
# Best Practices for Concrete Road Pavement Construction

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www.congresodevialidad.org.ar

# Concrete Paving

# Critical Factors

- A good concrete mixture
- A good grade & trackline for paving
- Stringline management
- Continuous supply of concrete to paver
- Consistent concrete workability
- Well maintained paving equipment
- Proper operation of paving equipment
- Controlled density of concrete – just the right vibration & finishing
- A skilled and dedicated crew

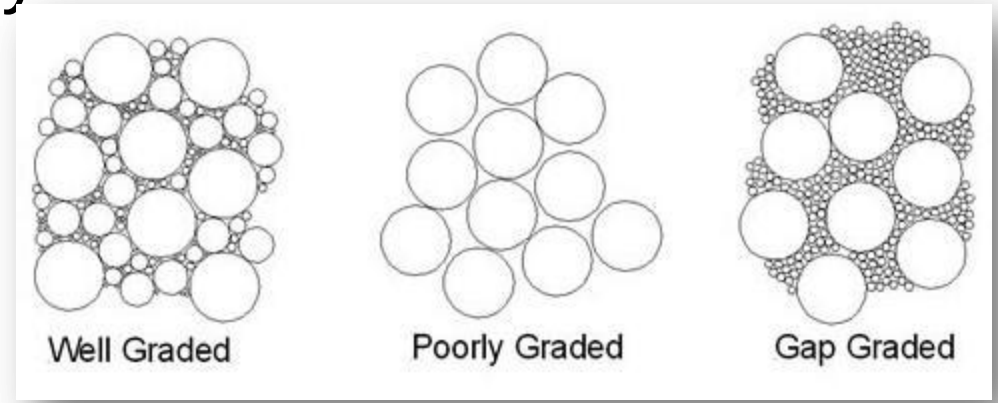
# Key Properties of Concrete

- Workability
- Durability
- Strength

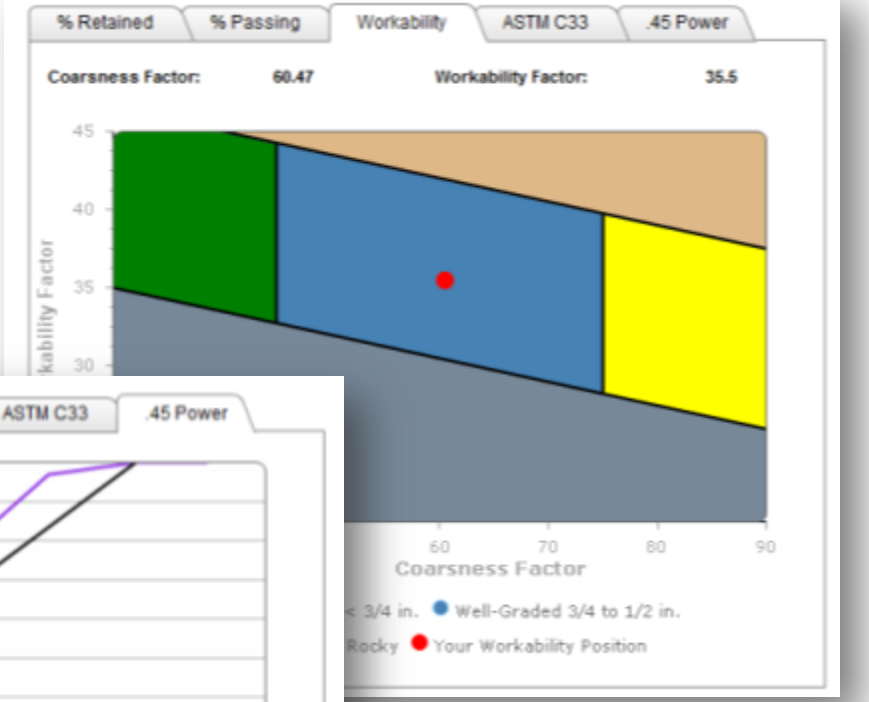
(Workability and durability are as important as strength)

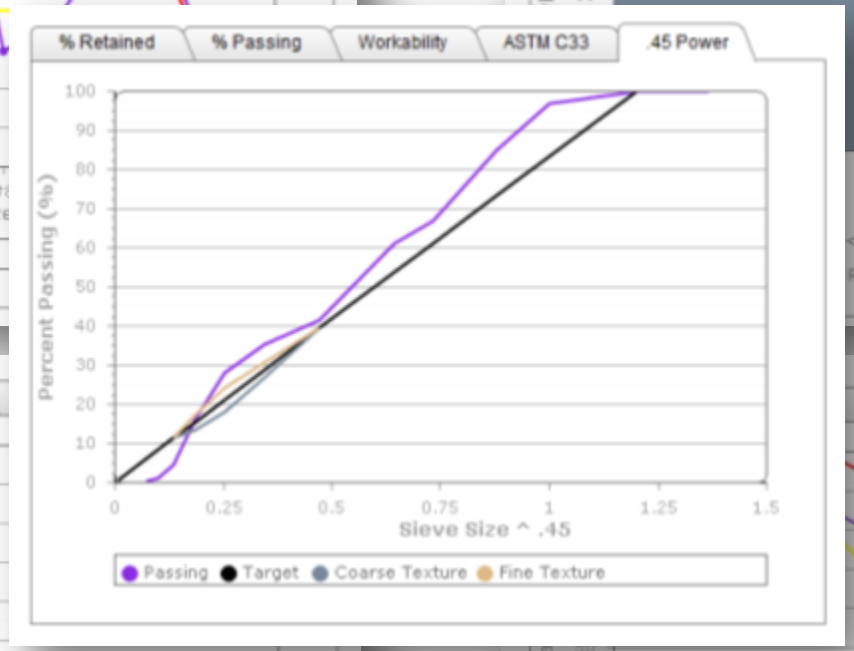
# Aggregate Gradation

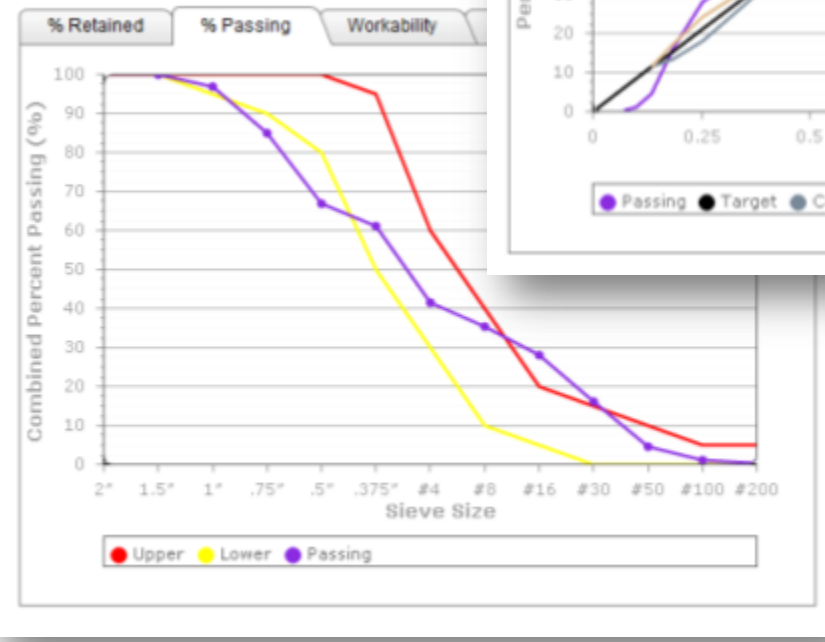
- CONTROLS workability!!
- Well-graded combined aggregate gradation will:
  - Reduce water demand
  - Lower drying shrinkage
  - Increase workability
  - Improve strength

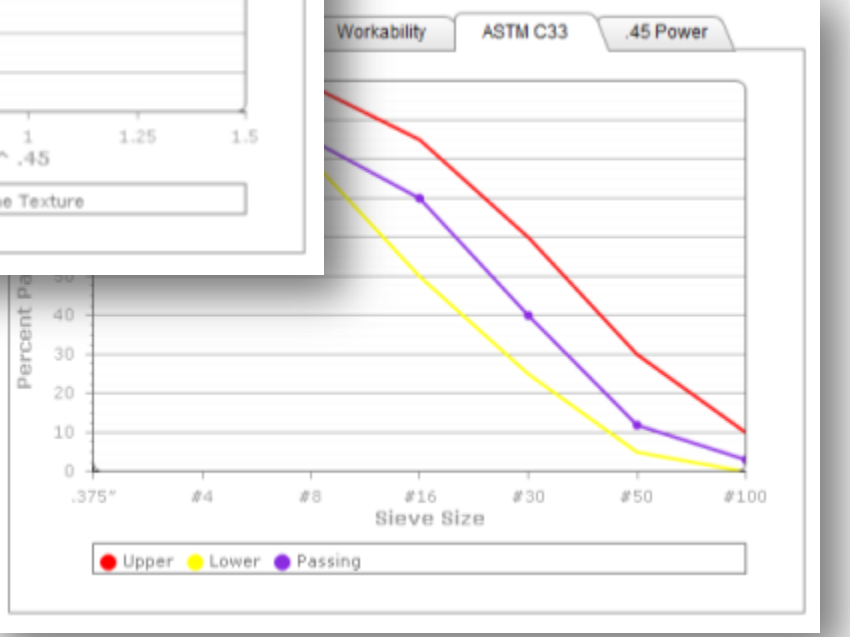


## Combined Gradation Plots

# Aggregate Bins

# Cement

- The “glue” that holds concrete together
- More cement *can* mean more strength, but:
  - Need more air entraining admixture for desired air
  - Need more water, resulting in more drying shrinkage
  - Increased risk of segregation with more paste
  - More bleed water, increasing permeability
  - Earlier sawing required
  - Stiffer mixture
  - Less fatigue capacity

# Cementitious Materials Content

- Use no more cementitious material than is necessary to meet strength and workability
  - Typical minimum is about 300 kg/m$^3$ for slipform

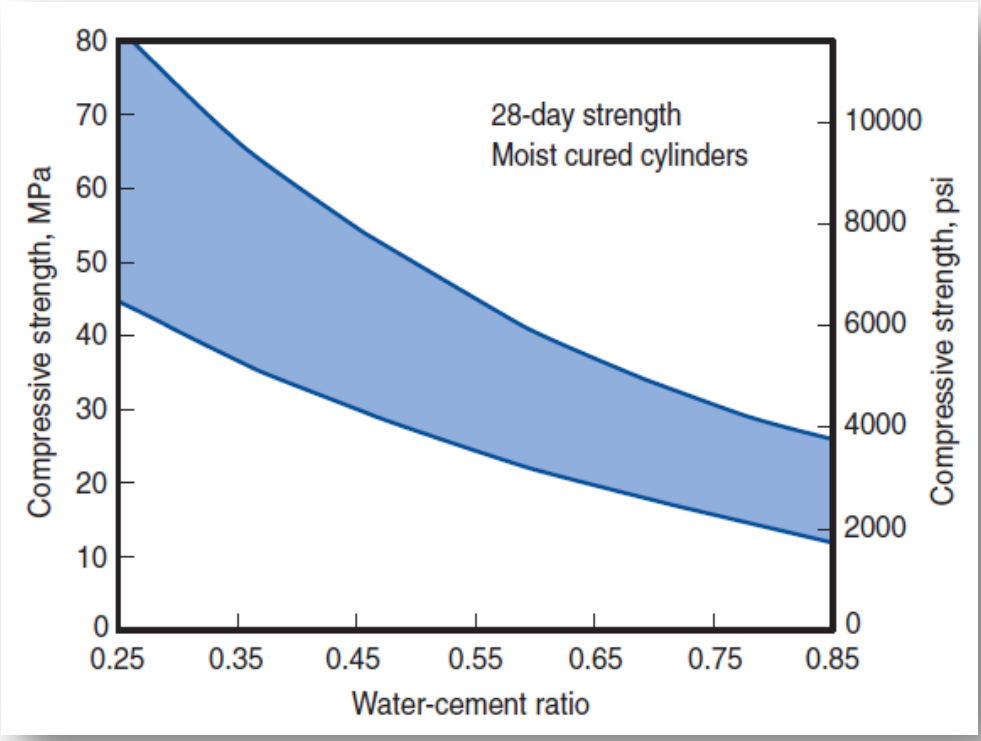
| Material | Maximum Dosage (%, by weight) |
|---|---|
| Fly ash | 25% |
| Slag cement | 40% |
| Total of fly ash and slag cement | 50% |

- SCMs may retard strength gain

# Water-Cementitious Mat'l Ratio

- Lower w/cm = higher strength, durability
  - Slipform paving: 0.45 max (0.40 typ)
  - Fixed-form paving/hand pours: 0.50 max (0.45 typ)

- For w/cm below about 0.40, autogenous shrinkage may be a concern.



# Dowel Bar Options:
# many products are available

# Dowels Bars

- Corrosion resistant dowels a must
  - Stainless steel or zinc clad (~$12 to $20)
  - FRP – but effectiveness not proven yet
  - Epoxy coated (low cost option) (~$4 to $5)
- 37 mm diameter minimum for t $\geq$ 300 mm
- Can reduce no. of dowels – middle 2 to 3 dowels not necessary
  - May use 9 (5&4) or 10 (5&5) to reduce cost
- Length = 450 mm

# FRP Dowels

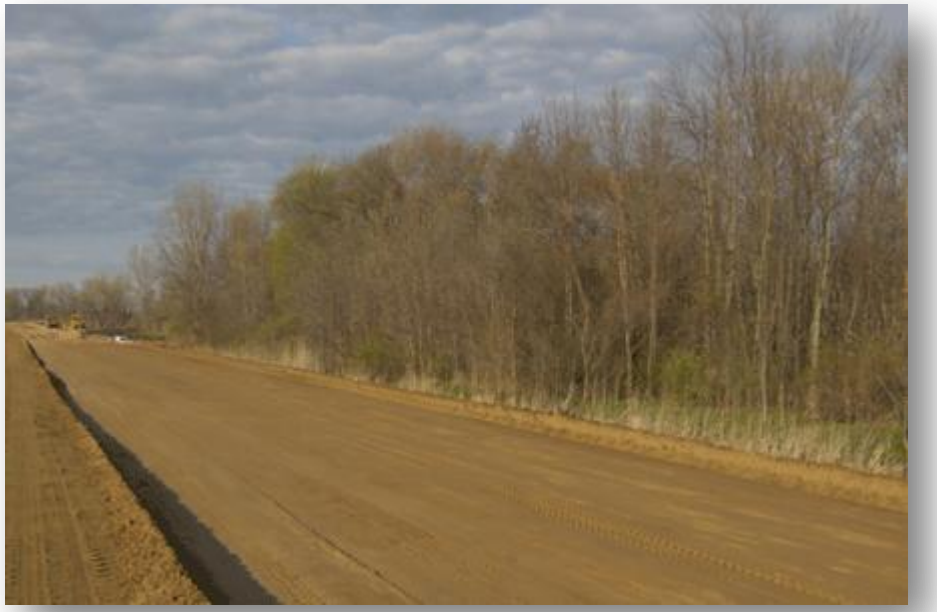
# Modifying FRP Dowel LT System Design for Structural Equivalence with Metallic Dowels

| Dowel Type | Diameter (mm) | Dowel Modulus, E (GPa) | Applied Shear Force (kN) | Dowel Deflection at Joint Face (mm) | Bearing Stress (MPa) |
|---|---|---|---|---|---|
| Metallic | 38 | 4.1 | 8.6 (300mm spacing) | 0.023 | 0.203 |
| FRP | 38 | 0.8 | 8.6 (300mm spacing) | **0.038** | **0.312** |
| FRP | **49** | 0.8 | 8.6 (300mm spacing) | 0.023 | 0.201 |
| FRP | 38 | 0.8 | **5.6 (200mm spacing)** | 0.023 | 0.203 |

**There is additional deflection across the joint …**

# Quality Starts from the Ground Up

- Roadbed (subgrade and subbase) design and construction are key to:
  - Long-term performance
  - Smoothness (initial and long-term)



# What is Good Support?

- **Uniformity in material and grading (most important!)**
- Resistant to erosion
- Engineered to control subgrade soil expansion/frost heave

# Place Base to Specified Tolerances

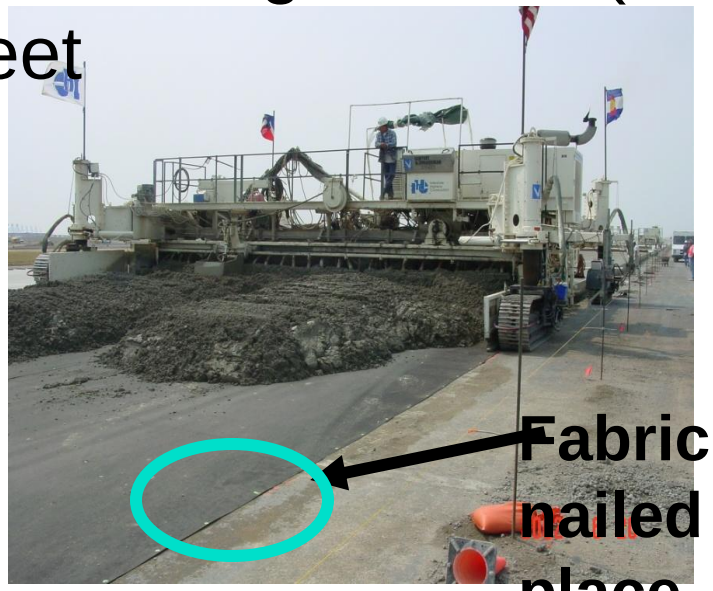
- Enhance pavement performance
- Minimize loss of concrete
- Minimize/eliminate thickness penalties
- Enhance smoothness

# Stabilized Bases

- Stabilized bases – SC, CTB, ATB, PATB
- Strength issue for SC/CTB/LCB
  - Specify min/max values (7 DAY 5.0/8.0 MPa psi common)
- Base stiffness affects pavement performance
  - Potential for random cracking high for very stiff bases


# Interface with Cement-Stabilized Base

- Bonded (match joints)
- Unbonded: asphalt emulsion, curing compound (double-coat), 25 – 50mm asphalt concrete (Austria), 5mm thick geotextile (Germany), Geo-fabric, plastic sheet




Geo-fabric bond-breaker over CTB at Denver Airport

5 mm geotextile over CTB (German practice)

# Track Line & String Line

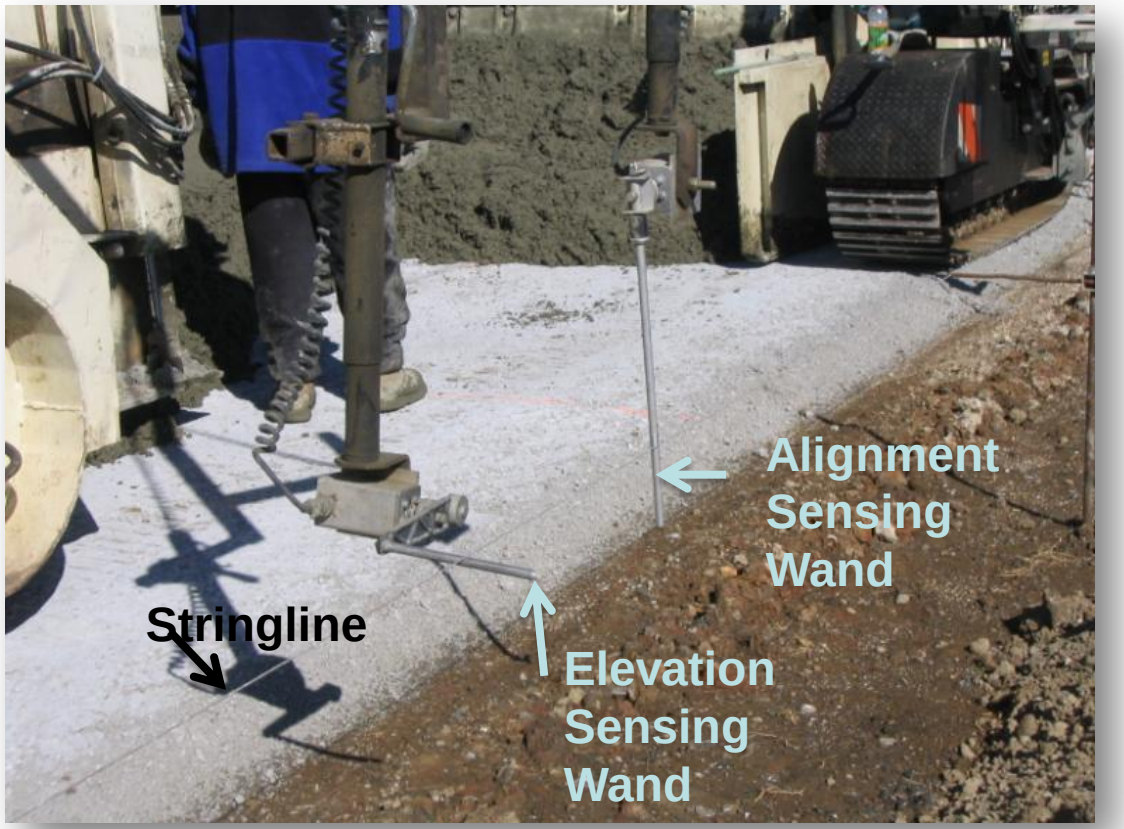
- Extend base 1 m beyond outside edge of pavement - keep it clean
- String line management very important to final smoothness of pavement

**STRINGLINE AIDS**

- **Use rigid stakes**
- **Use quality line**
- **Monitor & maintain line**

# Stringlines

- Stringlines control the “steering” of the paver
- Stringlines control the elevation and slab thickness

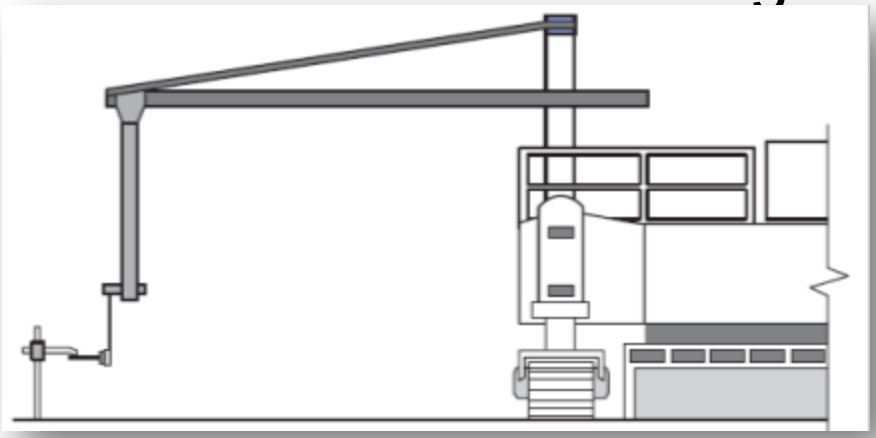


# Set Stringline

- Can be wire, cable, woven nylon, polyethylene rope, or another similar material
- Clean and tight splices
- Rigid stakes – watch for staking errors
- Maximum stake spacing of 25 ft
  - No perceptible sagging
  - Adjust stake spacing to fit conditions
  - See Staking Interval Calculator at apps.acpa.org for recommendations on curves

# Stringline Considerations (cont.)

- Continually check tension
- Place winches at ≤ 300m
- Stringlines on both sides of paving?
- Some situations require cantilever or trusses for sensors to reach stringline



# Stringless Paving: Example

Leica's "Direct Connect" 3D Control System Software
communicates directly with
networked Microprocessor Control System

# Concrete Placement

- Deposit concrete as close to paver as possible
- Avoid stop & go operation
- Maintain uniform speed & head
- No front end loaders or backhoes to distribute concrete

# Concrete Placement Issues

- Do not add water to concrete in front of paver
  - Reduced strength
  - Reduced durability


- Proper vibration effort
  - Control consolidation across paving width
  - Provide just enough fines at surface for a tight finish

# Consolidation

- The internal vibrators on the paver fluidize the concrete for extrusion
- Adequate consolidation
  - Required around dowels and tie bars
  - Throughout the slab

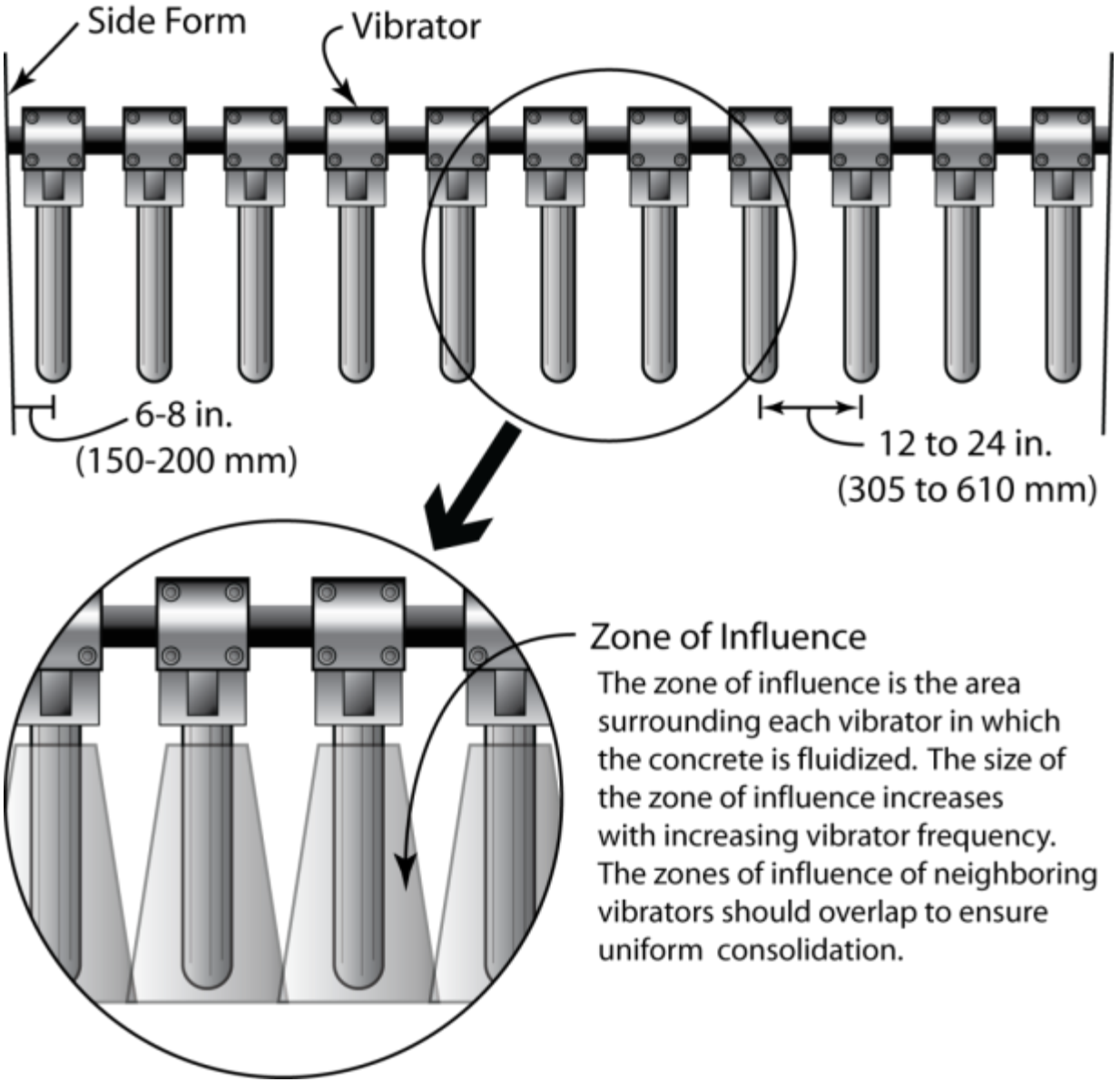
# Poor Consolidation

Lower in-place strength, honeycombing

# Over-Consolidation

- Over vibration can cause settlement, loss of air void system, less durable concrete


# Vibrator Setup

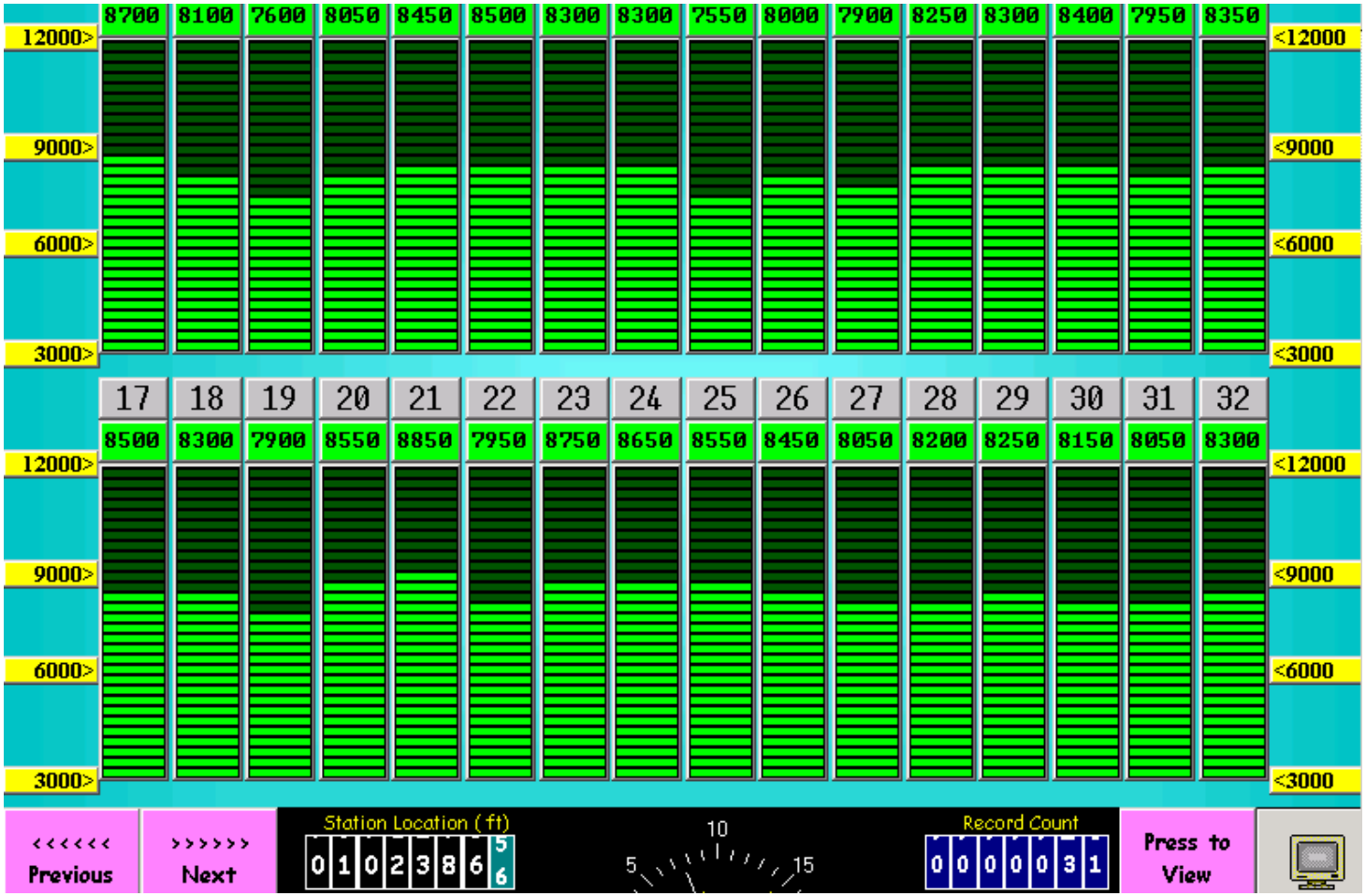



## Zone of Influence

The zone of influence is the area surrounding each vibrator in which the concrete is fluidized. The size of the zone of influence increases with increasing vibrator frequency. The zones of influence of neighboring vibrators should overlap to ensure uniform consolidation.

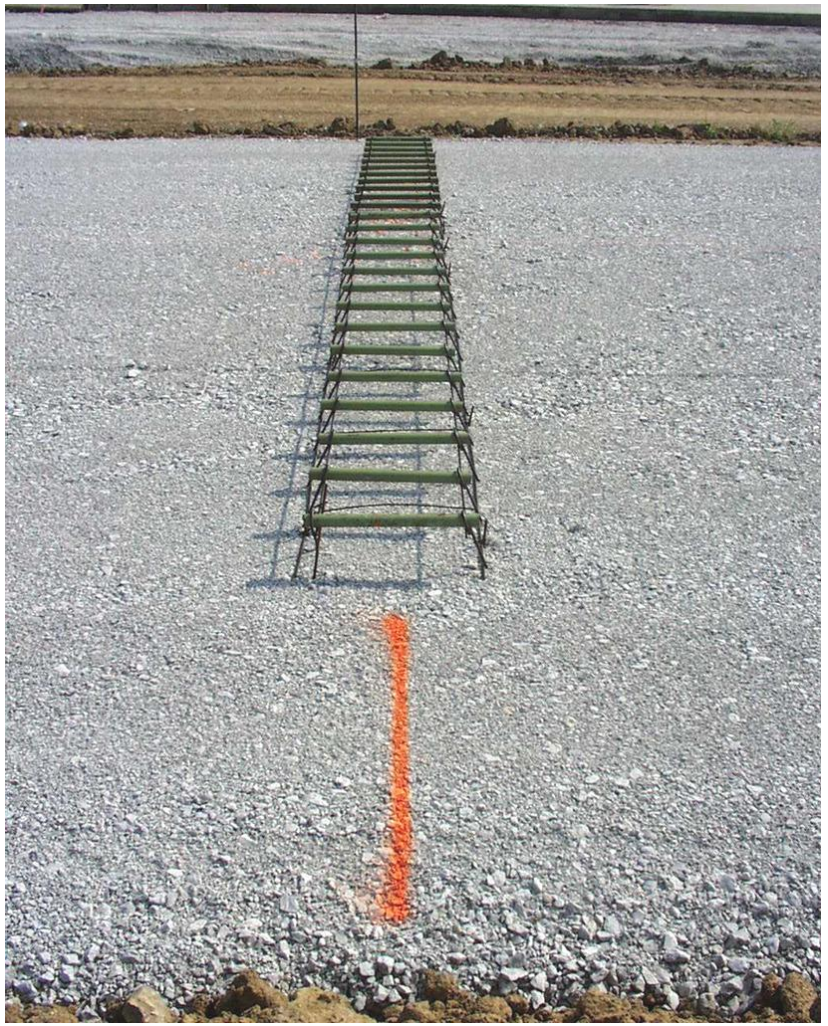
# Effect of Paver Speed on Consolidation


# Vibrator Sensor Monitoring



# Dowel Bars and Tiebars

- Pre-placed bars
  - Staked adequately
  - Cut/don't cut the tie wires
  - Careful marking of location
- Inserted bars

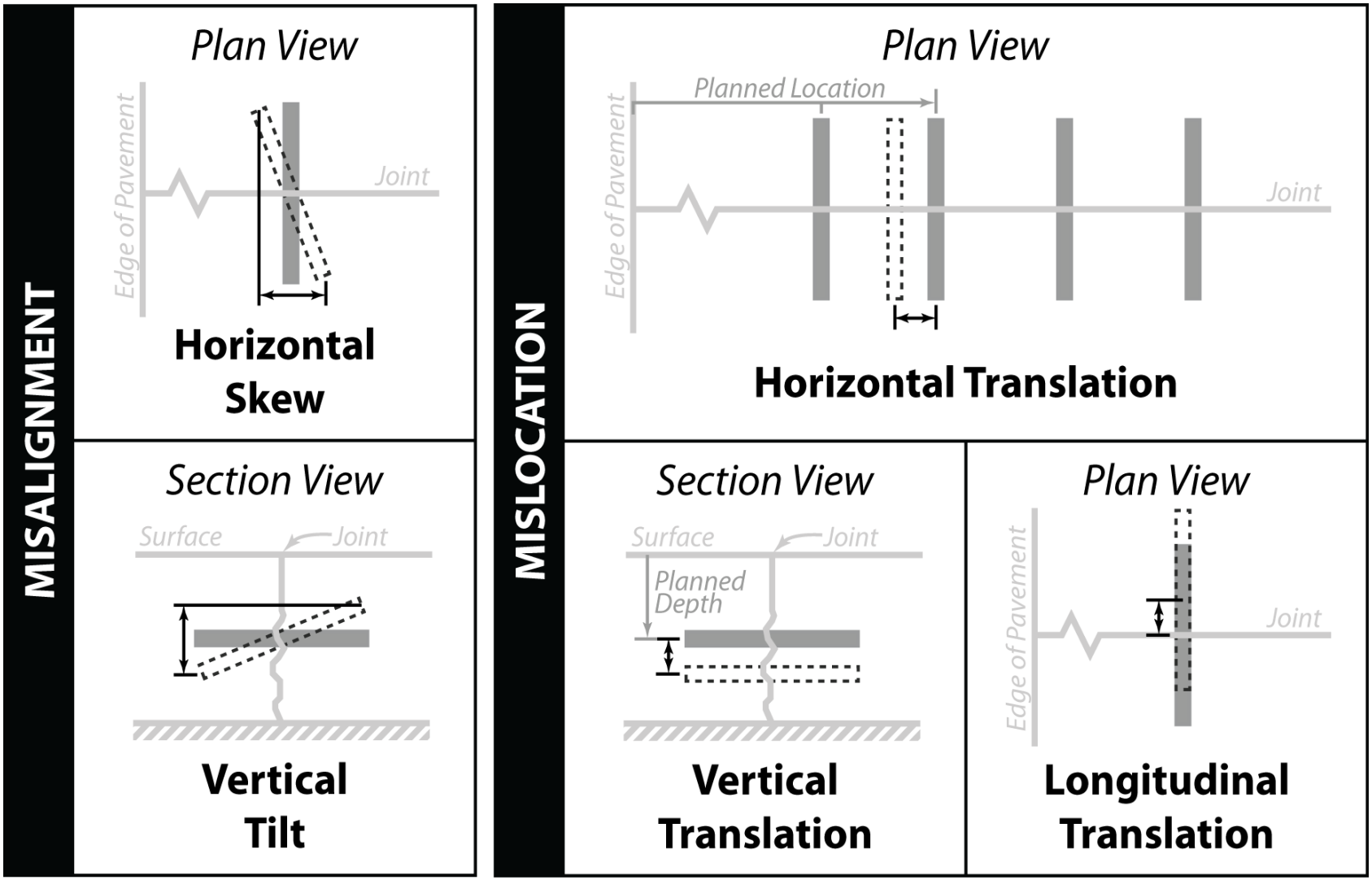


# Staking Dowel Baskets

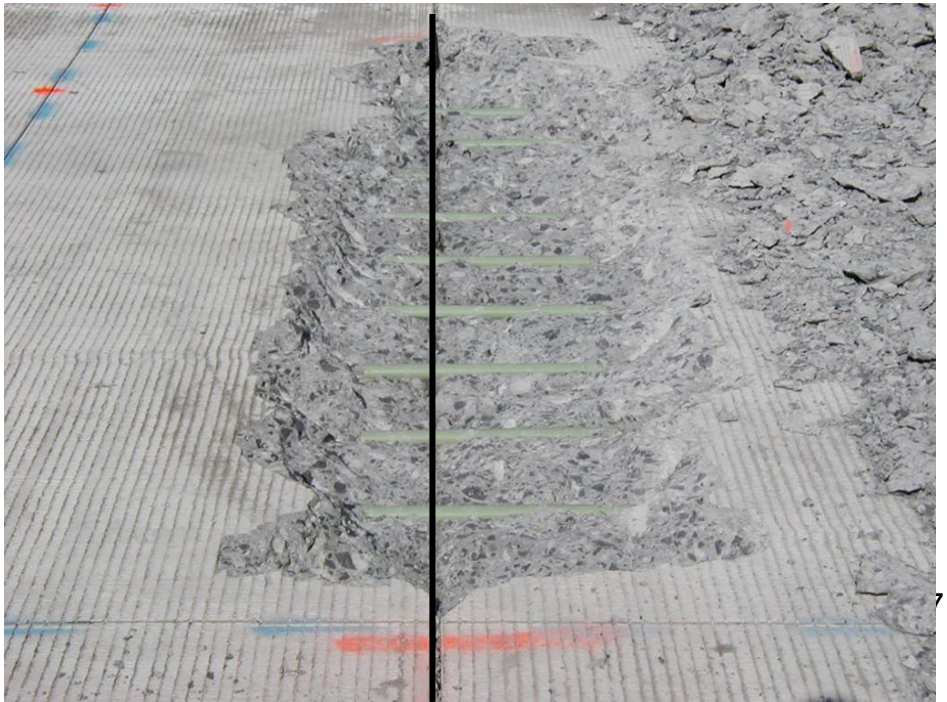
# Dowel Bar Placement Issues

- Baskets
  - Basket rigidity (wires/design)
  - Basket stability – cut shipping wires (?), anchor type/length, base stability
  - Dowel debonding agent
  - Basket length
- Mechanical implantation
  - Consolidation around dowel bars
  - Dowel debonding agent
  - Dowel  alignment

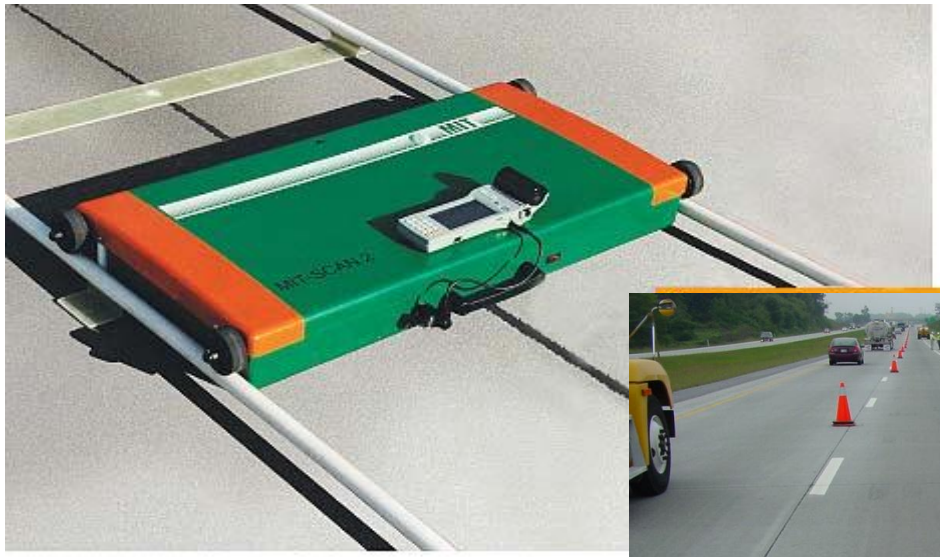
# Dowel Bar Misalignment Categories



# Dowel Misalignment Examples



# Dowel Bar Alignment Testing




**German MIT SCAN Device**


Ultrasonic (MIRA) and GPR (Hilti) devices are also available.

# Dowel Bar Misalignment Limits

- Skew (vertical or horizontal):
  - Accept: ≤ 15 mm per 450 mm
  - Action: > 15 mm per 450 mm
- Horizontal Translation:
  - Accept: ≤ 50mm
  - Action: >100mm or less than 75mm to edge
- Long. Translation :
  - Accept: ≤ 50mm
  - Action: ≥ 125mm
- Vertical Translation (Depth):
  - Accept: ≤25mm and > 5mm clearance to saw cut
  - Action: <65mm concrete cover (top or bottom) or <5mm clearance to saw cut

# Dowel Bar Misalignment Joint Score

| Single Dowel Total Misalignment (mm) | Weighting Factor, W |
|---|---|
| < 15 mm | 0 |
| 15 – 20 mm | 2 |
| 20 – 25 mm | 4 |
| 25 – 38 mm | 5 |
| ≥38 mm | 10 |

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

# Dowel Bar Misalignment Joint Score

| Joint Score | Risk of Joint Lockup |
|---|---|
| ≤ 5 | Very Low |
| 5 – 10 | Low |
| 10 – 15 | Moderate |
| > 15 | High |

Joint Score Limits:

Accept: ≤ 10

Action: All joints in MALL have JS >10

MALL= Maximum Acceptable Locked Length

= 20m, including no more than 3 locked joints

# Finishing Operations

- Minimize hand finishing – do not over-finish
  - Surface does not have to be super-smooth
- Longer straight edges produce smoother surface
- Do not add water to facilitate finishing – if used, it should be fogged, not sprayed
- Finishers have final impact on smoothness and surface durability



**High Spalling Potential**

# Use 5-m float for smoothness


- Need for finishing is minimized by
  - Selecting a workable mix
  - Properly operating the paving equipment

# Concrete Texturing
## (affects safety & noise level)

- Common Methods
  - Transverse tine (3 by 3 mm, random) – out of favor!!
  - Longitudinal tine (3 by 3 by 20 mm) – better/preferred?
  - Turf/broom drag
  - Diamond grinding (for new??)

# *Exposed Aggregate Surface*


**Step 1 - Curing compound + retarder**

- water-repellent coefficient > 90 % (first 24 h)

**Step 2 - Curing compound (applied after brushing)**

- water-repellent coefficient > 85 %

# Brushing Machine

Exposed aggregate surface
8 or 11 mm max size

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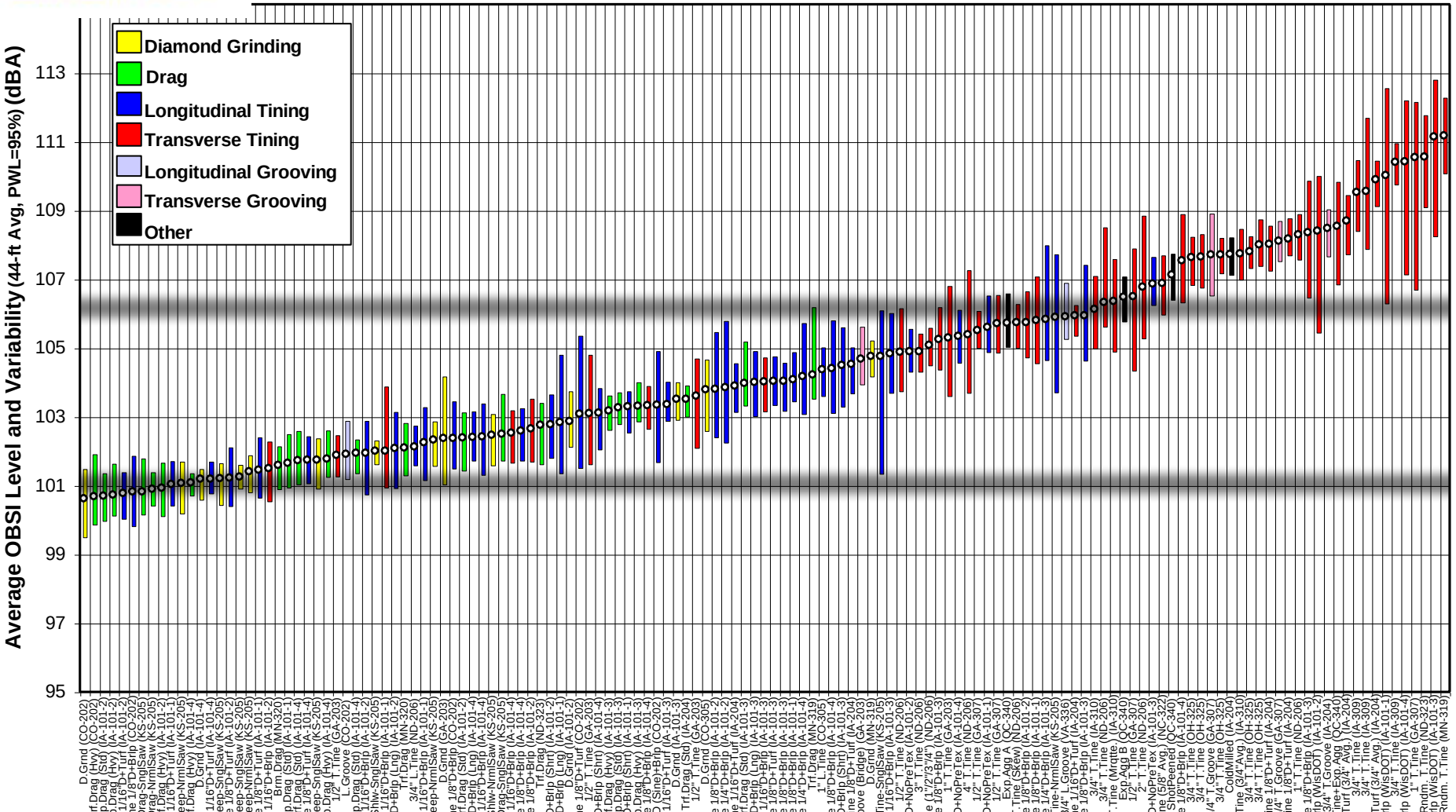
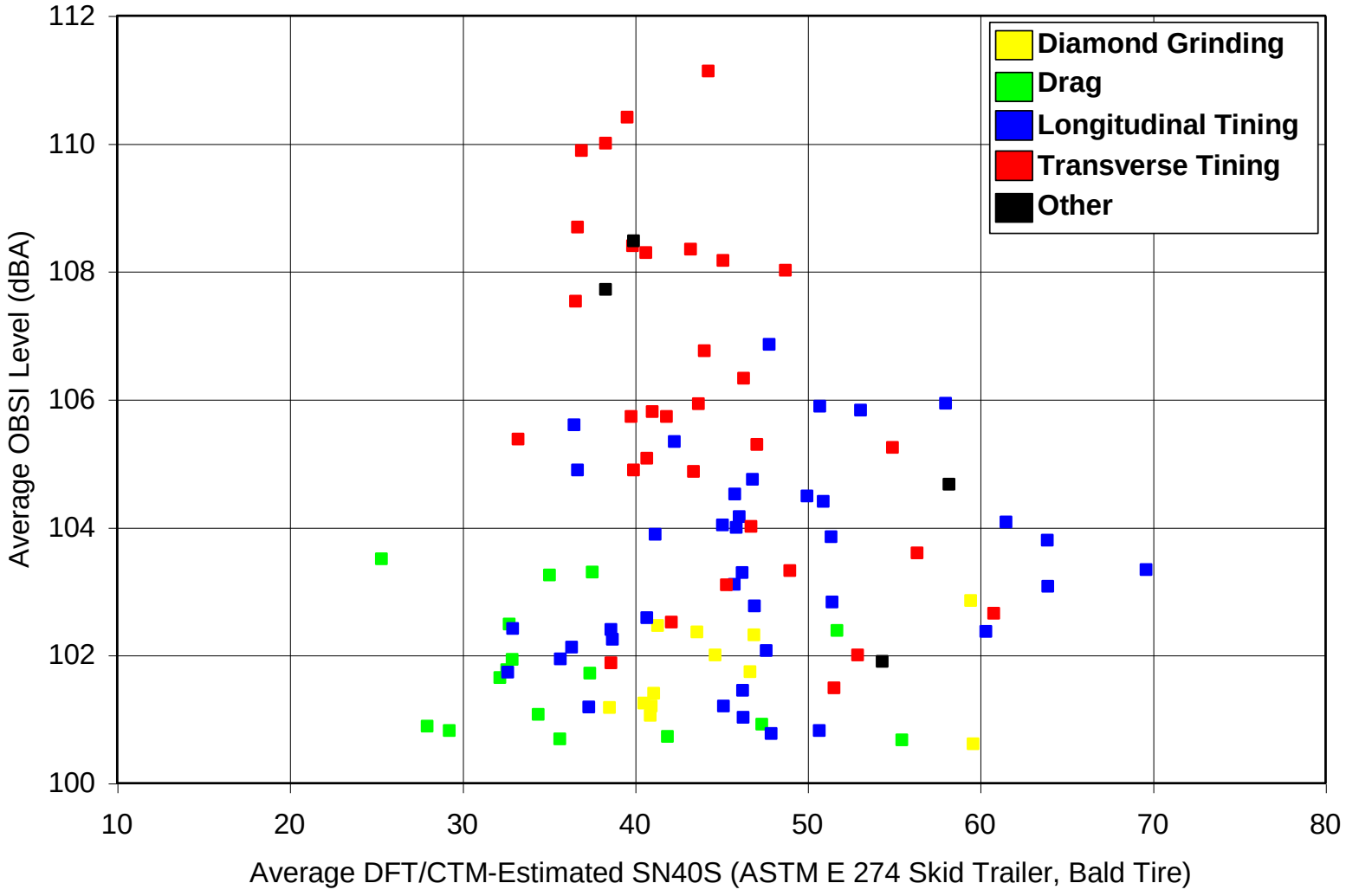
# Noise vs. Surface Texture



# Noise vs. Friction



# Concrete Curing

- Need to maintain adequate moisture & temperature regimes
- Inadequate curing leads to
  - Excessive moisture loss at surface = plastic shrinkage cracking
  - Weak surface => durability problems
  - Excessive slab warping (built-in warp)
- Must assure timely curing behind paver

# Curing Methods

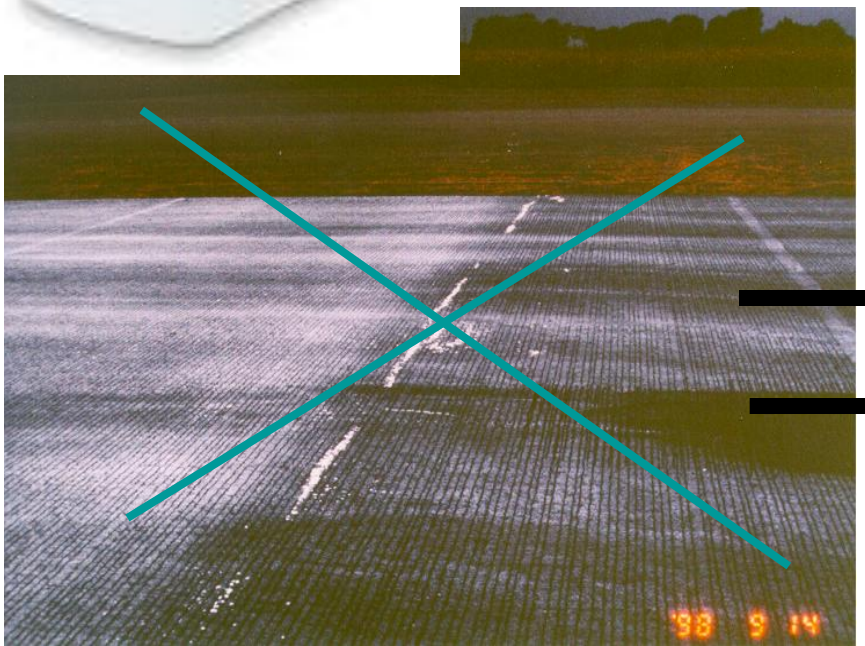
- Ponding/continuous sprinkling
- Burlap/cotton mats
- Plastic sheeting
- Curing compounds

# Curing Compounds

- Coating placed on concrete surface to prevent moisture loss
  - Resin or ~~wax based~~
  - Clear or white-pigmented
- Advantages:
  - Easy to use - not labor intensive
  - Economical
- ASTM C 309 & AASHTO M148 (Type 2, Class B)
- All curing compounds are not created equal even if they meet specs
  - Water retention is a key to successful curing

# Curing Compound Application

- Time of application
  - Apply as soon as surface sheen has disappeared
- Use automated equipment for uniform coverage
- Cover all exposed surfaces (incl. sides)
  - Re-apply at joints after sawcutting
- Typical application rate: 4 to 5 $m^2/l$ (150-200 $ft^2/gal$) Curing time: Typically 72 to 96 hours
- Check nozzles regularly for uniform spray (avoid clogging)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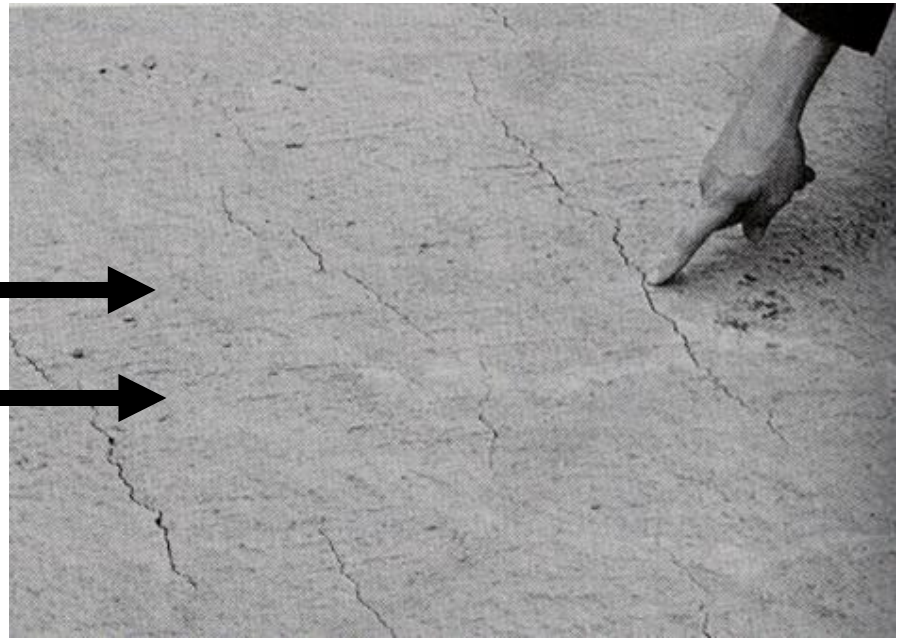
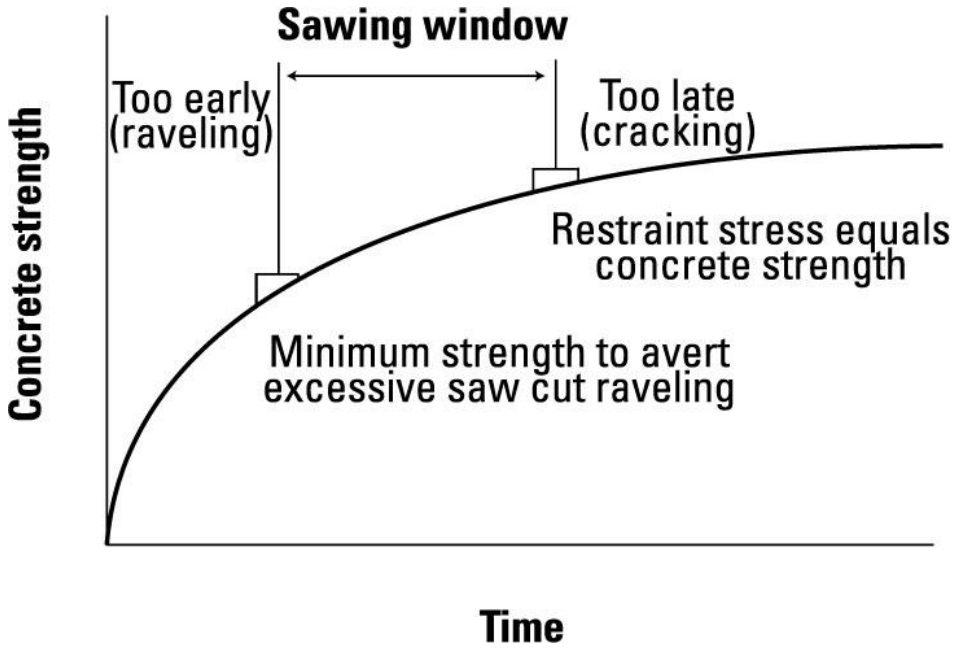


# Joint Sawing

- Why saw?
- Saw timing
  - Sawing window
  - Maturity testing
  - HIPERPAV
  - Early-entry saws
  - Joint width
- Mixture effects

# Joint Sawing



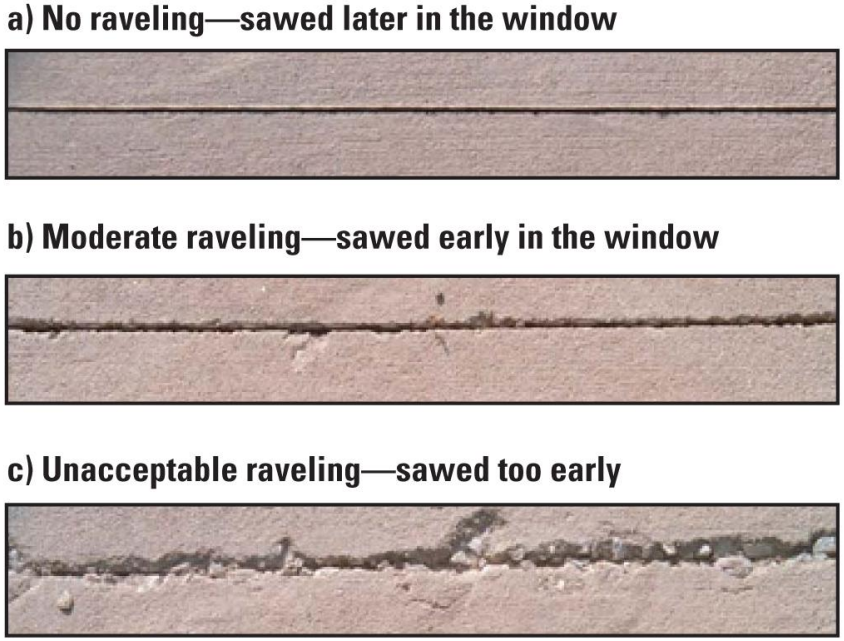



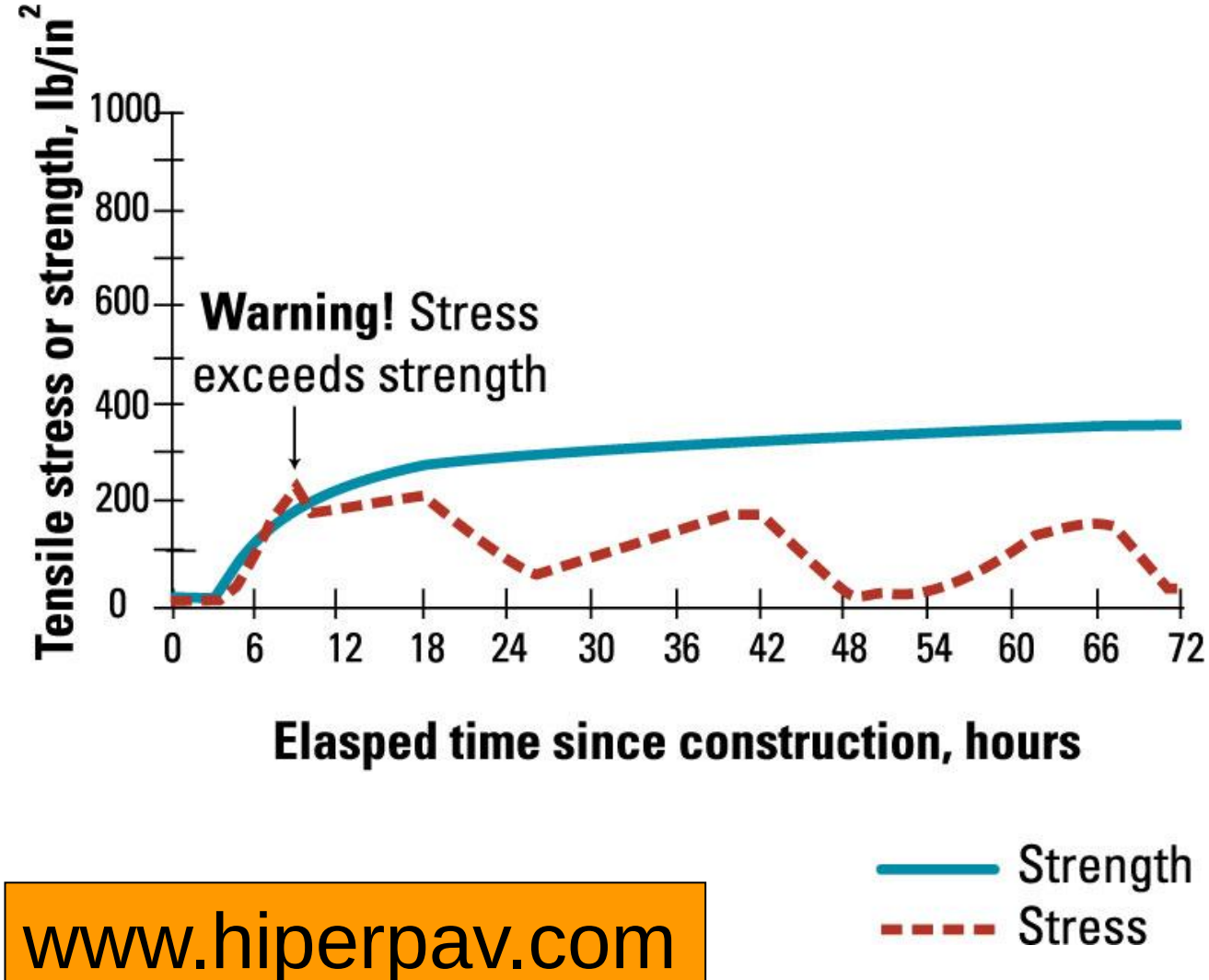

Figure 8-23. Close-up of different degrees of raveling caused by joint sawing (ACPA)

# Factors that Shorten Window

- Sudden temperature drop
- High wind, low humidity
- High friction base
- Bonding between base & slab
- Porous base (PATB)
- Retarded set (delayed and shortened)
- Delay in curing application

# Crack Prediction with HIPERPAV

(free download)




www.hiperpav.com

# Joint Sawing QA/QC Issues

- Check planned vs. actual locations
- Check sawcut depth
- Check sawcut carried through vertical edge


# Joint Sealing

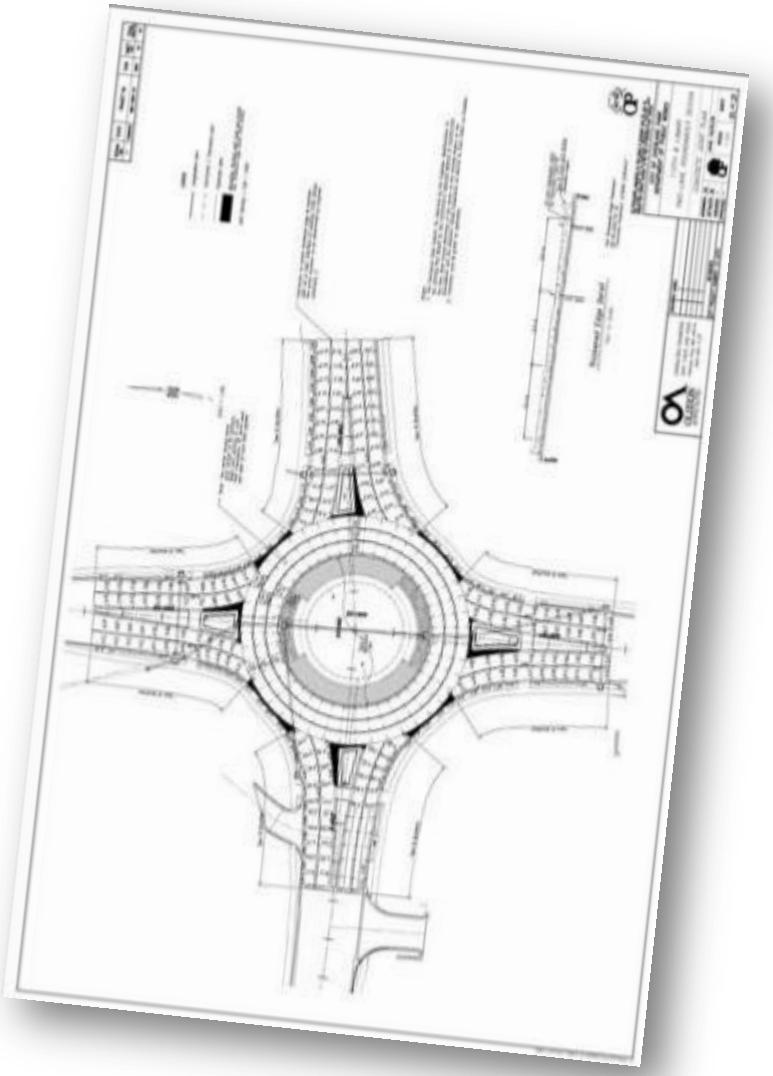
- Minimize infiltration of water and incompressibles
- Types
  - Hot pour
  - Silicone
  - Compressive seals
- Reservoir preparation
  - Clean
  - Shape
- Current debate: to seal or not to seal?

# Joint Sealing Approaches

- Conventional Approach
  - Initial sawcut – 3 mm
  - Widening cut for sealant reservoir – shape factor
- Single cut Approach – 4 to 5 mm
  - Narrow unsealed
  - Narrow filled
  - Narrow sealed

# *Joint Layout*

- Critical to crack control
- Typically decided by engineer
  - No knowledge of contractor, equipment, processes
  - Hard to precisely place things like utilities
- **Field adjustments can and should be made**



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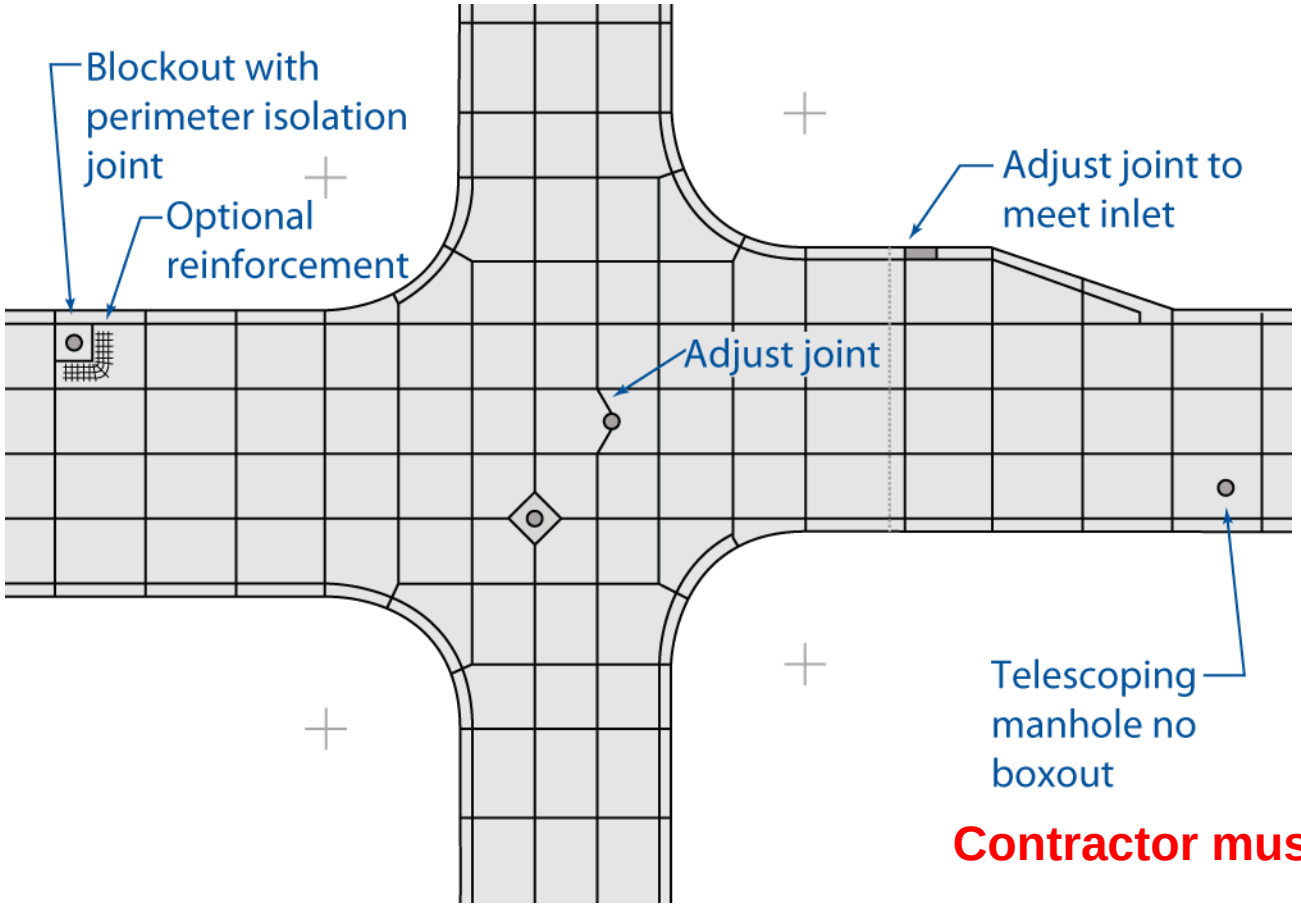
XVI
CÓRDOBA, 2012

# If Joints Aren't Properly Adjusted…

# Field Adjustments are Necessary

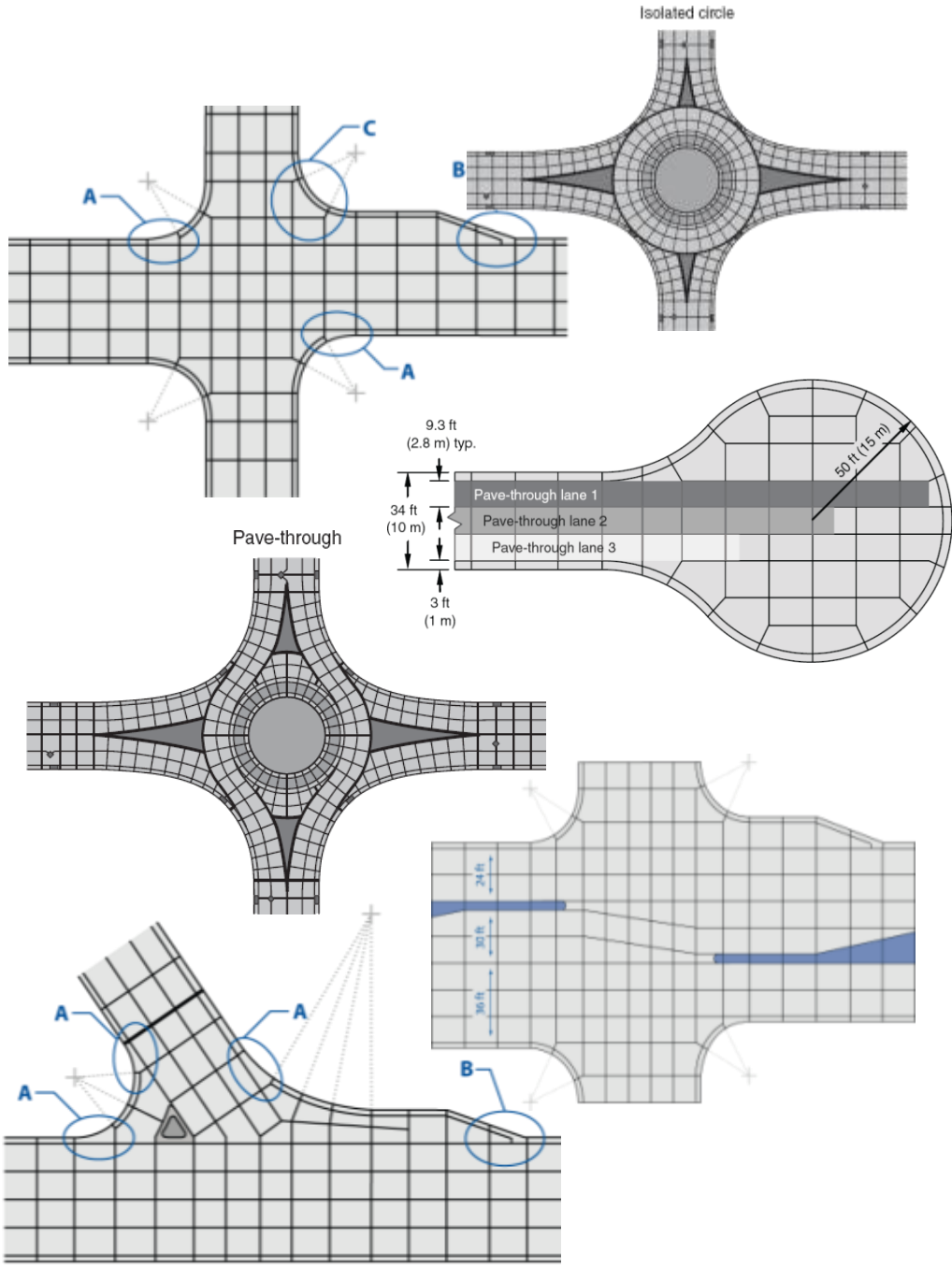
**Adjust joints that are within 5 ft of a utility!**




**Contractor must also consider impact of relocating joints!!!**

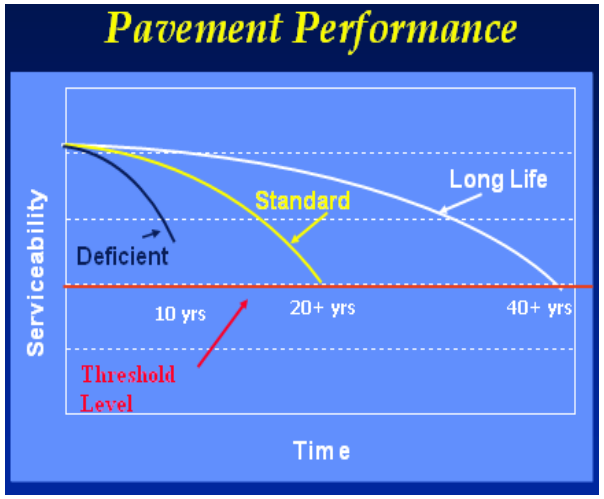
# Joint Layout Design

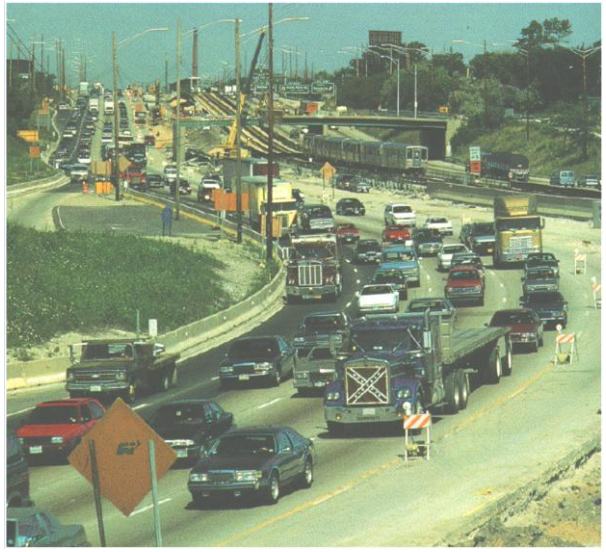
- EB237 – Concrete Pavement Field Reference: Pre-Paving
- IS006, Intersection Joint Layout
- IS061 – Design and Construction of Joints for Concrete Streets
- R&T Update 6.03 – Concrete Roundabouts
- TB010 – Design and Construction of Joints for Concrete Highways
- TB017 – Airfield Joints, Jointing Arrangements and Steel
- TB019 – Concrete Intersections: A Guide for Design and Construction



# *Summary: Cost of Poor Quality*

- For highway agencies
  - Traffic congestion & accidents
  - Reduced service life
  - Higher life cycle costs
- For contractor
  - Corrective measures
  - Partial payments
  - Cost of claims (litigation)
  - Liquidated damages



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