

# ACPA's New Dowel Alignment Specification



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## Dowel Bar Alignment and Location for Placement by Mechanical Dowel Bar Insertion

January 7, 2013

### Scope, Background and Applicability

This guide specification is directly applicable to 18 in. (457 mm) long, round metallic dowel bars, with and without coatings, for use in jointed plain concrete pavements with joint sawcuts made perpendicular to the edge of pavement (e.g., non-skewed joints); many of the underlying principles may be applicable to round dowels with other lengths and diameters. The requirements herein recognize that round dowel bars must be:

- 1) *Aligned* such that they impose no intolerable restraint on joint opening/closing.
- 2) *Located* such that they provide adequate long-term load transfer and have adequate concrete cover to prevent shear failures.

The alignment of dowel bars is important because significant misalignment of dowel bars in a doweled joint may prevent that joint from properly opening/closing. The occurrence of a single joint that does not open/close effectively will not necessarily result in a mid-panel crack or other pavement defect, but the risk of mid-panel cracking and joint distress increases with each successive joint with limited opening/closing capabilities (see FHWA 2007).

Longitudinal translation (see DBAL.1) is important to ensure the proper embedment length of the dowel bar for long-term load transfer. Thus, the allowable longitudinal translation is a function of construction (e.g., location per plans and proper location of sawcut over the dowel) and the dowel bar length.

Control of vertical translation (see DBAL.1) is important to ensure that there is enough concrete over the steel to resist corrosion of steel dowel bars and must be such that the concrete will not develop shear cracking or spalling above the dowels as loads are transferred across the joint. Thus, the allowable vertical translation is a function of as-constructed pavement thickness and planned dowel vertical location.<sup>1</sup> Consideration must also be given for sawcut depth such that the dowels are not cut during sawing operations.

<sup>1</sup> See NCC 2011 for details on planned dowel locations that do not necessarily place dowel bars at the mid-depth of the pavement.

# Dowel baskets

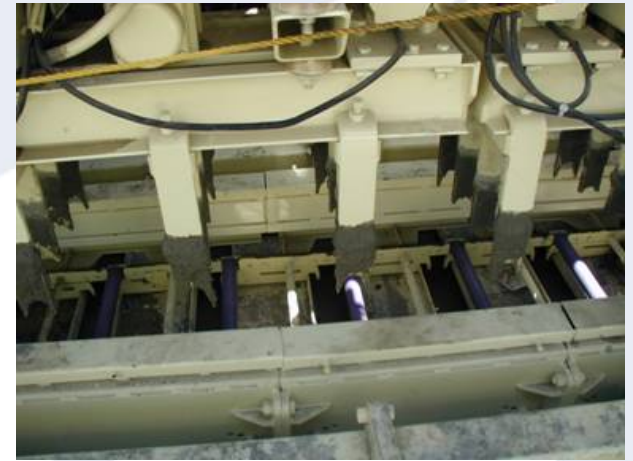
Improper handling can be a significant cause of poor alignment



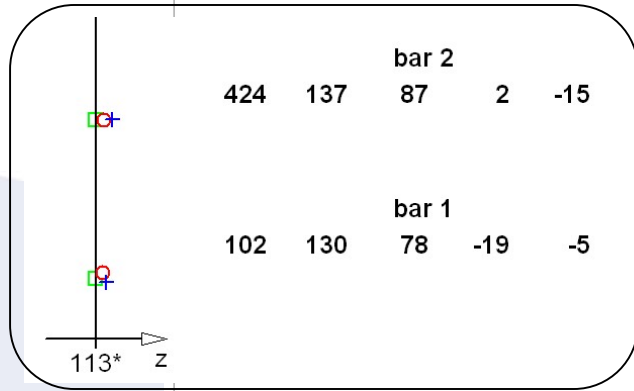
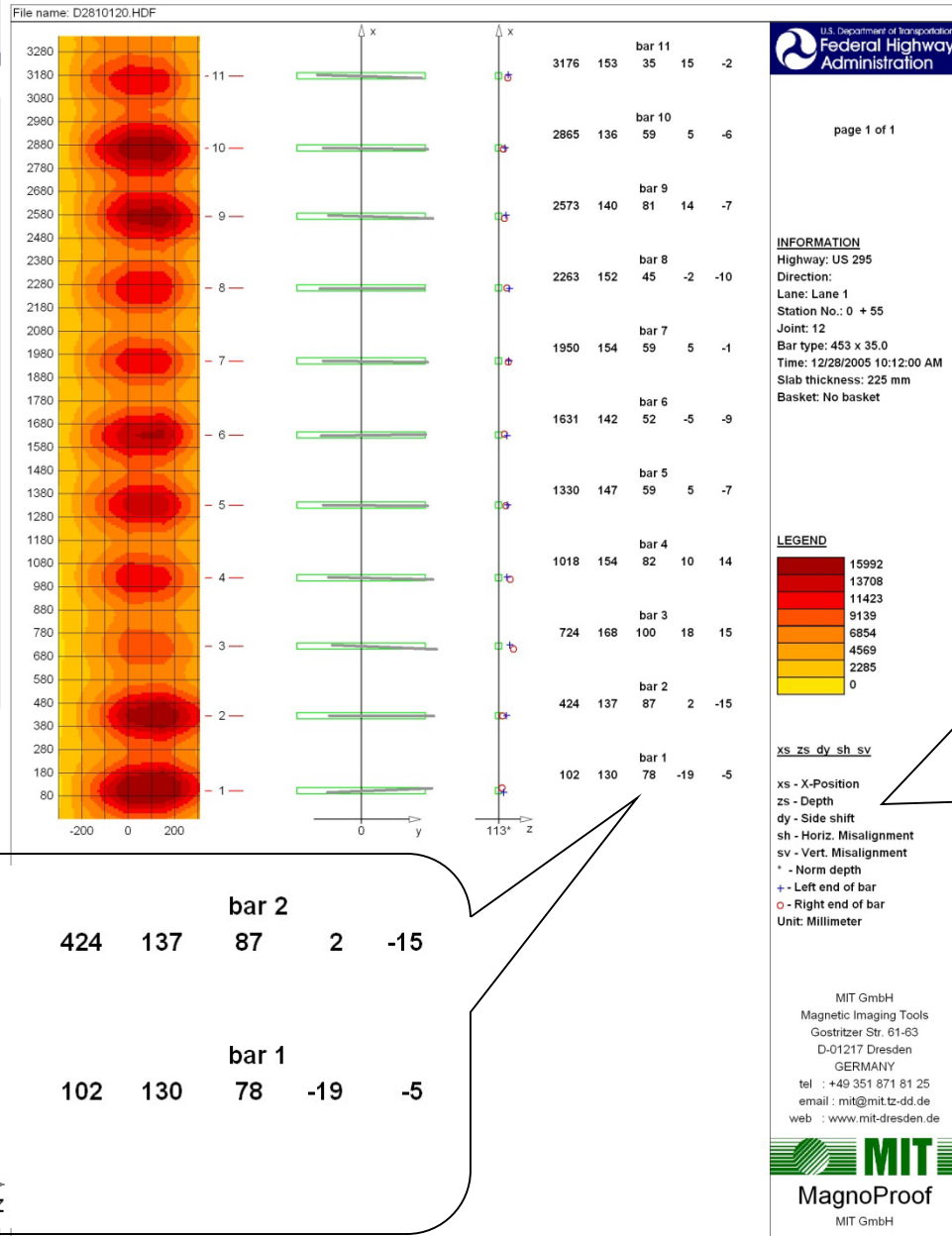


# MIT Scan-2

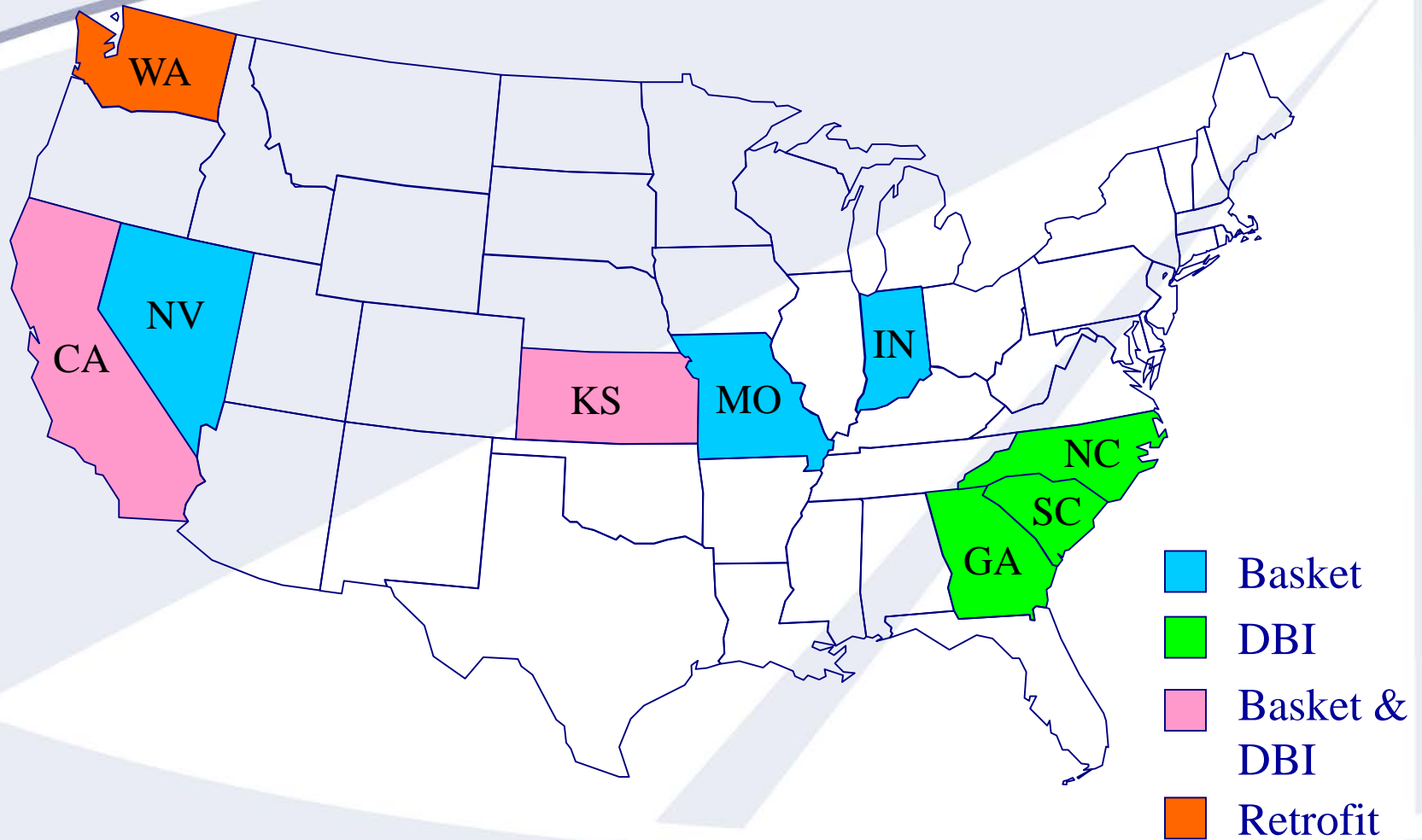
- Designed specifically for measuring dowel bar position and alignment
- Offers practical means of evaluating dowel placement accuracy



# Example Output



# 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 dowel bars
- Dowel alignment achieved using baskets and DBI are comparable

# Dowel Placement Specifications

(CPTP Techbrief FHWA-HIF-07-021)

- Ideally, dowel bars should be placed without any placement error
- Stringent, but constructible, requirements should be specified, and allowance should be made for tolerable errors
- Improved guidelines are needed on dowel placement tolerance



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# The Scope

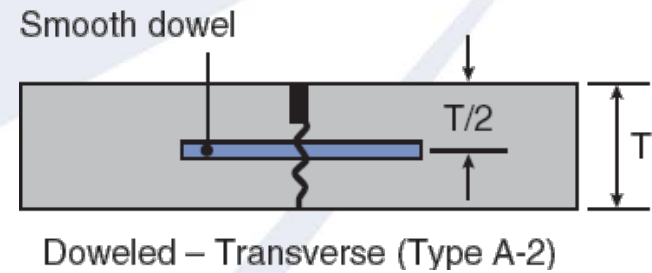
- Dowels that are:
  - **Inserted with DBI**
  - 18 in. (457 mm) long
  - Round
  - Metallic
  - With & without coatings
- JPCP with joints sawed perpendicular to edge

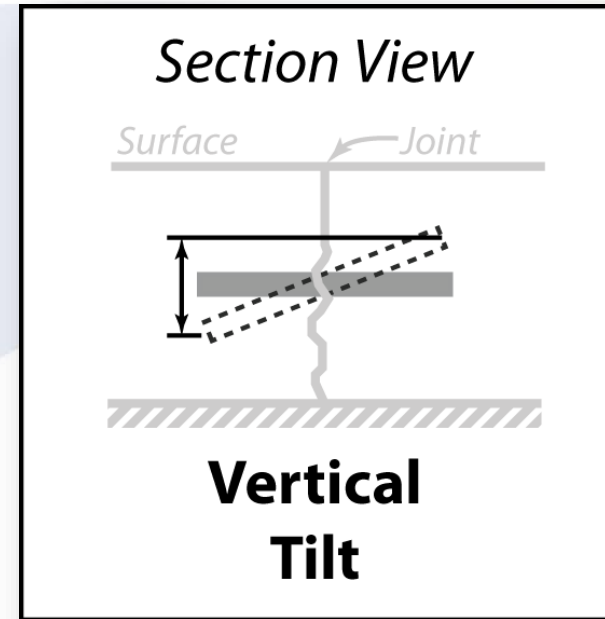
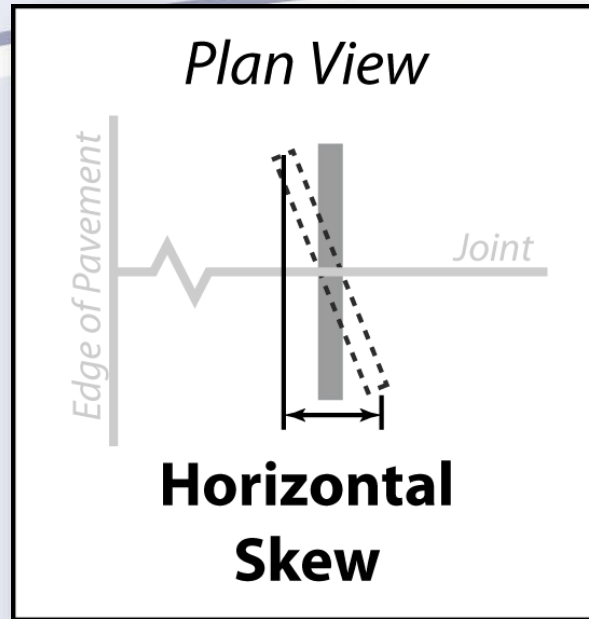




# The Goal

- 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 or close to each other or pavement edge





# Misalignment

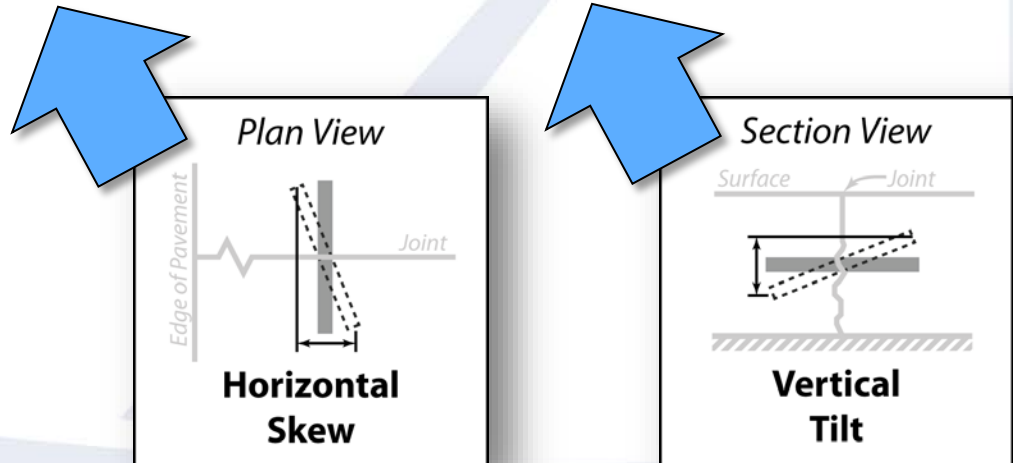
Any deviation in either the horizontal or vertical plane from a true alignment condition (e.g., *horizontal skew* or *vertical tilt*).

# How do We Quantify Misalignment?

- *Single Dowel Misalignment (SDM)* – the degree of misalignment applicable to a single dowel bar:

*Single Dowel Misalignment (SDM) =*

$$\sqrt{(\text{Horizontal Skew})^2 + (\text{Vertical Tilt})^2}$$





# 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):

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

where:

- $n =$  number of dowels in the single joint
- $W_i =$  weighting factor for dowel  $i$

# Excessive Misalignment = Locking

Single Dowel Misalignment (SDM)	W, Weighting Factor
$SDM \leq 0.6$ in. (15 mm)	0
$0.6$ in. (15 mm) < $SDM \leq 0.8$ in. (20 mm)	2
$0.8$ in. (20 mm) < $SDM \leq 1$ in. (25 mm)	4
$1$ in. (25 mm) < $SDM \leq 1.5$ in. (38 mm)	5
$1.5$ in. (38 mm) < $SDM$	10

- The potential for locking of a single joint:
  - $JS \leq 5$  | very low risk of joint restraint
  - $5 < JS \leq 10$  | low risk of joint restraint
  - $10 < JS \leq 15$  | moderate risk of joint restraint;  
**potentially locked**
  - $JS > 15$  | high risk of joint restraint; joint locked

# Not All Joints are 12' Wide

- *Joint Score Trigger (JST)* – A scaling of the Joint Score risk value to account for the actual number of dowels per a single joint:

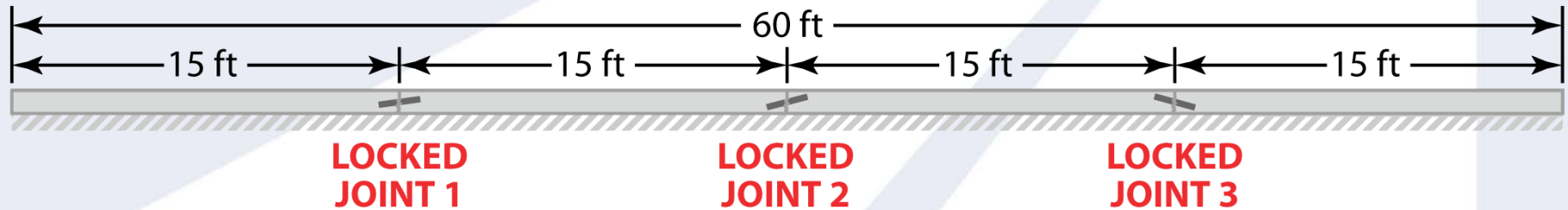
*Joint Score Trigger (JST)* =

$$10 * \frac{\text{\# of Dowel Bars in Single Joint}}{12}$$

# of Dowel Bars in Single Joint	JST
10	8.3
11	9.2
12	10.0
13	10.8
14	11.7

# 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  $JS > JST$ .



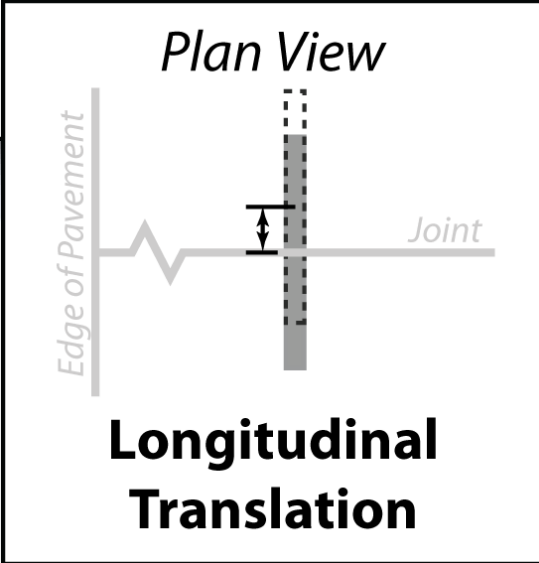
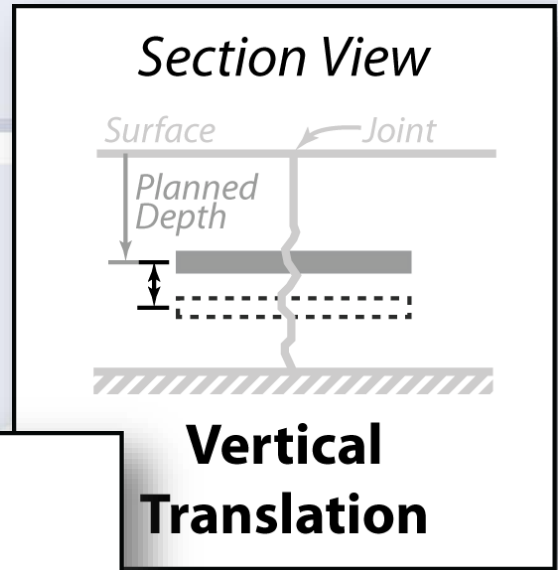
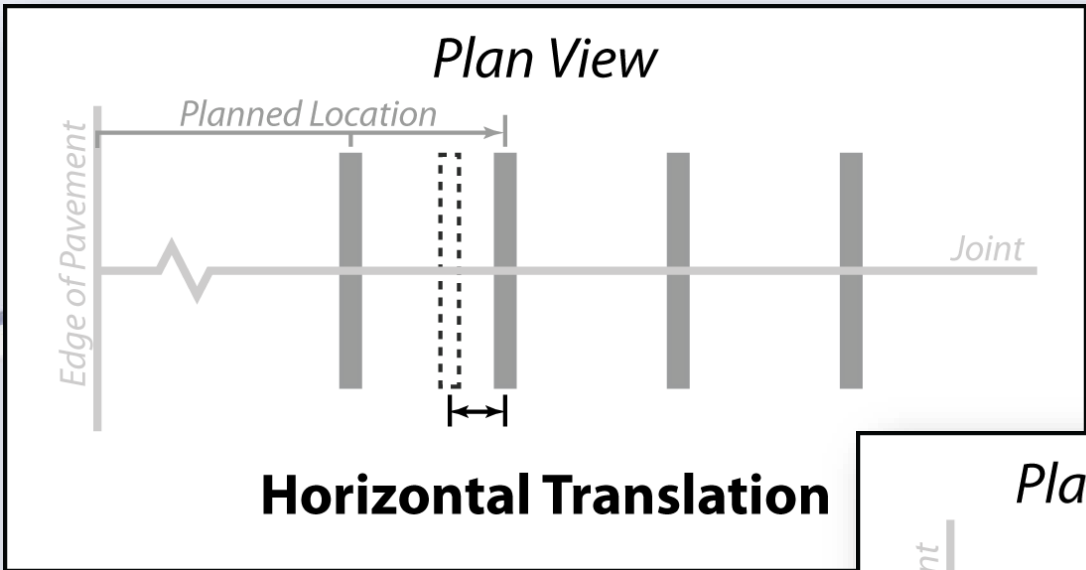
=

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



How many lanes can you tie together?





# Mislocation

Any deviation of a dowel bar from its planned location. DOES NOT LOCK THE JOINT!



# Alignment Tolerances

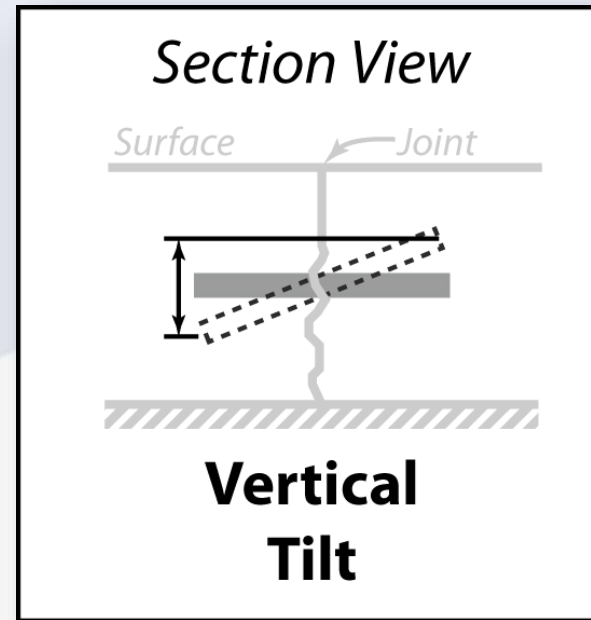
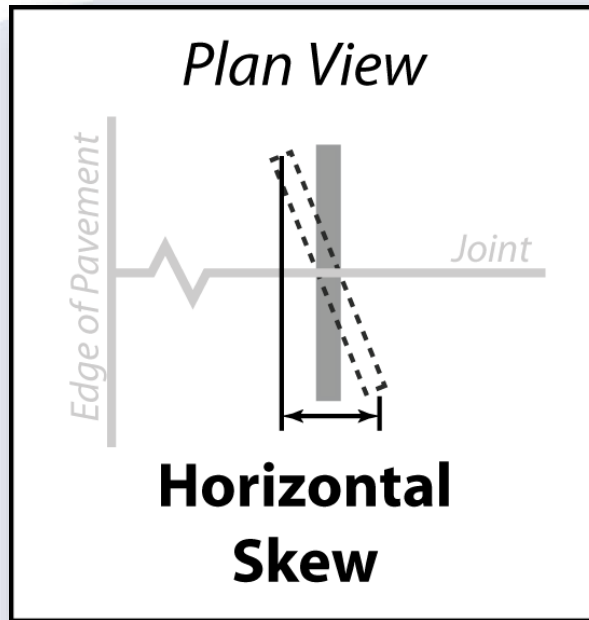
3 levels defined for each misalignment/mislocation type

**Accept** – Placement causes no potential problems and indicates process is well-controlled

**QC Trigger** – Placement has low risk of causing problems, but process should be adjusted to achieve “Accept” level

**Requires Action** – Placement has significant risk of causing problems; corrective action should be considered and process should be adjusted as required

# Alignment of Individual Dowel



Horizontal Skew AND Vertical Tilt < 0.6 in. (15 mm)

Horizontal Skew OR Vertical Tilt  $\geq$  0.6 in. (15 mm)

SDM > 1.5 in. (38 mm)

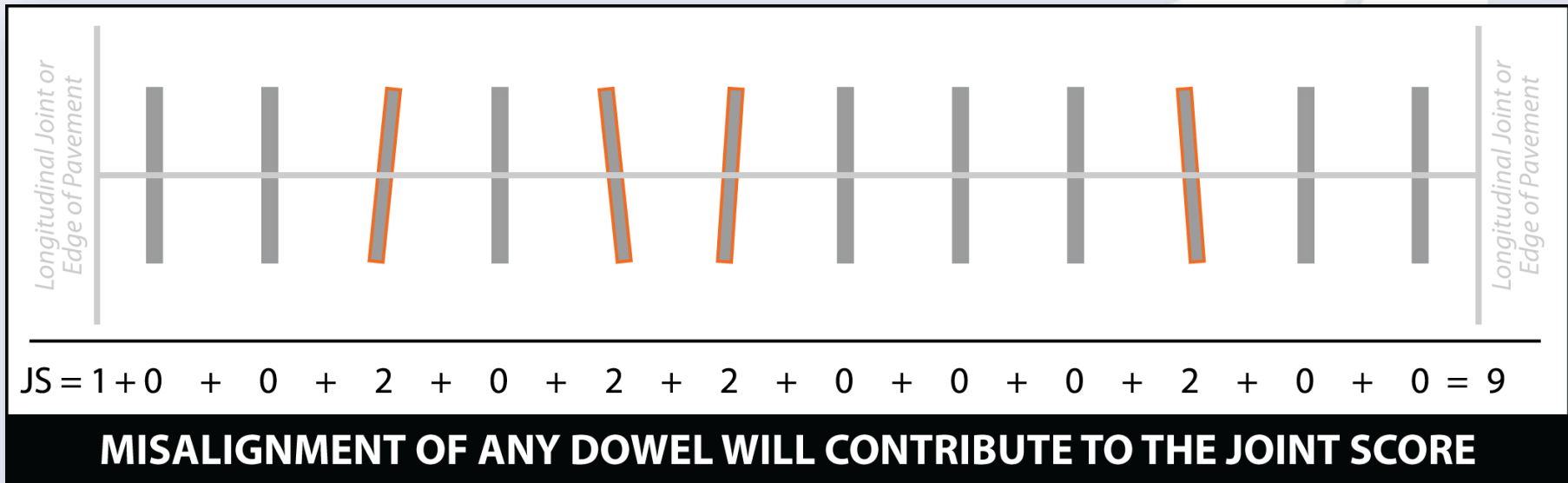
| **Accept**

| **QC Trigger**

| **Requires Action**

# Alignment of Single Joint

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



JS ≤ JST

JS > JST

JS > JST for all joints over MALL

| Accept

| QC Trigger

| Requires Action



# Location of Individual Dowel

- **Longitudinal Translation**

≤ 2 in. (50 mm)

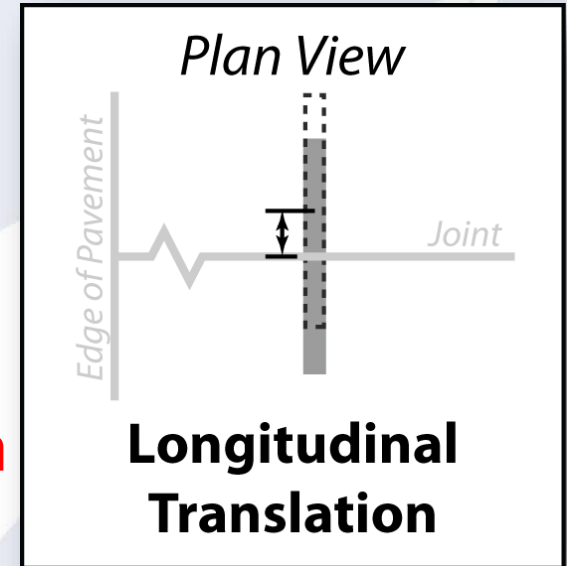
| **Accept**

> 2 in. (50 mm)

| **QC Trigger**

> 5 in. (125 mm)

| **Requires Action**



The **Accept** and **QC Trigger** limits:

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

The **Requires Action** limit:

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

# Location of Individual Dowel

- **Horizontal Translation**

≤ 2 in. (50 mm)

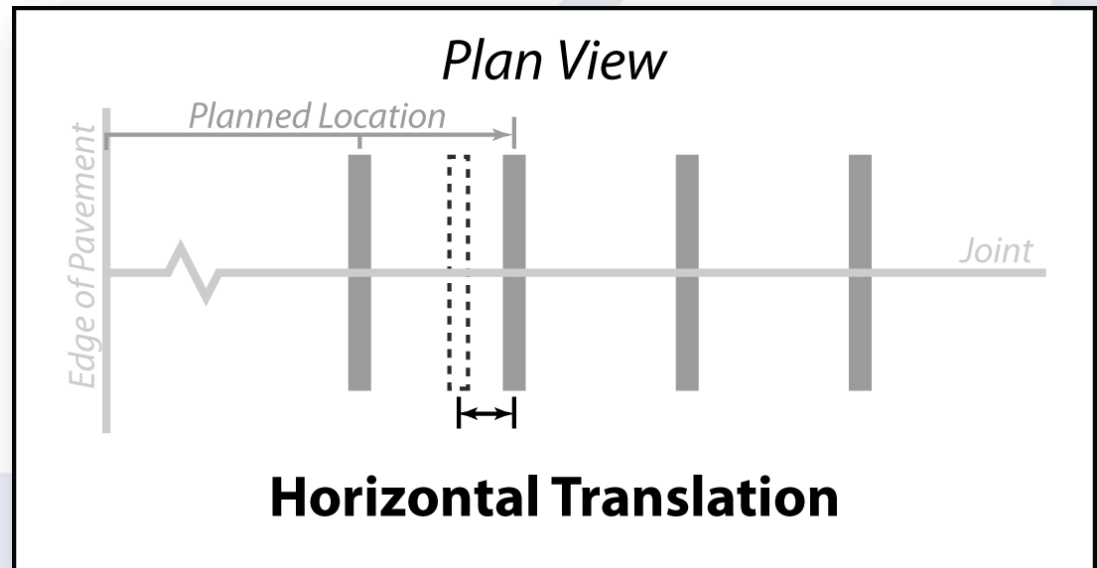
| **Accept**

> 2 in. (50 mm)

| **QC Trigger**

> 3 in. (75 mm)

| **Requires Action**



# Location of Individual Dowel

- **Vertical Translation**

- Dowel above mid-depth

≤ 1 in. (25 mm)

| **Accept**

> 1 in. (25 mm)

| **QC Trigger**

Cover < 2.5 in. (64 mm) | **Requires Action**

**AND**

Distance between top of dowel and bottom of sawcut:

≥ 0.5 in. (12 mm)

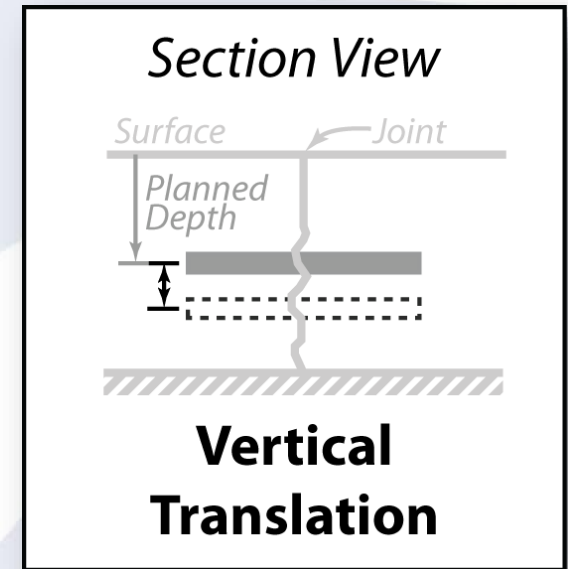
| **Accept**

< 0.5 in. (12 mm)

| **QC Trigger**

< 0.25 in. (6 mm)

| **Requires Action**



# Location of Individual Dowel

- **Vertical Translation**

- Dowel below mid-depth

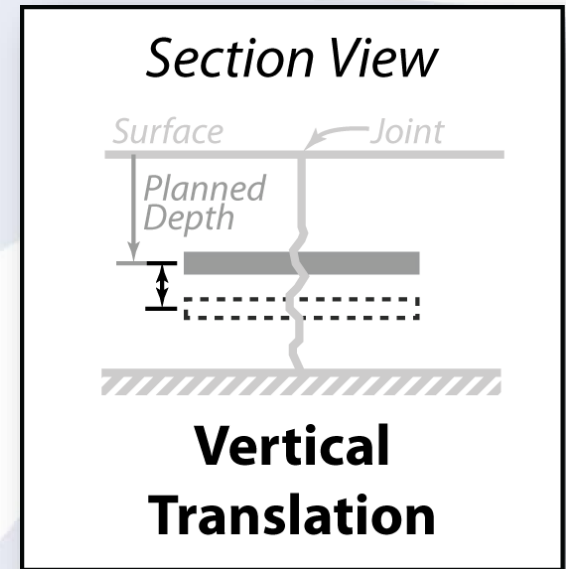
≤ 1 in. (25 mm)

| **Accept**

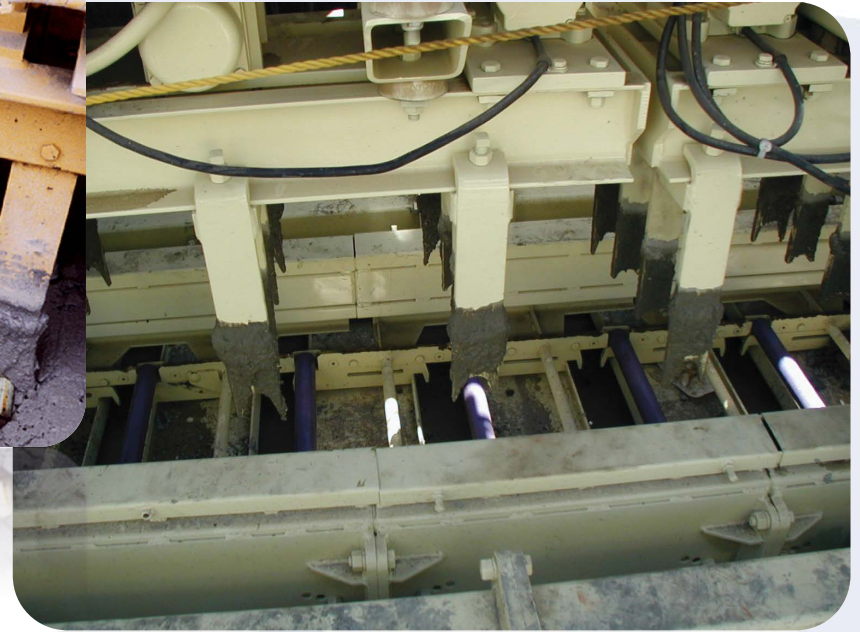
> 1 in. (25 mm)

| **QC Trigger**

Cover < 2.5 in. (64 mm) | **Requires Action**







# Field Measurement Procedures

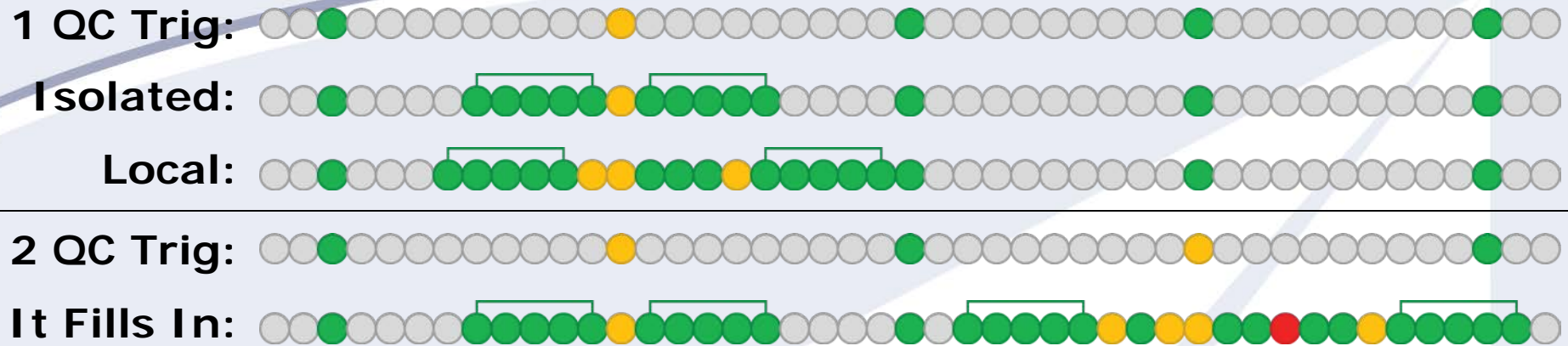
# Trial Section

- First 50 joints is trial section; this can be start of production paving at contractor's discretion
- Acceptable w/ approval of Engineer if:
  - Each JS is less than JST **AND**
  - 90% of dowel bars are within the **Accept** limit **AND**
  - No dowels violate the **Requires Action** limit
- Another trial section needed if:
  - not accepted;
  - concrete mixture, dowel installation method or equipment setup change during production;
  - if paving suspended more than 15 days

# Quality Control (QC)

- Measure alignment and location for every 10<sup>th</sup> joint
- If ALL misalignments, mislocations, AND JSs are within **Accept** limits, use data to refine the paving process
- If ANY misalignments, mislocations, OR JSs violate a **QC Trigger** limit, perform process adjustment
- **Satisfactory Control:** When ALL measures of dowel alignment, location and joint scores are within **Accept** limits for two consecutive production days or over a paving distance specified by the Engineer.
  - Upon establishment, measure and evaluate every 20<sup>th</sup> joint.
  - The frequency of testing will resume to every 10<sup>th</sup> joint if any **QC Trigger** limit is hit and until satisfactory control is re-established.

# Quality Assurance (QA)



- Measure the joints on each side of the actionable dowel bar or joint as directed by the Engineer until five (5) consecutive joints are found within the **Accept** limits
  - In exceptional cases with apparent systematic misalignment and/or mislocation, the Engineer may opt to have all dowels/joints measured and assessed on a single day's production
- Take corrective actions on any individual dowel bar or joint that violates a **Requires Action** limit

# Measurement Equipment

- Provide an operator who is properly trained to operate the measurement device
- See specification for details on operating temperature, minimum measurement range, and maximum measurement tolerances
- Calibrate the measurement device per the recommendations of the device manufacturer for the project conditions (including dowel bar size, material, and spacing; and testing environment)

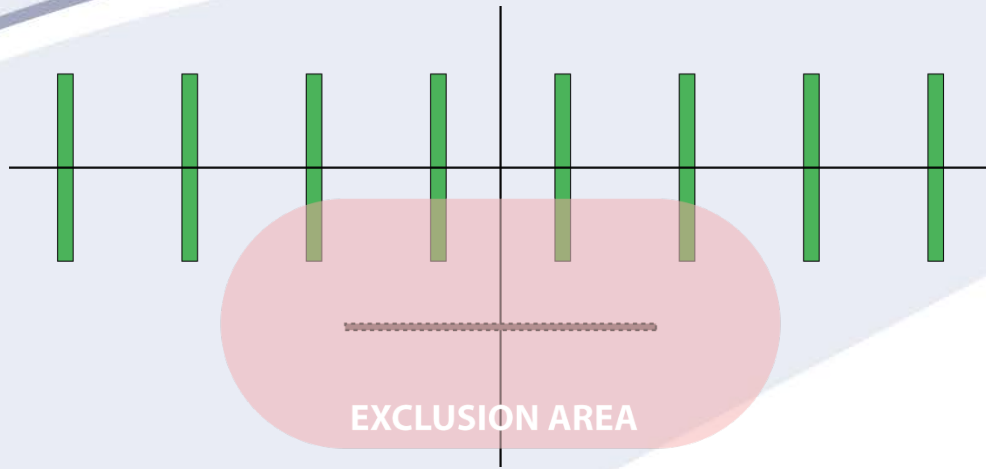




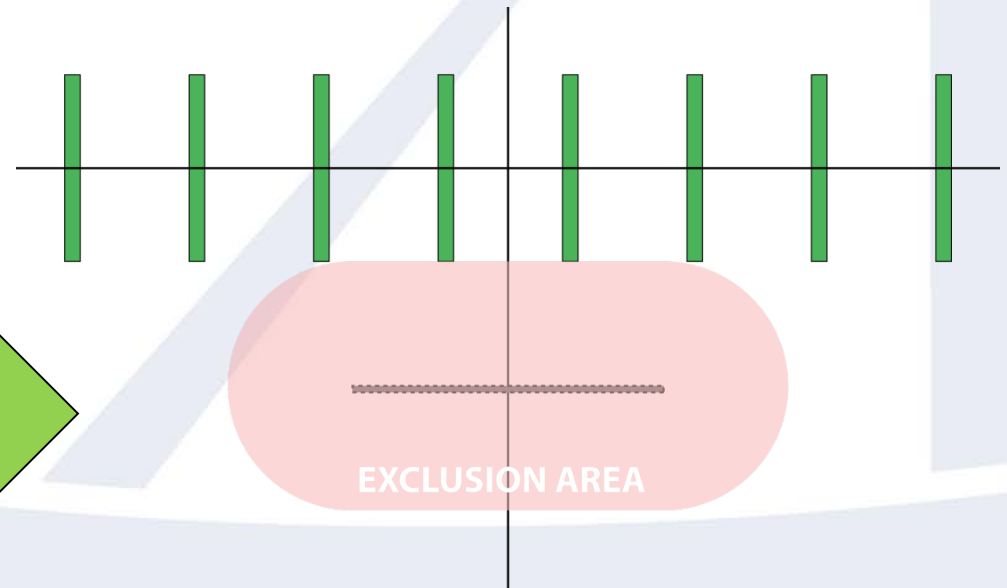
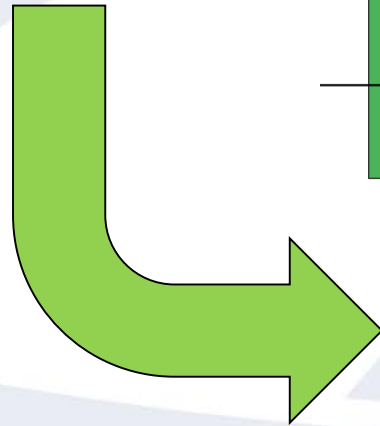
# Measurement Interference

- Prior to paving, review the measurement equipment applicability for the project conditions with the Engineer and establish how the measurement device can meet the project conditions
- To account for magnetic interference from embedded tiebars, exclude from JS calculation any dowel bar(s) closer than 12 in. (300 mm) in any direction to tiebars in the longitudinal joint(s) due to magnetic interference
  - At the Engineer's discretion, establish the location of excluded dowels by another equivalent non-destructive method or by probing.

# Measurement Interference



If an issue,  
change the  
tiebar spacing  
to resolve.



# Reporting

- Prepare and submit to the Engineer no later than 48 hours after each day's production a report including at least the following:
  - *General Details*
  - *Measuring Device Data and Printouts*
  - *Dowel Details*
  - *Misalignment and Mislocation Identification*
  - *Joint Score Details*
  - *Locked Joint Identification*
- See the spec for more details.

# Corrective Action

- Corrective action must be assessed case-by-case
- See the spec for **SUGGESTED** corrective actions



# Suggested Corrective Actions – Example: Misaligned Dowels(s)

- If  $JS < JST$  and damage or complete restraint is unlikely, DO NOTHING
- Saw through actionable dowel
- Saw through actionable dowel(s) and retrofit dowel(s)
- Place full-depth repair (remove joint and actionable dowels)
- Replace full slabs to remove joint(s) and actionable dowel(s)

# FHWA Dowel Alignment Task Force Meeting – February 2013

- No tie bars within 12 inches of dowel ends
- Need for calibration/validation of alignment measurement equipment
  - Headers?
- Incentives/disincentives?
- Recommendations for bringing process under control
- Provision of a “commentary” to accompany guide spec
- NCC role in development/adoption



# Discussion/Questions?



Main Website | [acpa.org](http://acpa.org)  
Free Apps | [apps.acpa.org](http://apps.acpa.org)  
Resources | [resources.acpa.org](http://resources.acpa.org)  
Your Local Contact | [local.acpa.org](http://local.acpa.org)

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