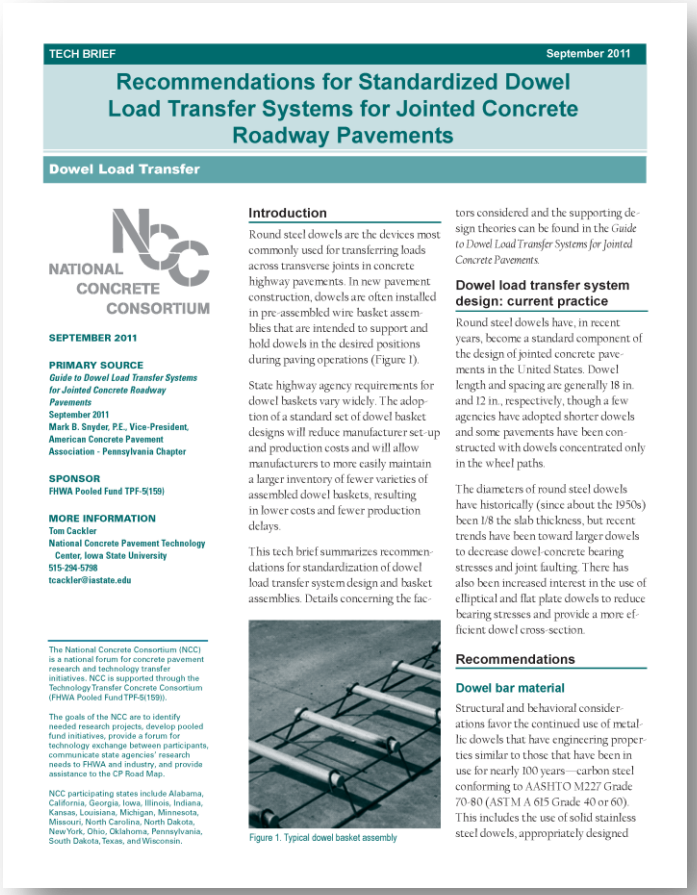
Images: ACPA

Dowel Basket Assemblies

- Consist of multiple components.
- Typically made of steel.
- Typically use the dowels as part of the basket.
- Often alternate affixing the dowel to the basket frame on each side.
- Sometimes called “cages”.
- There is no one standard for the frame design.

Dowel Basket Standardization Goal

- National Concrete Consortium goal for more than a decade.
- Among other recommendations:
  - ➢ Basket rail wire should be:
    - ➢0.306 in. min. diameter (1/0 gauge).
  - ➢ Loop wires should be:
    - ➢U or V style.
    - ➢0.243 in. min. diameter (3 gauge).
  - ➢ Spacer or tie wires should be:
    - ➢ 0.177 in. dia. (7 gauge).
    - ➢4 used per standard-width basket.



TECH BRIEF September 2011

Recommendations for Standardized Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements

Dowel Load Transfer

NATIONAL CONCRETE CONSORTIUM

SEPTEMBER 2011

PRIMARY SOURCE
Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements
September 2011
Mark B. Snyder, P.E., Vice-President, American Concrete Pavement Association - Pennsylvania Chapter

SPONSOR
FHWA Pooled Fund TPF-5(159)

MORE INFORMATION
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The National Concrete Consortium (NCC) is a national forum for concrete pavement research and technology transfer initiatives. NCC is supported through the Technology Transfer Concrete Consortium (FHWA Pooled Fund TPF-5(159)).

The goals of the NCC are to identify needed research projects, develop pooled fund initiatives, provide a forum for technology exchange between participants, communicate state agencies' research needs to FHWA and industry, and provide assistance to the CP Road Map.

NCC participating states include Alabama, California, Georgia, Iowa, Illinois, Indiana, Kansas, Louisiana, Michigan, Minnesota, Missouri, North Carolina, North Dakota, New York, Ohio, Oklahoma, Pennsylvania, South Dakota, Texas, and Wisconsin.

Introduction

Round steel dowels are the devices most commonly used for transferring loads across transverse joints in concrete highway pavements. In new pavement construction, dowels are often installed in pre-assembled wire basket assemblies that are intended to support and hold dowels in the desired positions during paving operations (Figure 1).

State highway agency requirements for dowel baskets vary widely. The adoption of a standard set of dowel basket designs will reduce manufacturer set-up and production costs and will allow manufacturers to more easily maintain a larger inventory of fewer varieties of assembled dowel baskets, resulting in lower costs and fewer production delays.

This tech brief summarizes recommendations for standardization of dowel load transfer system design and basket assemblies. Details concerning the factors considered and the supporting design theories can be found in the *Guide to Dowel Load Transfer Systems for Jointed Concrete Pavements.*

Figure 1. Typical dowel basket assembly

Dowel load transfer system design: current practice

Round steel dowels have, in recent years, become a standard component of the design of jointed concrete pavements in the United States. Dowel length and spacing are generally 18 in. and 12 in., respectively, though a few agencies have adopted shorter dowels and some pavements have been constructed with dowels concentrated only in the wheel paths.

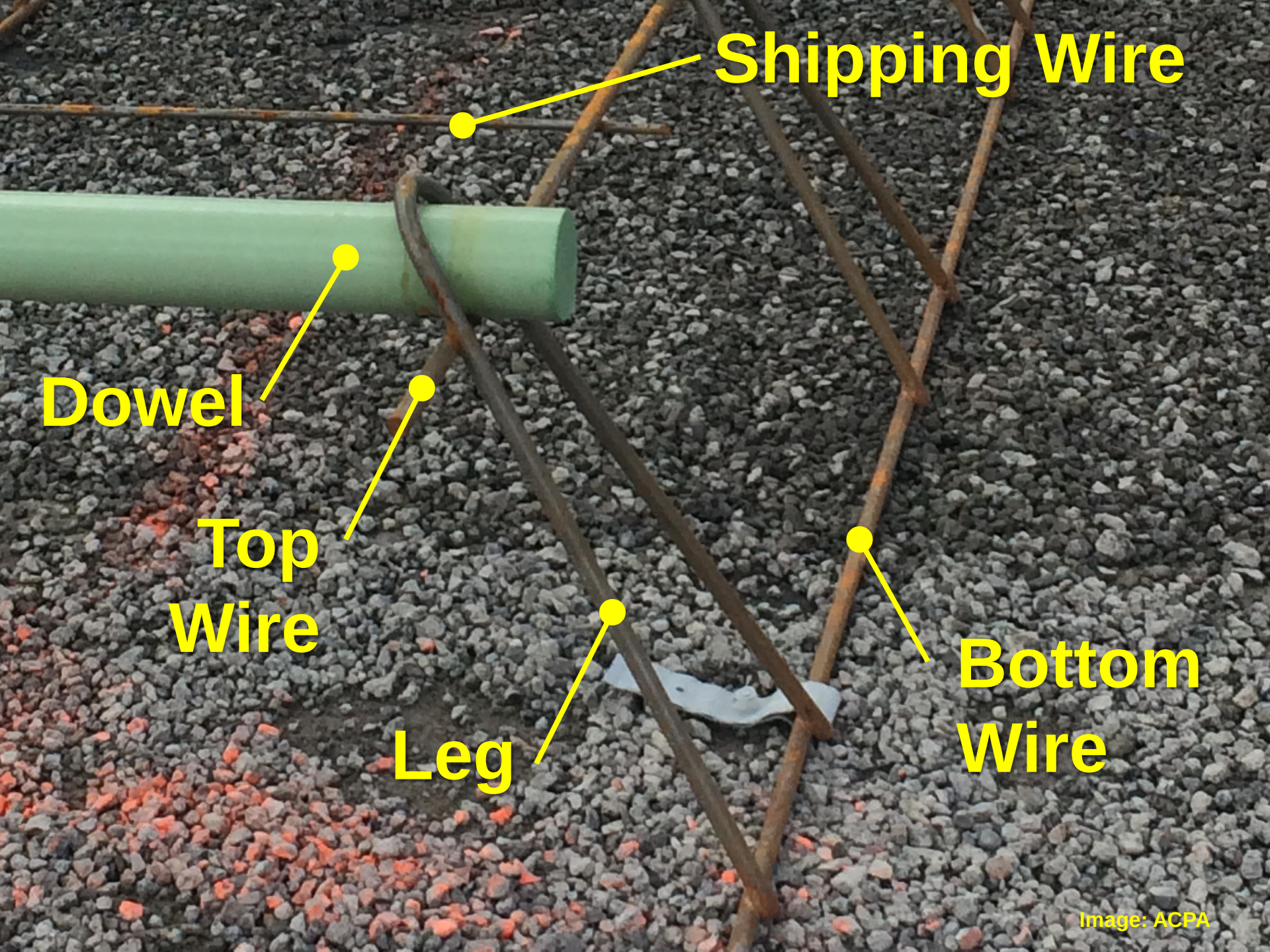
The diameters of round steel dowels have historically (since about the 1950s) been 1/8 the slab thickness, but recent trends have been toward larger dowels to decrease dowel-concrete bearing stresses and joint faulting. There has also been increased interest in the use of elliptical and flat plate dowels to reduce bearing stresses and provide a more efficient dowel cross-section.

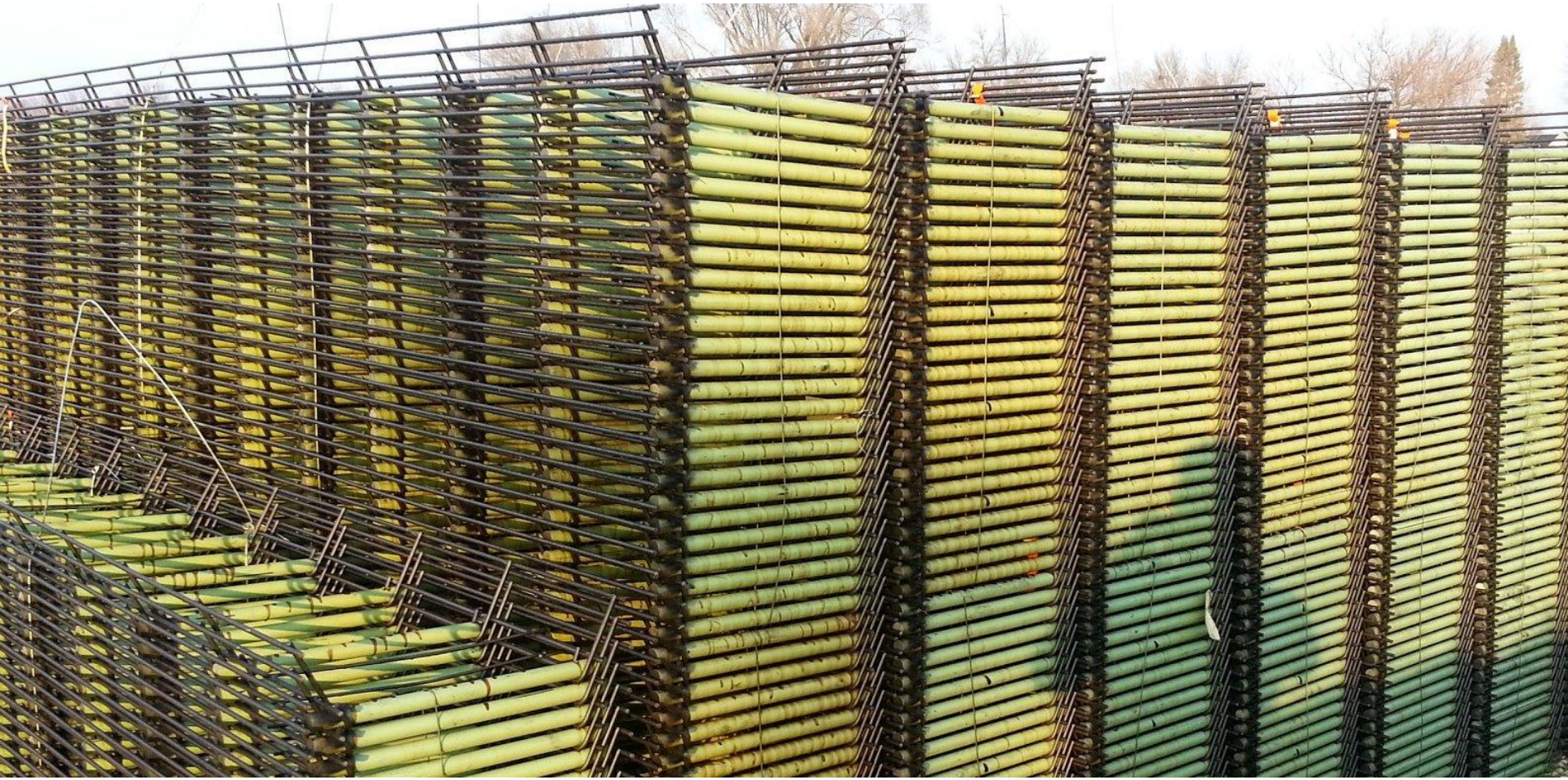
Recommendations

Dowel bar material

Structural and behavioral considerations favor the continued use of metallic dowels that have engineering properties similar to those that have been in use for nearly 100 years—carbon steel conforming to AASHTO M227 Grade 70-80 (AST M A 615 Grade 40 or 60). This includes the use of solid stainless steel dowels, appropriately designed

Dowel Basket Assemblies


Shipping Wire
Dowel
Top Wire
Leg
Bottom Wire
Image: ACPA



Dowels stacked and Stored for Use

Image: ACPA

The Variety of Dowels

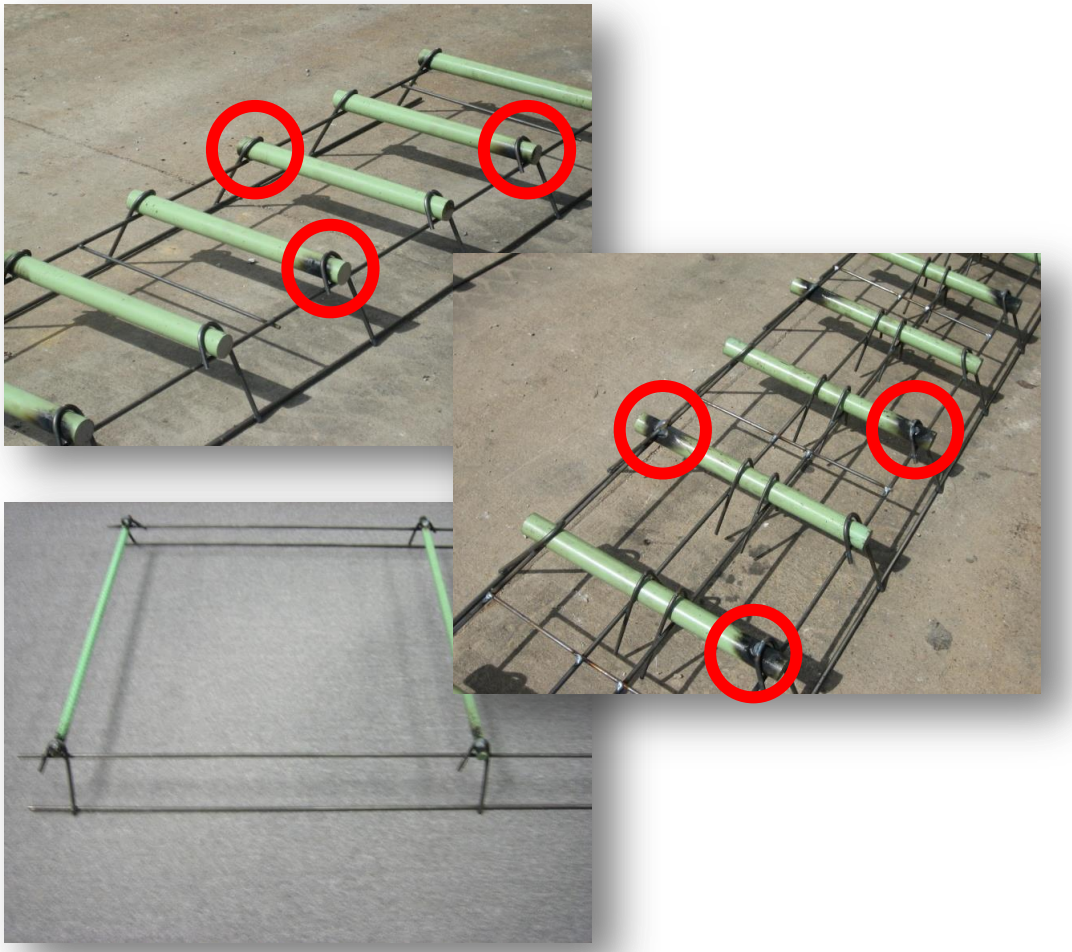
- Variables:
  - Shape
  - Size
  - Length
  - Material
  - Ends (cut & treatment)
  - Coating (type & thickness)

DOT Epoxy Coating Mil Thickness Variation

AL 5-9	IN 7 min	NY 10-18	SD 5-10
AZ 8-12	IA 6 min	NV 8-12	TN 8-12
AR 8-12	KS 8-12	NC 7-13	TX 8-12
CO 5-9	KY 9-15	NM 6-10	UT 8-12
DE 5-9	MI 8-12	ND 8-12	VA 8-12
FL 7-12	MN 8-12	OH 5-9	WA 8-12
GA 10-14	MO 5 min	OK 7-12	WV 7 min
ID 5-9	MT 8-12	PA 8-12	WI 5-9
IL 7-12	NE 5-9	SC None	WY 5-9

Types of Dowel Basket Assemblies

- Contraction joint
  - Conventional
  - Half-width
  - Tapered baskets
  - Skewed baskets
  - Stepped baskets
- Expansion joint
- Rebar baskets
  - Tied joint
  - Hing-joint baskets



Images: Dayton Superior

Dowel Basket Assembly Variations

- Design of basket
- Wire gauges
- Number of shipping wires
- Number of dowels
- Spacing of dowels
- Dowel height
- Leg Style

Images: Dayton Superior

Dowel Basket Leg Styles

- J
- U
- V
- R
- Choked V

Images: Dayton Superior

Dowel Basket Assembly – Typical Dowel Spacing

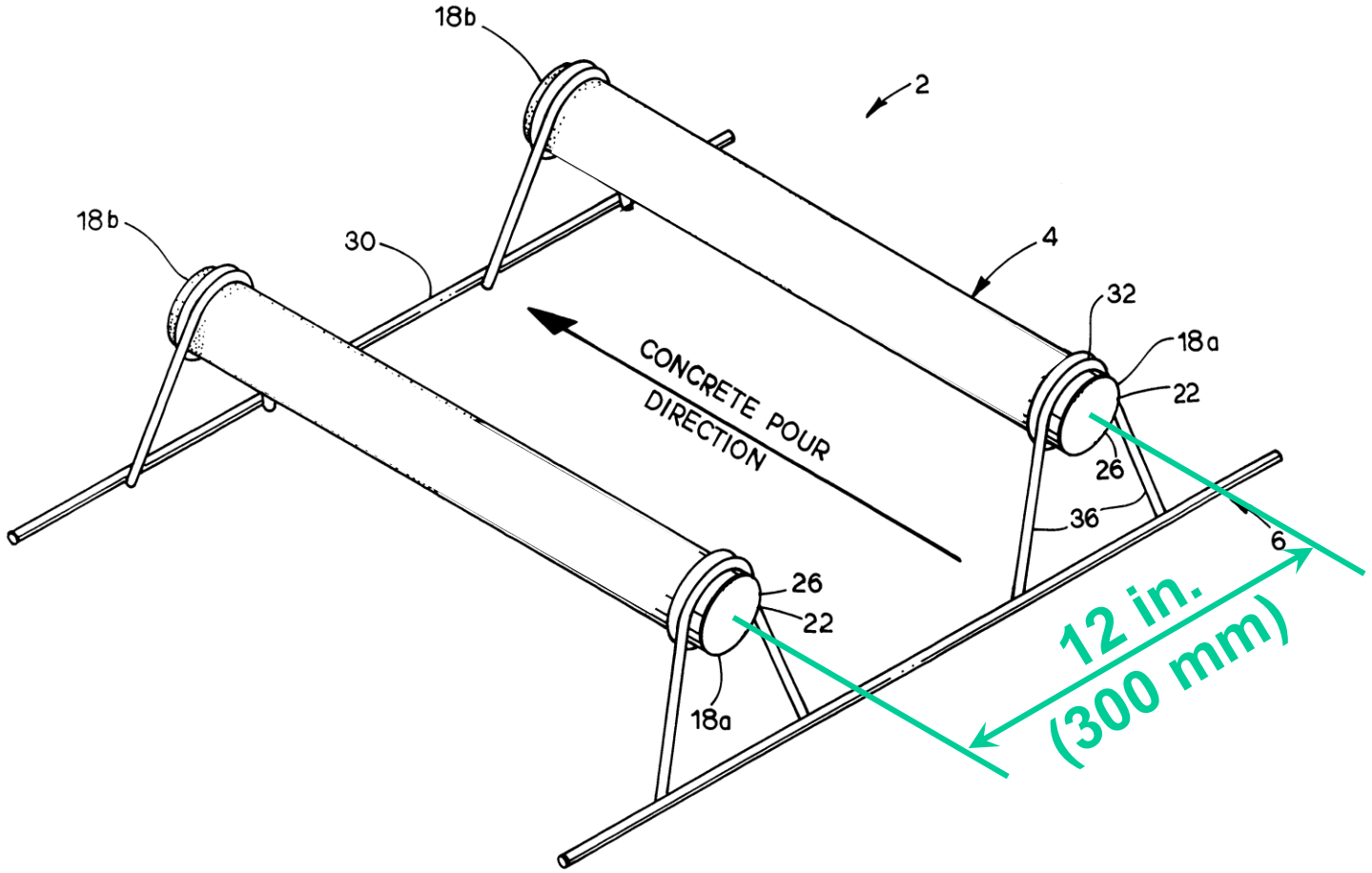


Image: ACPA

ANCHORING BASKET ASSEMBLIES

Types of Anchors

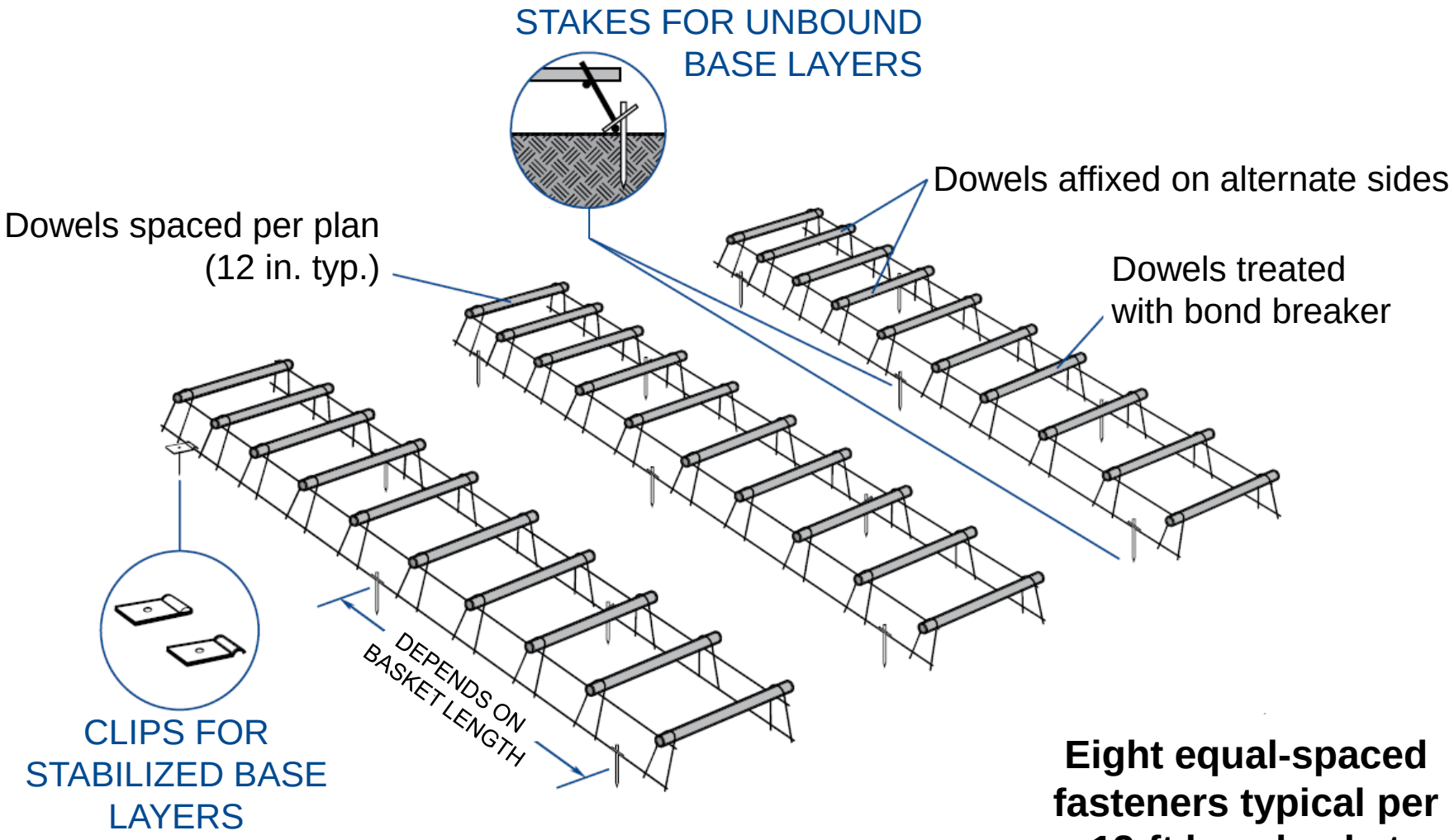
- Pins
- Stakes
- Spikes
- Clips

Image: ACPA

Number of Anchors

- Practice varies by:
  - Specification requirement (sometimes)
  - Contractor experience
  - Base type
- Recommended minimums:
  - 8 per basket (12-ft lane)
  - 10 per basket (14–15 ft lane)
  - Same number on each side
- Make Adjustments as Needed!

Number of Anchors per Basket

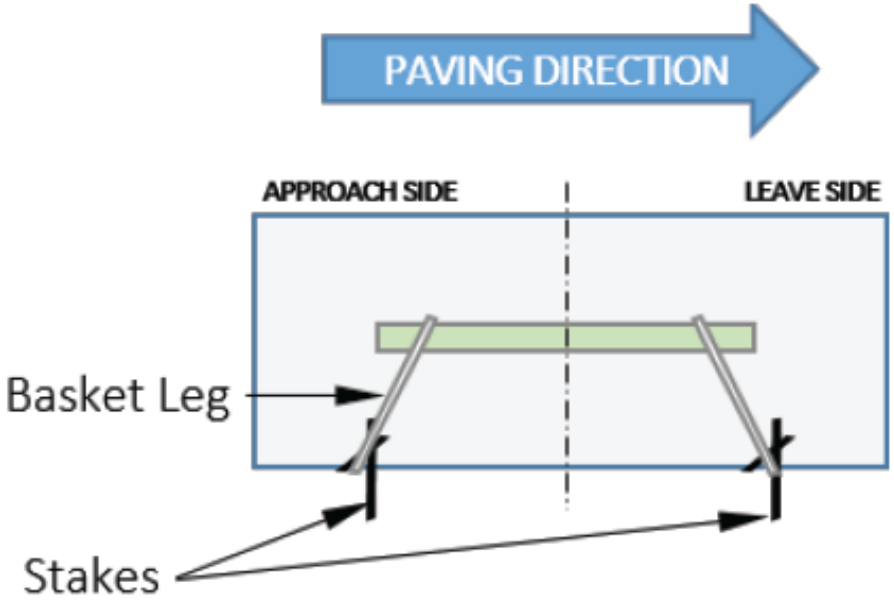


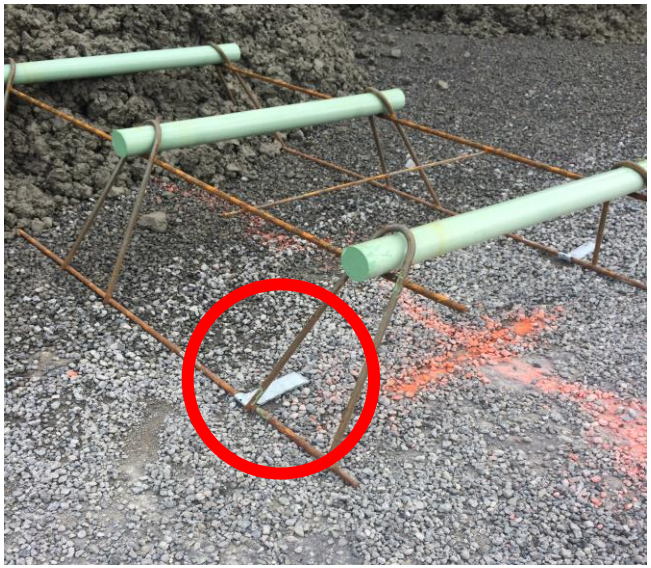
Eight equal-spaced fasteners typical per 12-ft lane basket

Anchoring Depth

- Granular Base
  - Most states require minimum of 12 in. (300 mm)
- Dense-Graded Stabilized Base
  - 4 in. (100 mm) usually sufficient
- Open-Graded Stabilized Base
  - 6 in. (150 mm) depth to hold
- Make Adjustments as Needed!

Anchoring on Leave Side of Joint





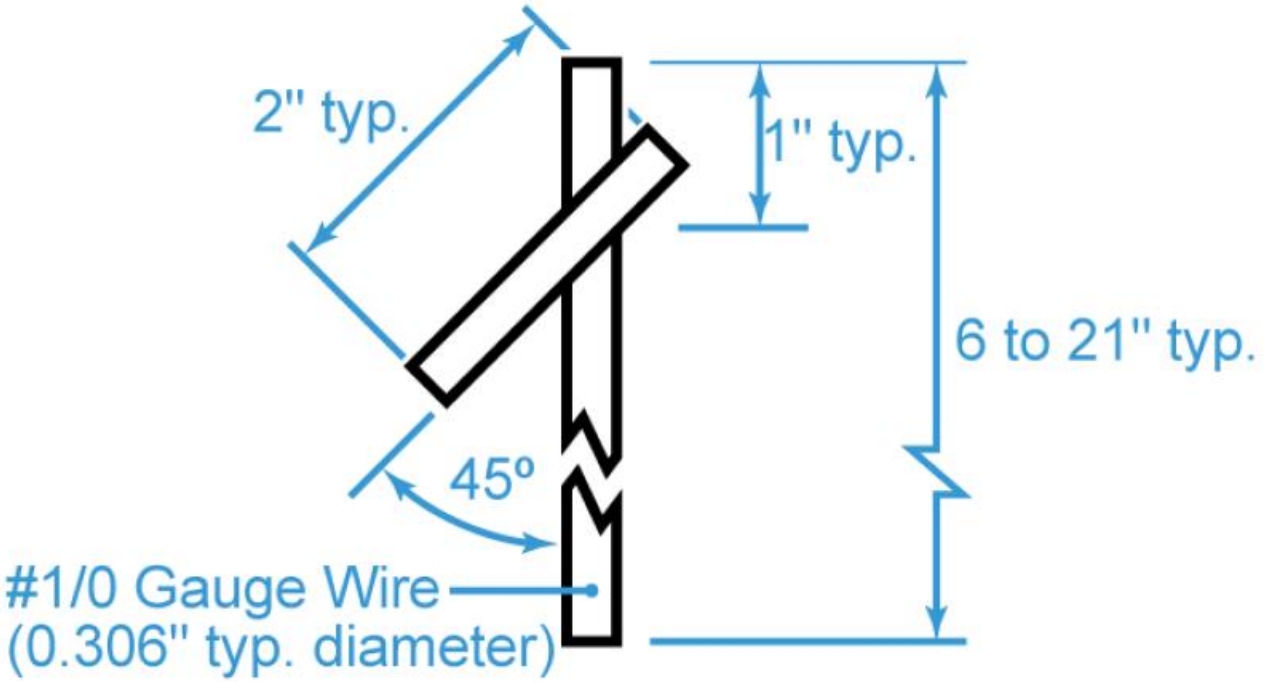
Drawing: Jerry Voigt, ACPA

Image: ACPA

Anchoring Dowel Baskets – Basket Stakes

Images: ACPA

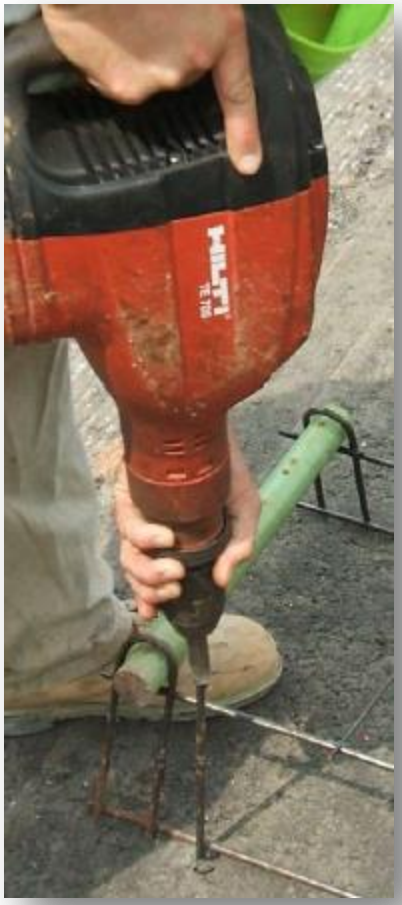
Baskets Stake – Typical Dimensions



Drawing: National CP Tech Center (after Iowa DOT)

Image: Dayton Superior

Basket Stakes – Driving into Grade



Images: Hilti North America (left) and ACPA (right)

Basket Stakes – Driving by Hand

Video: Power Pavers, Inc.

Basket Stakes – Driving with Pneumatic Hammer

Video: Power Pavers, Inc.

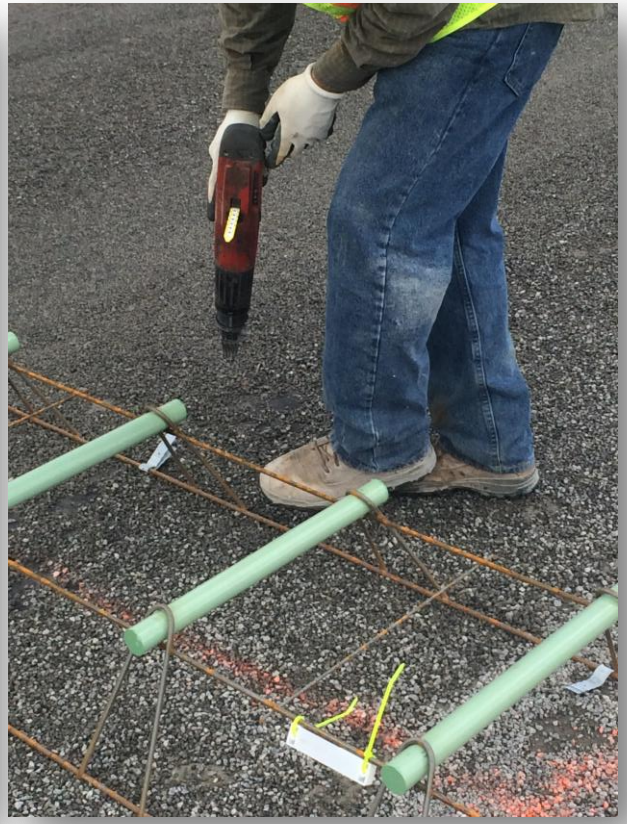
Basket Clips – Wrap-Around Type

Images: Maria Masten, MnDOT (left) and Hilti North America (right)

Basket Clips – Nail Down Type

Images: Maria Masten, MnDOT (left), Hilti North America (right), and Dayton Superior (across bottom)

Basket Clips – Nailing into Place



Images: Keith Thomas (from Jeff Reid), Hilti North America (left), John Privrat, Duit Construction Company, Inc. (center), and ACPA (right)

Nailing Tool and Pins

Images: ACPA

Anchoring Best Practices

Images: ACPA

Anchoring Dowel Baskets – Installation

Image: ACPA

CONCRETE PLACEMENT CONSIDERATIONS

Discharging on Baskets w/ Placer or Spreader

- Placer or Side Spreader placement provides good control to avoid damaging baskets.
- This method preferable on projects where haul road is available to deliver concrete.
- Ensures that the concrete head in front of the paver does not induce undue pressure on the basket.

Placer/spreader with side belt to
receive and distribute concrete from haul trucks.

Image: ACPA

Placer spreads concrete ahead of paver (nighttime construction).

Image: ACPA

Discharging on Baskets

- End dumping requires special attention to fastening
- Minimize the dump height if possible to avoid deforming the baskets.

Image: John Privrat, Duit Construction Company, Inc.

Anchoring Dowel Baskets

Image and Video: ACPA

Anchoring Dowel Baskets

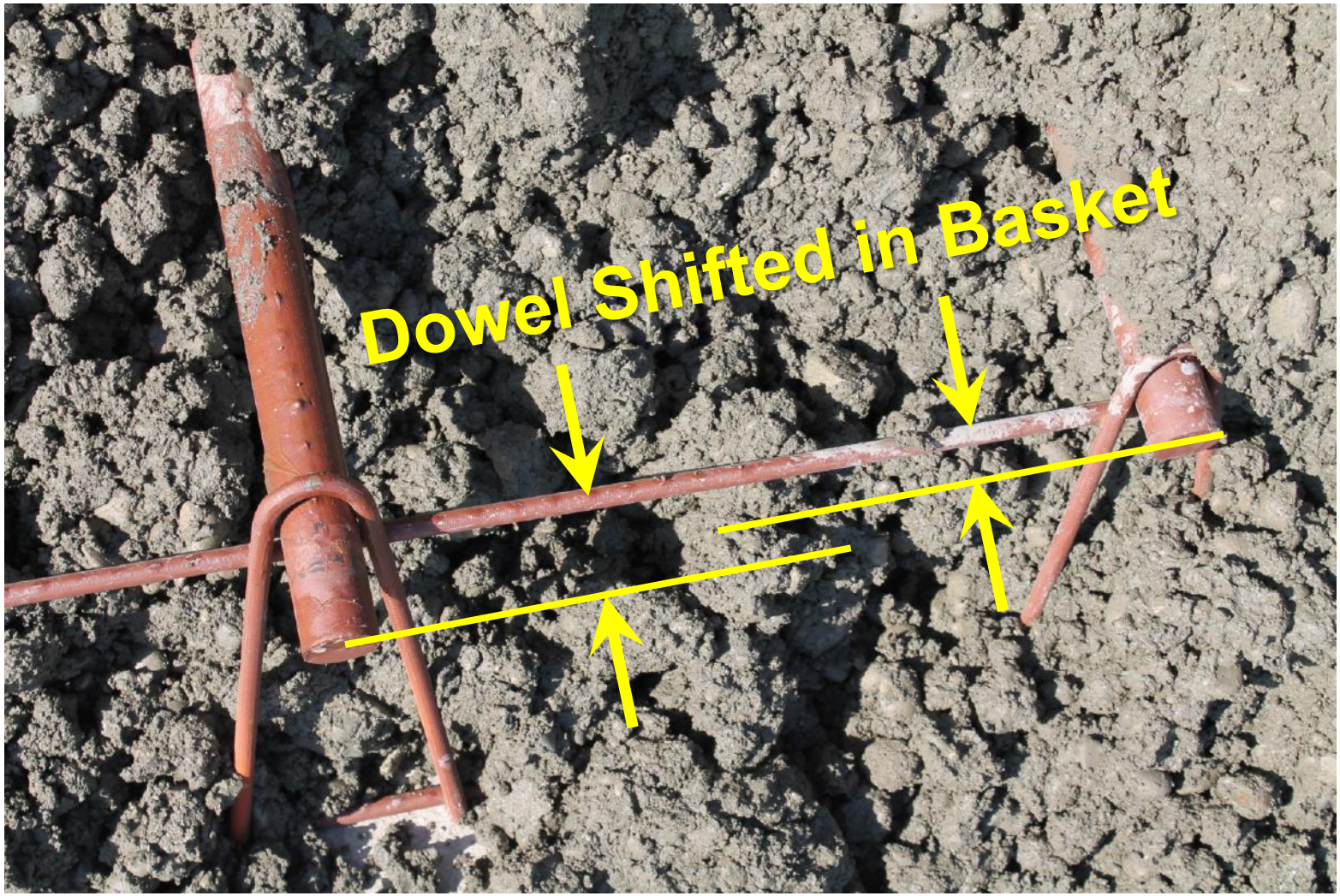
Image and Video: ACPA

ADDITIONAL SUPPORT AND BRACING CONSIDERATIONS

Basket Rigidity and Tie Wires

- With well-made and properly anchored baskets:
  - Dowel bars should not skew, tilt or translate
- Cutting basket tie wires reduces basket rigidity.
- ACPA recommends against this practice:
  - No proof of problems in field.
  - Engineering analysis indicates tie-wire welds will yield far before joint is restrained.

Basket Rigidity Important to Avoid Collapse

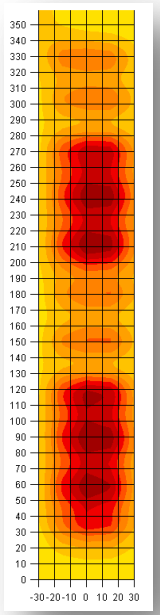


Basket Rigidity Important to Avoid Collapse

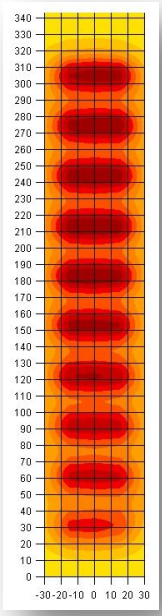
Images: Maria Masten, MnDOT (left) and ACPA (right)

Basket Rigidity – Shipping Wires

Cutting tie wires to facilitate MIT-Scan measurement can be counterproductive.



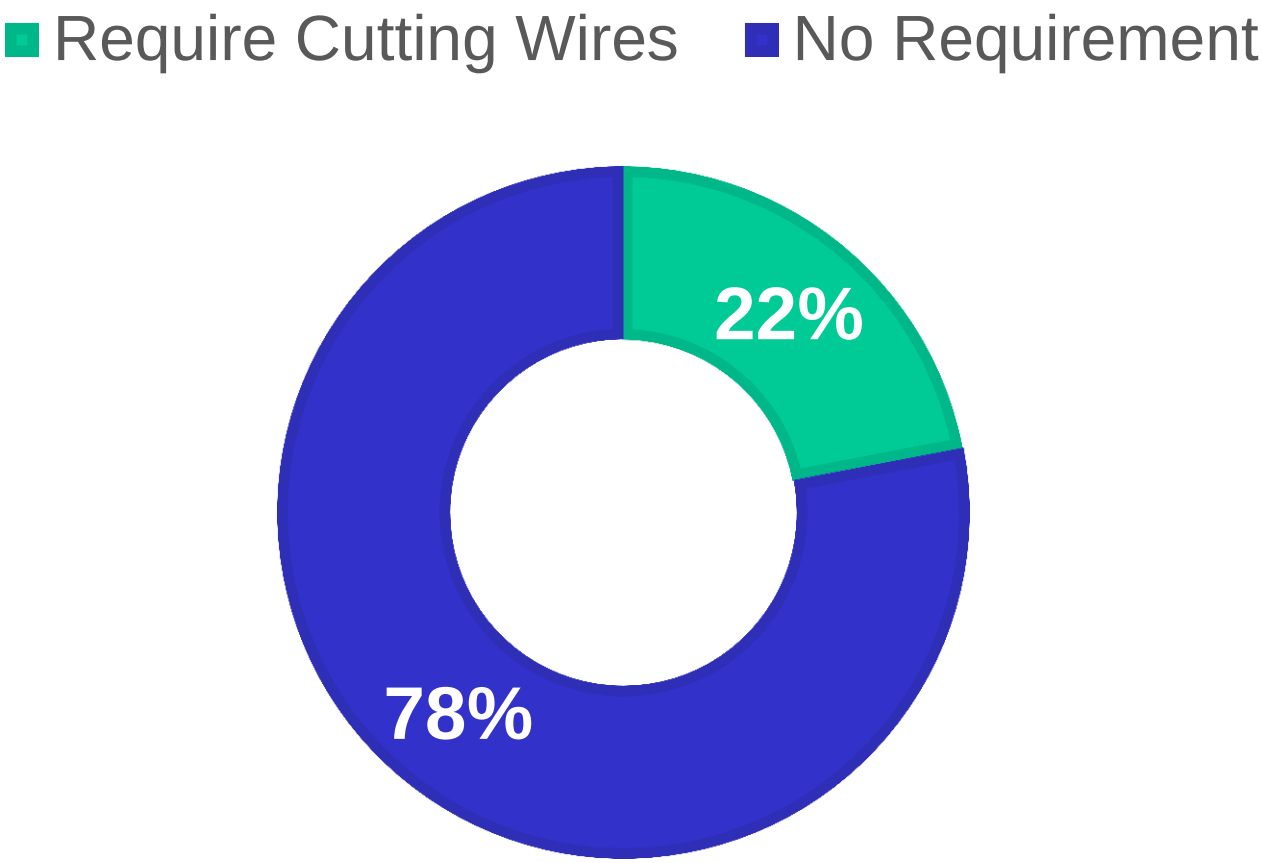
Erroneous Scan with Wires Intact



Better Scan with Wires Cut

Images: ACPA

Basket Rigidity – Shipping Wires



Basket Rigidity – KY Brace

- Provides additional leg stability
- Manufactured as part of the basket frame.
- Tool is used to rotate into position.

Image: ACPA

Basket Rigidity – KY Brace

Images: ACPA

Basket Rigidity – Sand Plates

Images: Dayton Superior

CONCLUSIONS & ADDITIONAL RESOURCES

Conclusions

- Dowels, placement, and alignment are critical to pavement performance
- Baskets must be secured properly with stakes or clips (typically 8 per basket)
- The type, number and depth of stakes or clips depends on the base type
- Anchoring on leave side of lower frame wire usually considered best

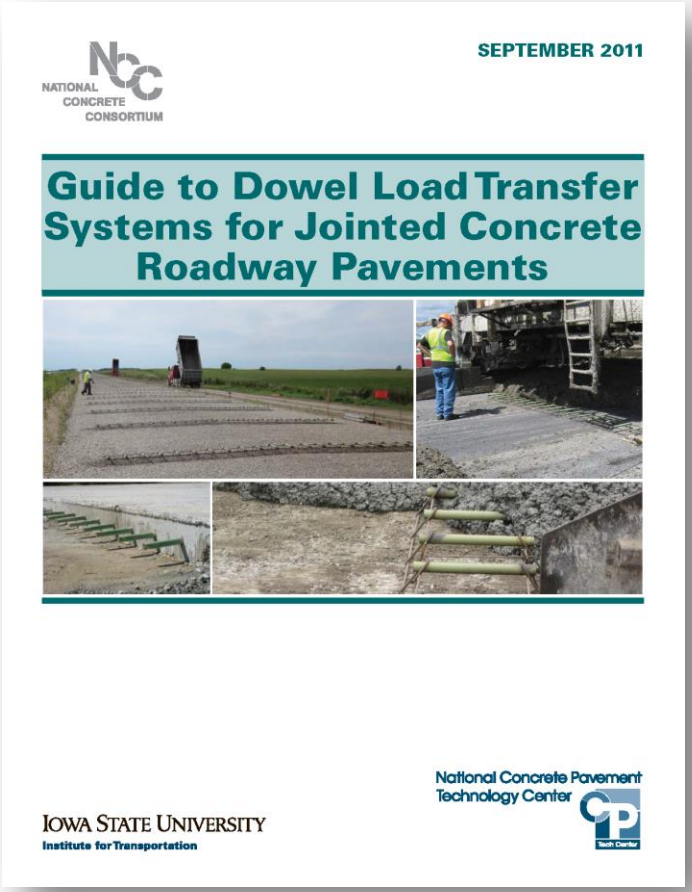
Conclusions

- Additional basket rigidity is important to prevent dowels from dislodging
- Rigidity can be provided by:
  - Not cutting shipping wires
  - Using the KY Brace
  - Using care in discharging concrete onto baskets
  - Using sand plates on weaker or looser base layer materials

Additional Resources

www.acpa.org

Additional Resources

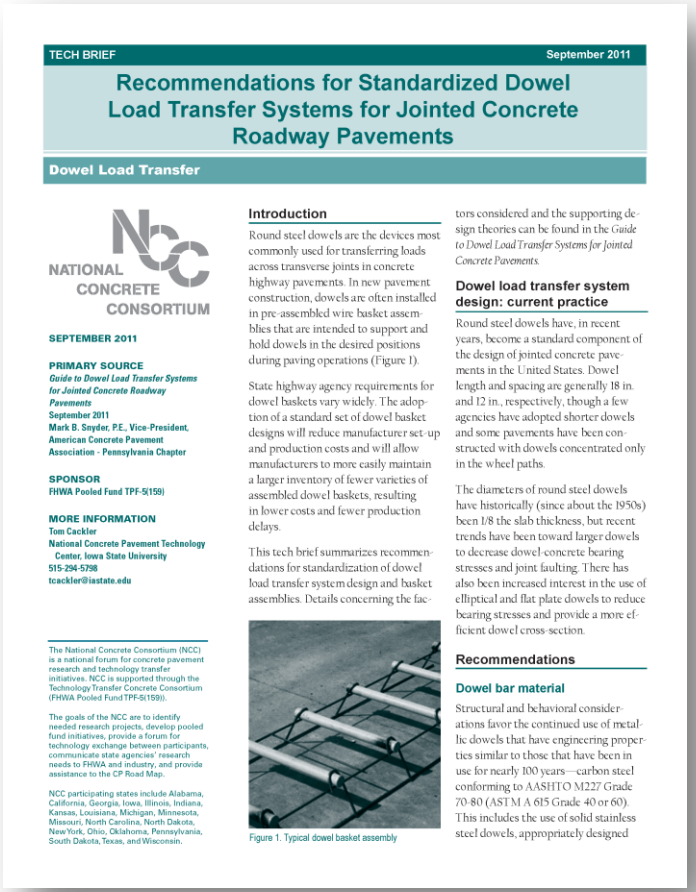

NATIONAL CONCRETE CONSORTIUM

SEPTEMBER 2011

Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements

IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center


TECH BRIEF September 2011

Recommendations for Standardized Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements

Dowel Load Transfer

NATIONAL CONCRETE CONSORTIUM

SEPTEMBER 2011

PRIMARY SOURCE
Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements
September 2011
Mark B. Snyder, P.E., Vice-President, American Concrete Pavement Association - Pennsylvania Chapter

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MORE INFORMATION
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The National Concrete Consortium (NCC) is a national forum for concrete pavement research and technology transfer initiatives. NCC is supported through the Technology Transfer Concrete Consortium (FHWA Pooled Fund TPF-5(159)).

The goals of the NCC are to identify needed research projects, develop pooled fund initiatives, provide a forum for technology exchange between participants, communicate state agencies' research needs to FHWA and industry, and provide assistance to the CP Road Map.

NCC participating states include Alabama, California, Georgia, Iowa, Illinois, Indiana, Kansas, Louisiana, Michigan, Minnesota, Missouri, North Carolina, North Dakota, New York, Ohio, Oklahoma, Pennsylvania, South Dakota, Texas, and Wisconsin.

Introduction

Round steel dowels are the devices most commonly used for transferring loads across transverse joints in concrete highway pavements. In new pavement construction, dowels are often installed in pre-assembled wire basket assemblies that are intended to support and hold dowels in the desired positions during paving operations (Figure 1).

State highway agency requirements for dowel baskets vary widely. The adoption of a standard set of dowel basket designs will reduce manufacturer set-up and production costs and will allow manufacturers to more easily maintain a larger inventory of fewer varieties of assembled dowel baskets, resulting in lower costs and fewer production delays.

This tech brief summarizes recommendations for standardization of dowel load transfer system design and basket assemblies. Details concerning the factors considered and the supporting design theories can be found in the *Guide to Dowel Load Transfer Systems for Jointed Concrete Pavements*.

Figure 1. Typical dowel basket assembly

Dowel load transfer system design: current practice

Round steel dowels have, in recent years, become a standard component of the design of jointed concrete pavements in the United States. Dowel length and spacing are generally 18 in. and 12 in., respectively, though a few agencies have adopted shorter dowels and some pavements have been constructed with dowels concentrated only in the wheel paths.

The diameters of round steel dowels have historically (since about the 1950s) been 1/8 the slab thickness, but recent trends have been toward larger dowels to decrease dowel-concrete bearing stresses and joint faulting. There has also been increased interest in the use of elliptical and flat plate dowels to reduce bearing stresses and provide a more efficient dowel cross-section.

Recommendations

Dowel bar material

Structural and behavioral considerations favor the continued use of metallic dowels that have engineering properties similar to those that have been in use for nearly 100 years—carbon steel conforming to AASHTO M227 Grade 70-80 (AST M A 615 Grade 40 or 60). This includes the use of solid stainless steel dowels, appropriately designed

www.cptechcenter.org

Questions and Discussion?