



# CONCRETE CRACKS !

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WELCOME TO THE WORLD OF  
*REALITY!*

***FEAR FACTOR***

**SURVIVOR**

**THE AMAZING RACE**

**SUPER NANNY**

**THE APPRENTICE**

**THE ADVENTURES OF THE**

**WONDER CRACK**

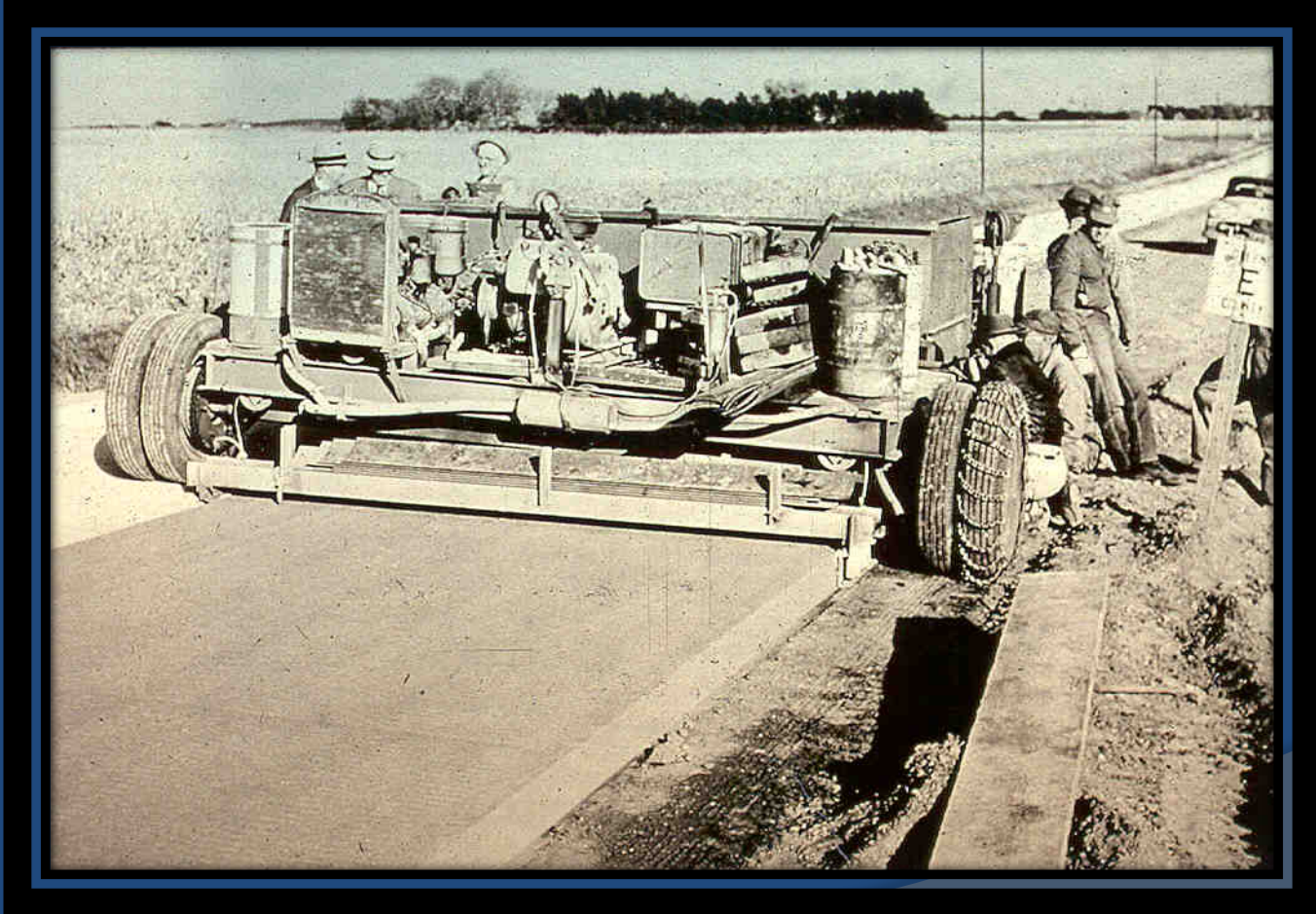
- ◎ WONDER HOW IT HAPPENED?
- ◎ WONDER WHAT TO DO?
- ◎ WONDER HOW IT WILL EFFECT YOUR PAVEMENT?





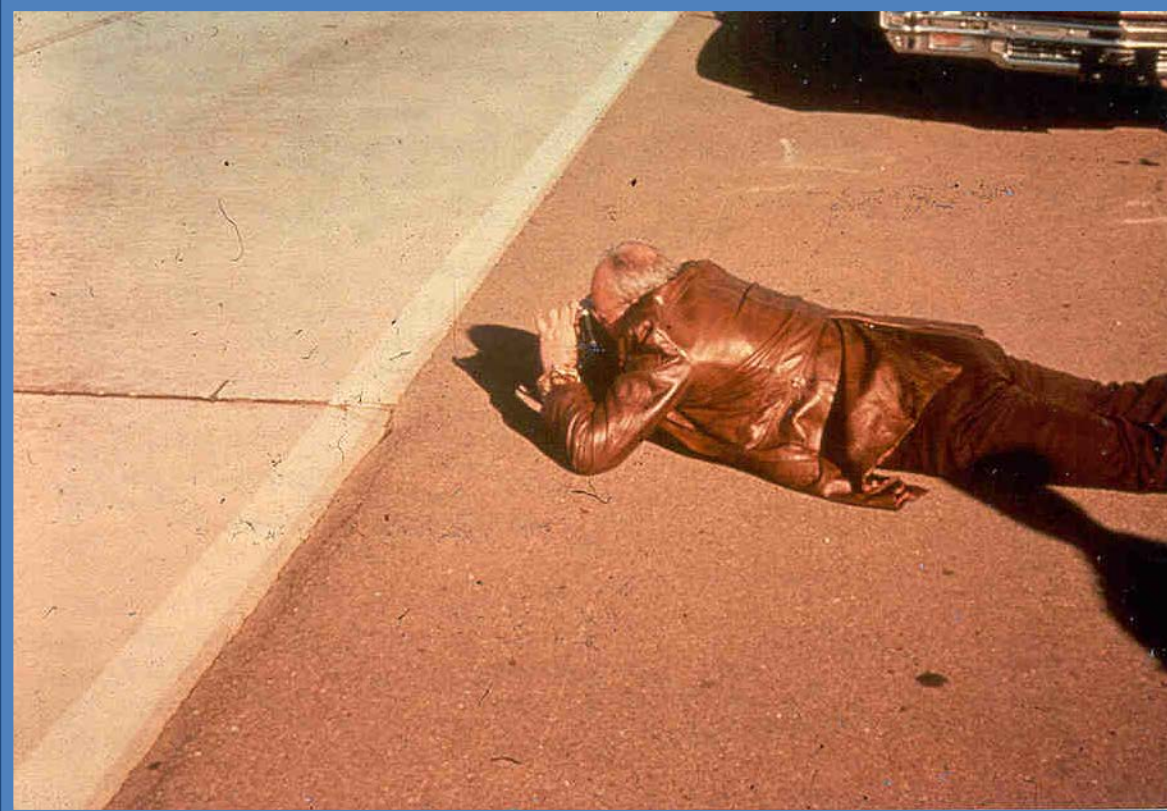
**QUALITY CONTROL**

# CONSTRUCTION





# ***OBSERVATION***

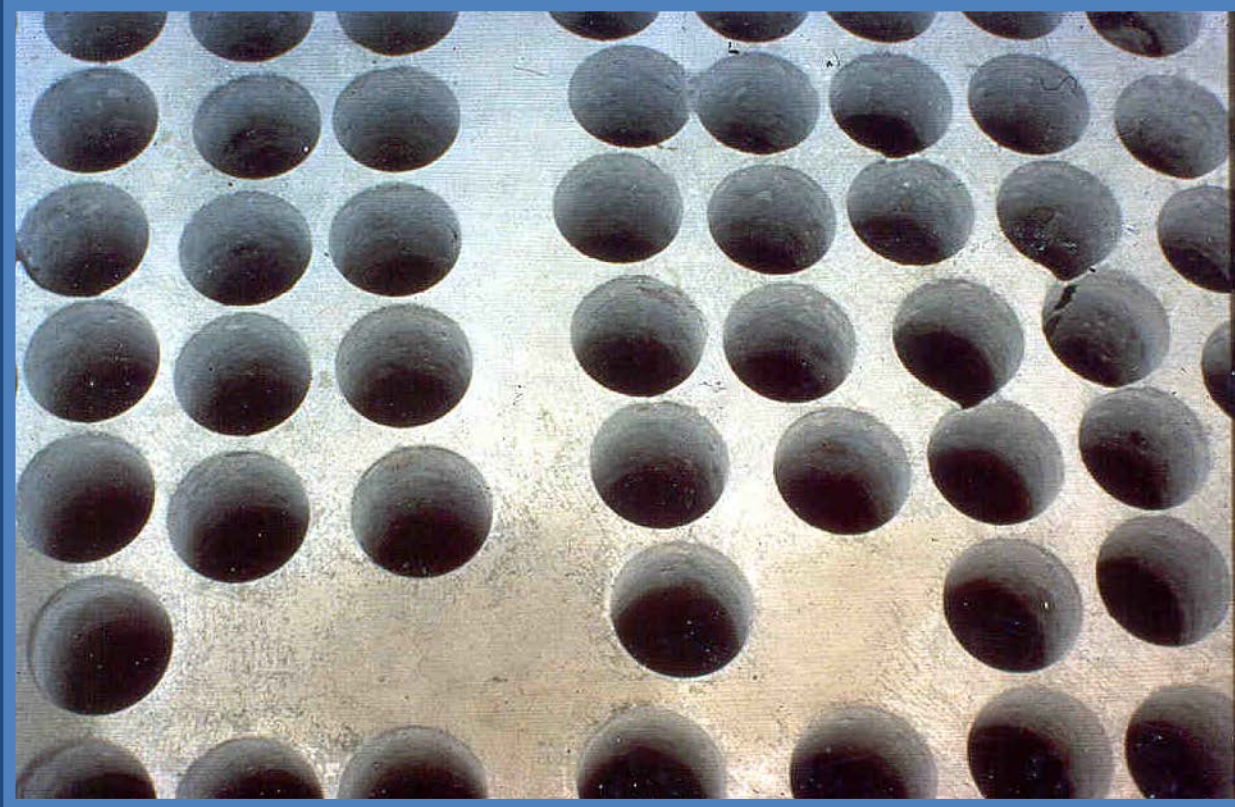




# INVESTIGATION



# TESTING

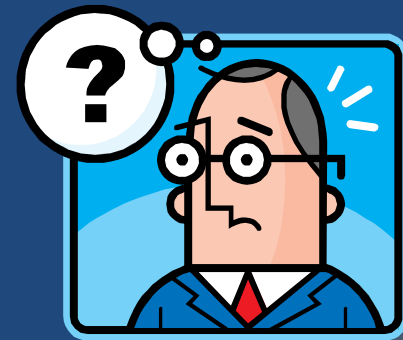


***BUT, WE JUST CAN'T CONTROL EVERYTHING!***



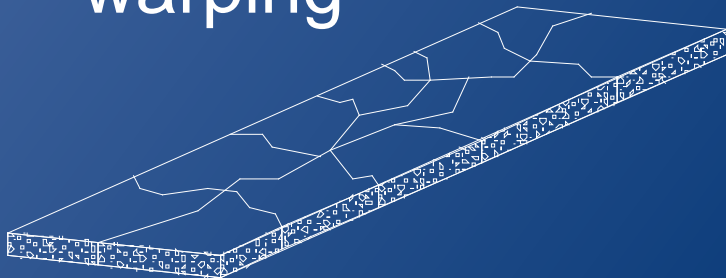
# *THE COMMON QUESTIONS?*

- WHAT THE #&@\*% HAPPENED?
- WHO'S AT FAULT?
- HOW'S THIS GOING TO IMPACT MY PAVEMENT PERFORMANCE?
- WHAT DO I DO NOW?

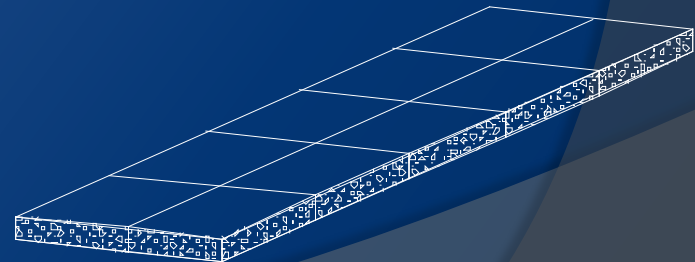


# WHY DOES CONCRETE CRACK?

- Resistance to subgrade restraint
- Stress caused by concrete drying shrinkage
- Stress caused by temperature/moisture differentials
- Applied traffic loads
- Combined effects of restrained curling and warping



Random Cracking without Sawing



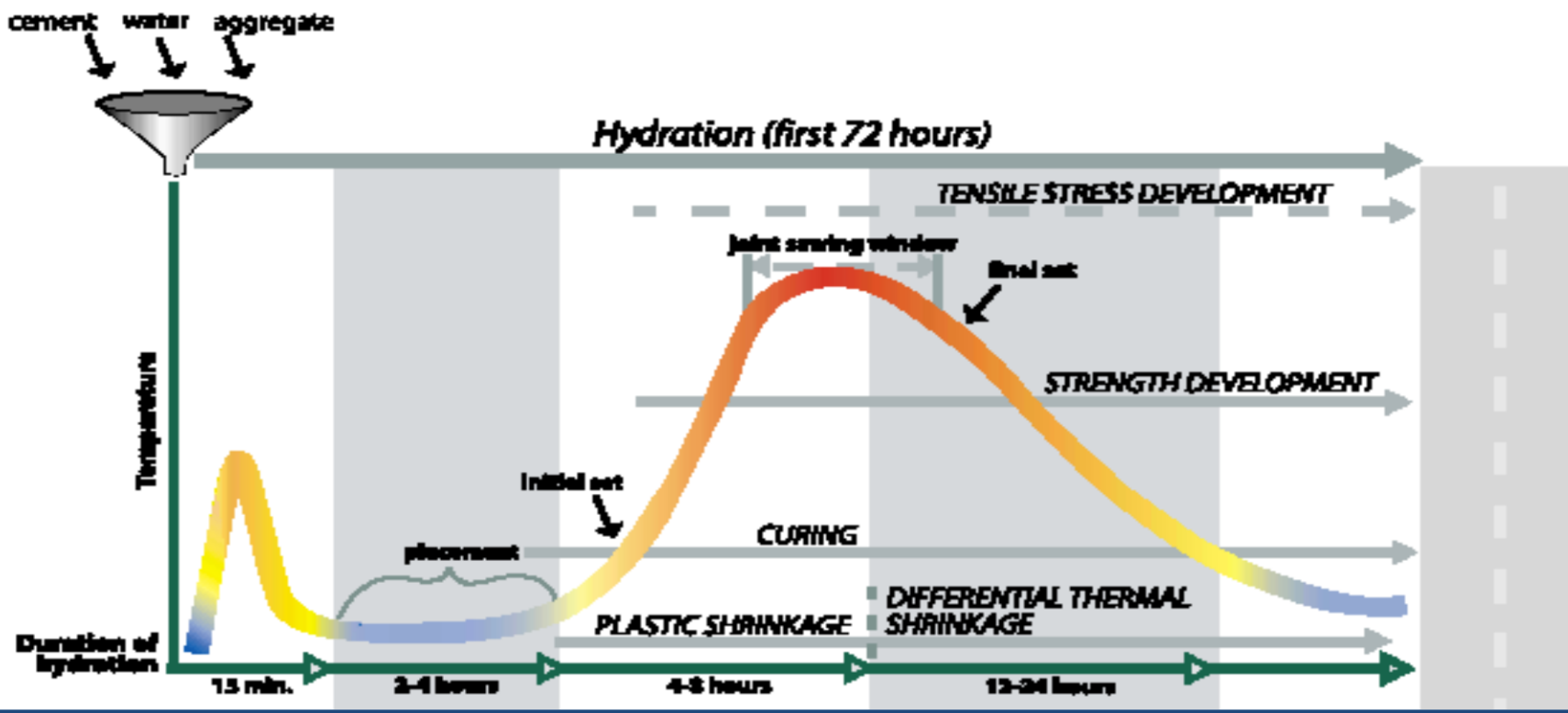
Controlled Cracking with Sawing

# *EARLY CRACK DEVELOPMENT*

## THE FIRST 72 HOURS

- Subgrade and subbase restraint
- Shrinkage (the change from liquid to solid)
  - Temperature change during hydration
  - Loss of water during hydration
- Curling





<u>Initial Mix</u> (15 minutes)	<u>Dormancy</u> (2-4 hours)	<u>Acceleration</u> (4-8 hours)	<u>Deceleration</u> (12-24 hours)	<u>Slow Hydration</u> (Indefinitely)
High heat followed by rapid cooling	Cool, plastic, workable	Significant heat, less workable, begins to harden	Becomes hard and dense	70 – 75%hydrated after 28 days
	Transport and Place	Begin curing Cut joints	Continue curing	Can continue indefinitely, as long as water can reach un-hydrated particles

# *THE FACT:* ALL CONCRETE CRACKS!

Our objective should be to control the cracking, but if we don't, let's not forget that even the joint is a crack!

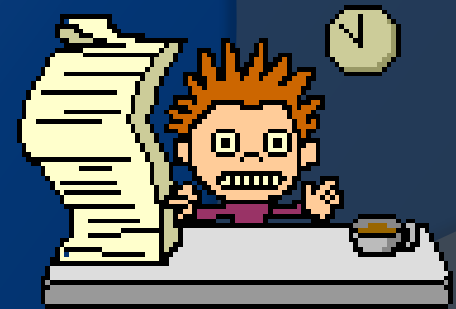
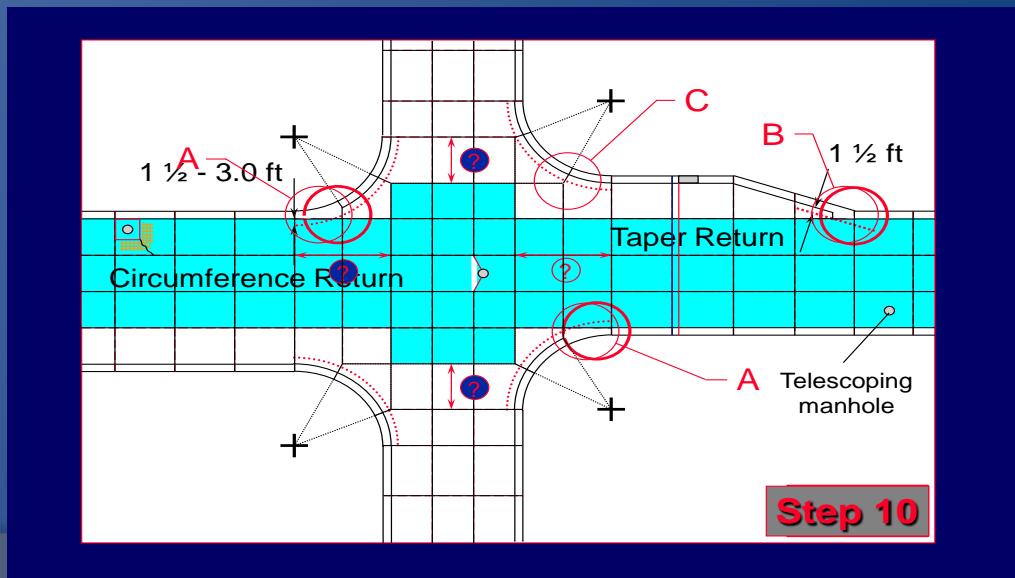
Is it then fair to conclude that cracks are necessarily detrimental to the performance of a pavement?





# HOW DO WE RELIEVE THE STRESS?

By properly designing and constructing (sawing) joints in the pavement



# *PRIMARY BENEFITS OF JOINTING*

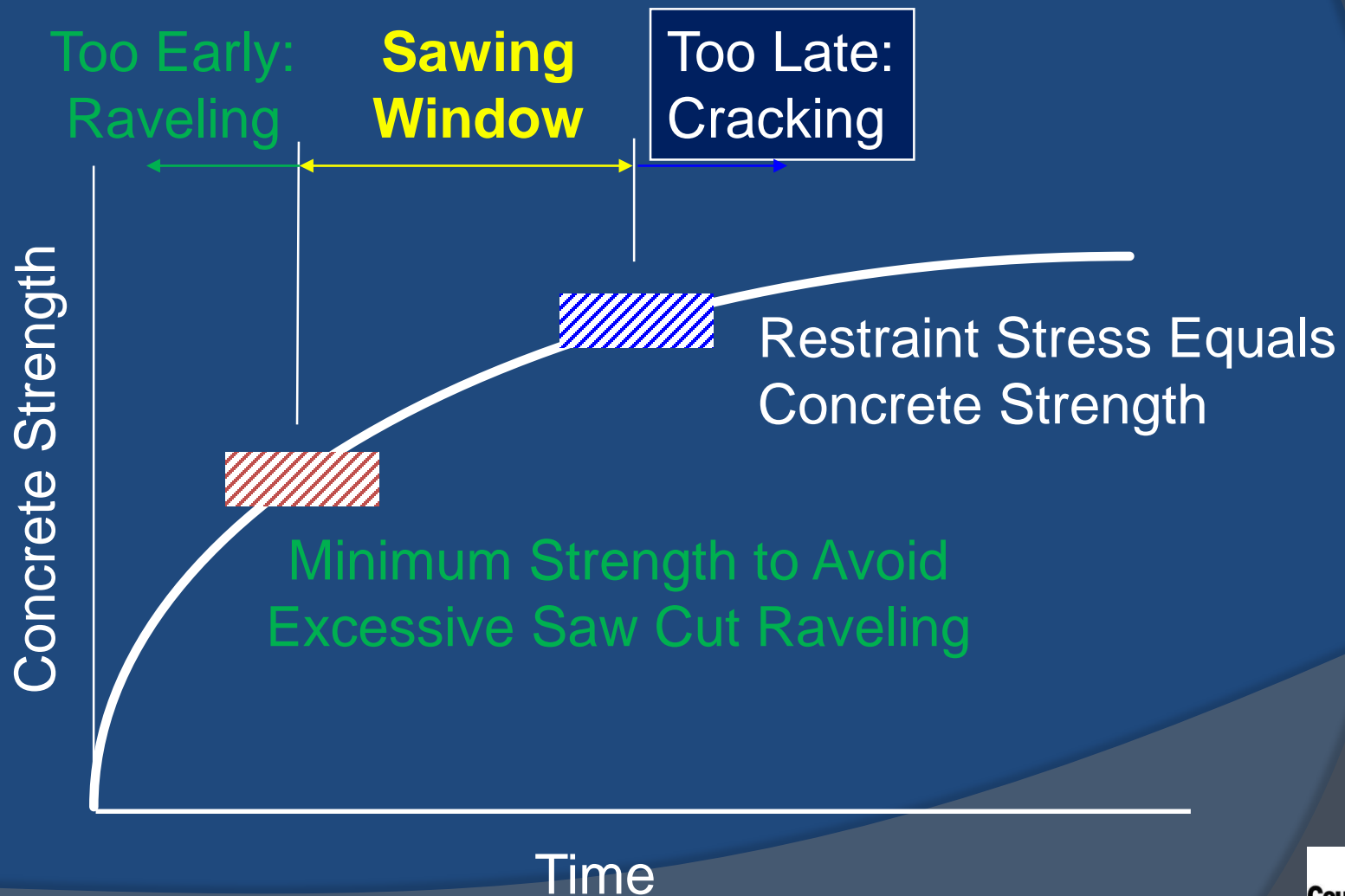
- ◎ Crack control (creating a plane of weakness).
- ◎ Accommodating slab movements.
- ◎ Providing desirable load transfer.
- ◎ Dividing the pavement into practical construction increments.
- ◎ Providing traffic guidance. (A secondary consideration.)

# *UNCONTROLLED CRACKING*

## THE FACTORS OF INFLUENCE

- ◎ Sawing operation
- ◎ Weather and ambient conditions
- ◎ Subbase
- ◎ Concrete mixture/materials
- ◎ Joint spacing

# SAWING : THE WINDOW OF OPPORTUNITY



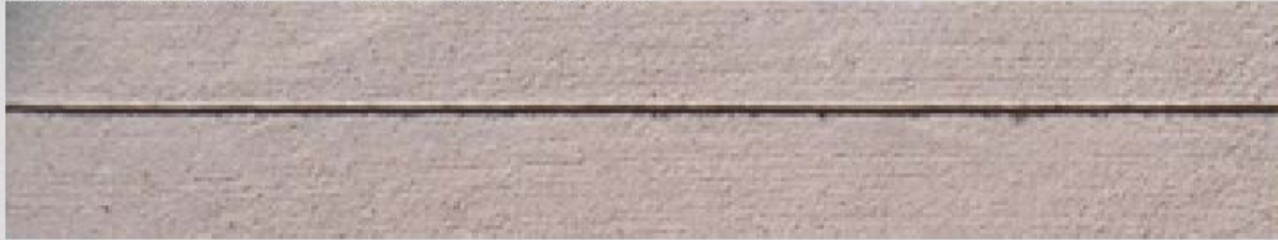
# *UNCONTROLLED CRACKING*

## SAWING OPERATIONS

- ◎ Timing
- ◎ Depth of cut
- ◎ Blade selection

# *RAVELING – THE SAWING WINDOW*

A. NO RAVELING – Sawn late in window



B. MODERATE RAVELING – Sawn early in window



C. UNACCEPTABLE RAVELING – Sawn too early



# *FACTORS AFFECTING SAWING WINDOW*

## **Weather:**

Sudden temperature drop or rainshower

Sudden temperature rise

High winds and low humidity

Cool temperatures & cloudy

Hot temperatures & sunny

## **Subbase:**

High friction between the subbase and concrete slab

Bond between the subbase and concrete slab

Dry surface

Porous aggregate subbase materials

## **Concrete Mixture:**

High water demand

Rapid early strength

Retarded set

Cementitious content and composition

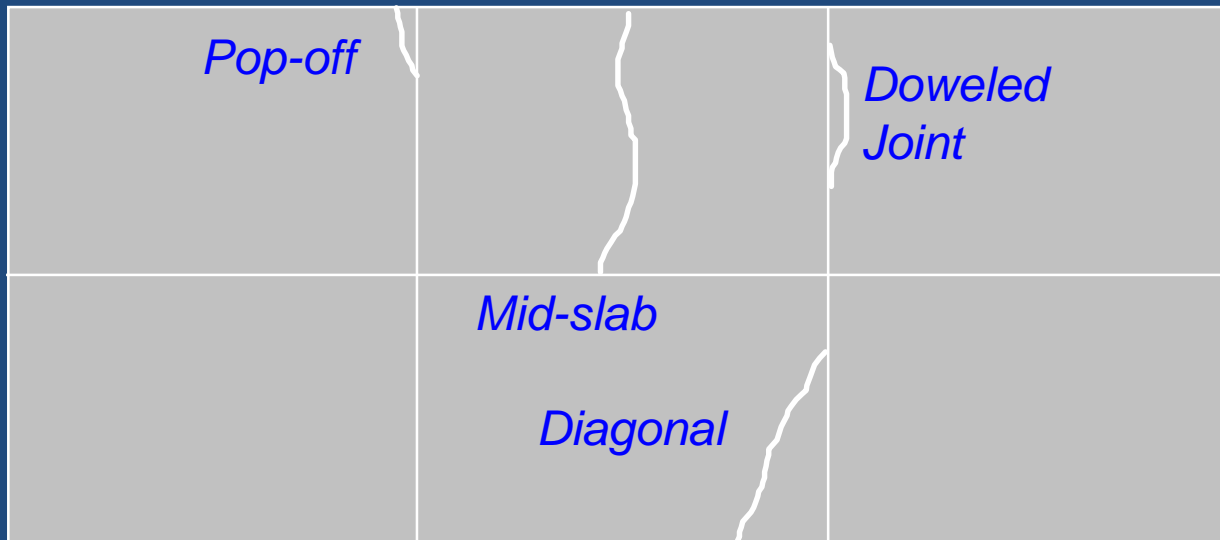
Supplementary cementing materials

Fine aggregate (fineness and grading)

Coarse aggregate (maximum size and/or percentage)

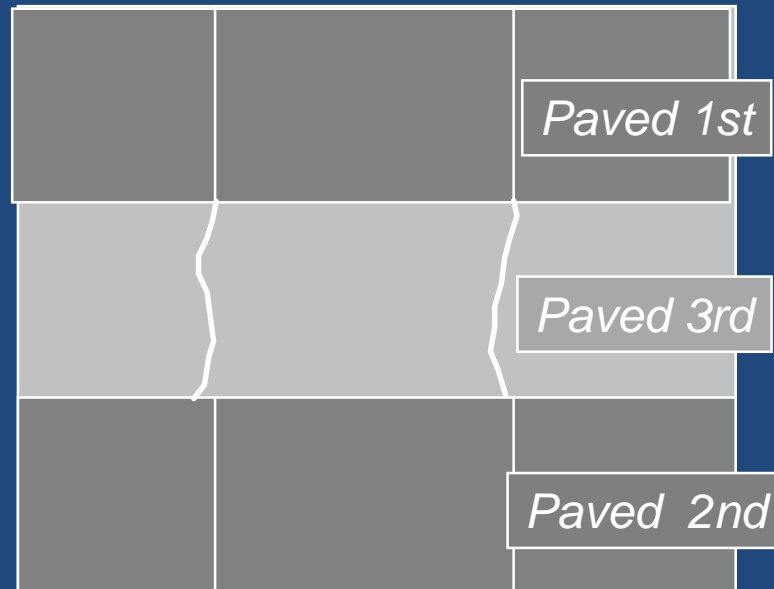
# CRACKS IN CONCRETE

TYPICAL ORIENTATIONS IF SAWING TOO LATE  
FOR GIVEN CONDITIONS



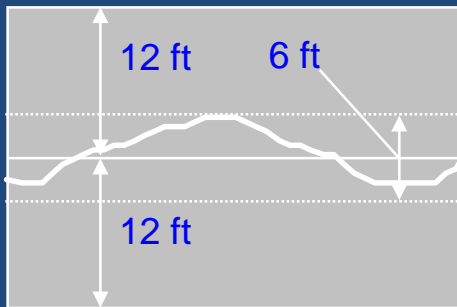


# EARLY TRANSVERSE CRACKS INDUCED BY EDGE RESTRAINT

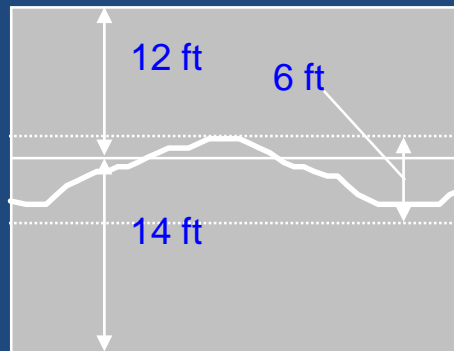


# EARLY LONGITUDINAL CRACKS

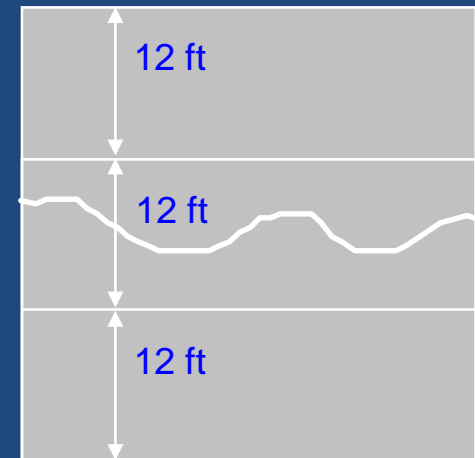
2-Lane Section:



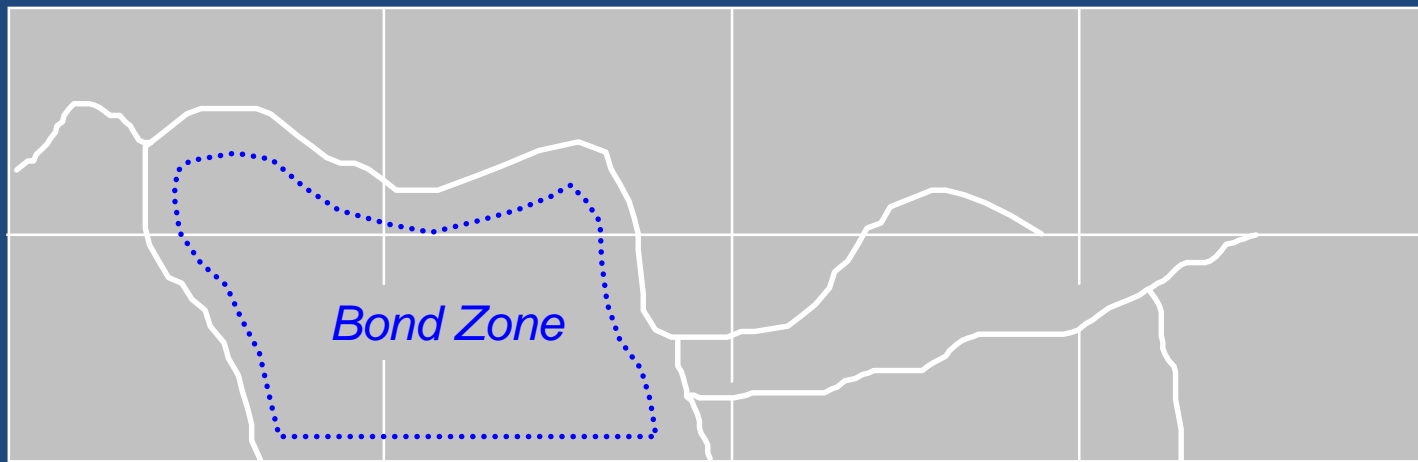
Widened Lane:



3-Lane Section:

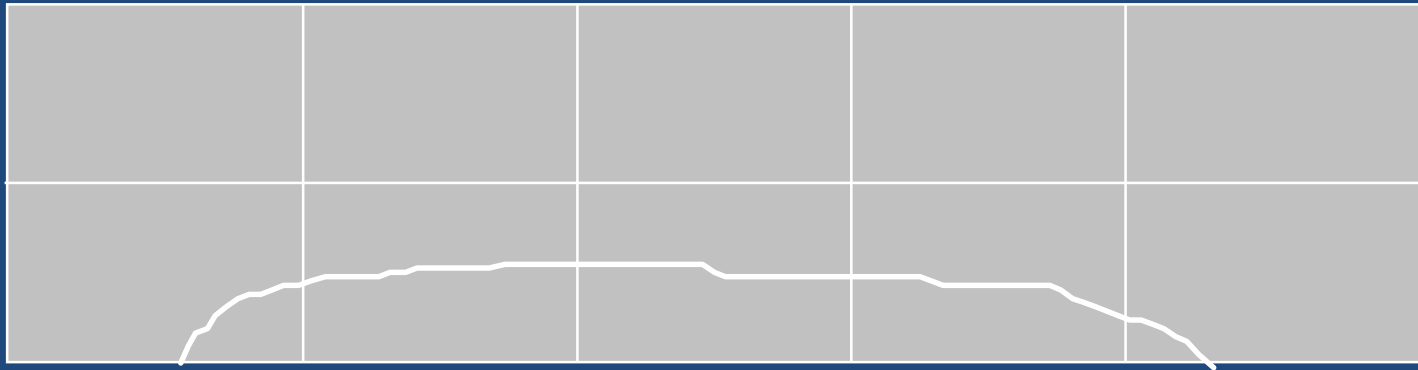


# ERRATIC PAVEMENT CRACKS



TYPICAL OF HIGH FRICTION  
OR BOND BETWEEN SUBBASE AND CONCRETE

# EDGE-TO-EDGE LONGITUDINAL CRACKS



TYPICAL OF PROBLEM FROM SUPPORT (HEAVE OR SETTLEMENT)  
OR HEAVY EARLY EDGE LOADINGS

# CRACKS IN LINE WITH STRUCTURES



# *UNCONTROLLED CRACKING*

## WEATHER & AMBIENT CONDITIONS

- ◎ Almost always a factor
- ◎ Time of day
  - Afternoon heat coincides with morning concrete hydration
  - Sun-heated aggregates produce “hot” afternoon concrete
- ◎ Differential contraction (>15°f)

# *UNCONTROLLED CRACKING*

## SUBBASE

- ◎ Frictional resistance
  - Varies by material (stabilized > unstabilized)
  - Use of bond breakers on stabilized lcb or ac
  - Trimming causes roughened areas on ctb
- ◎ Temperature
  - Differential curing
- ◎ Absorption
  - Differential shrinkage



# *UNCONTROLLED CRACKING*

## CONCRETE MIXTURE/MATERIALS

- ◎ Slow strength development
  - Cementitious materials
- ◎ Fast strength development
  - Higher maximum concrete temperature
- ◎ Thermal sensitivity
  - Coarse aggregate



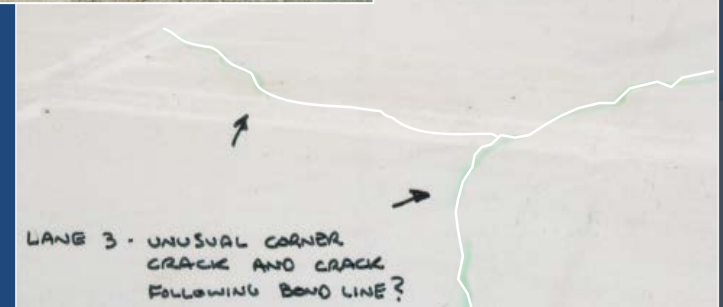
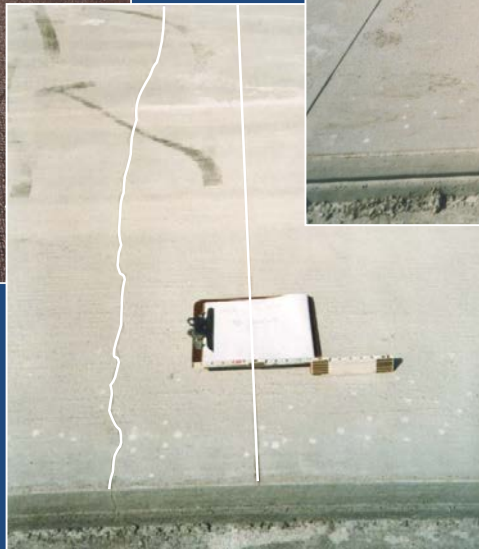
# *UNCONTROLLED CRACKING*

## JOINT SPACING

- ◎ Varies in practice (usually 15-20 ft.)
- ◎ Industry recommends
  - 24d (on granular subbases)
  - 21d (on stabilized subbases)
- ◎ In old days recommendations included aggregate type



# UNCONTROLLED CRACKS



# CRACK TREATMENT

Having observed cracks in concrete pavements for a number of years, it has become obvious that cracks filled and left alone have generally performed exceedingly well. Don't over react – sometimes the fixes are less permanent than the crack!

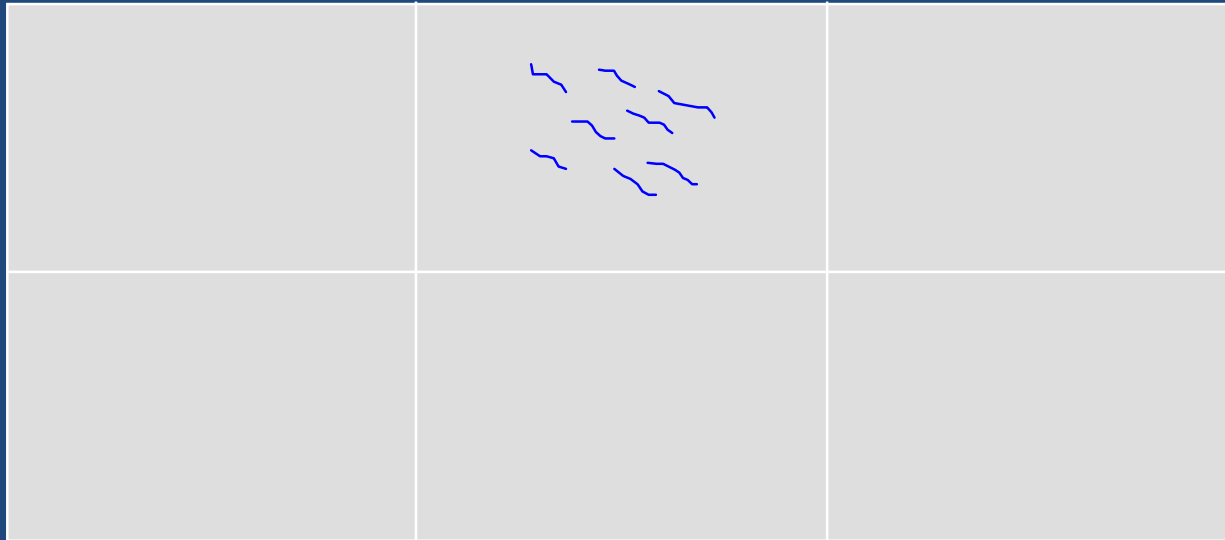


# A GUIDE FOR SEALING CRACKS

<b>ORIENTATION</b>	<b>WIDTH</b>	<b>REPAIR OR SEAL?</b>
TRANSVERSE OR LONGITUDINAL	< 1/8 in. (Hairline)	NO
	1/8 – 1/2 in.	SEAL
	> 1/2 in.	PATCH

# REPAIRING PAVEMENT DEFECTS

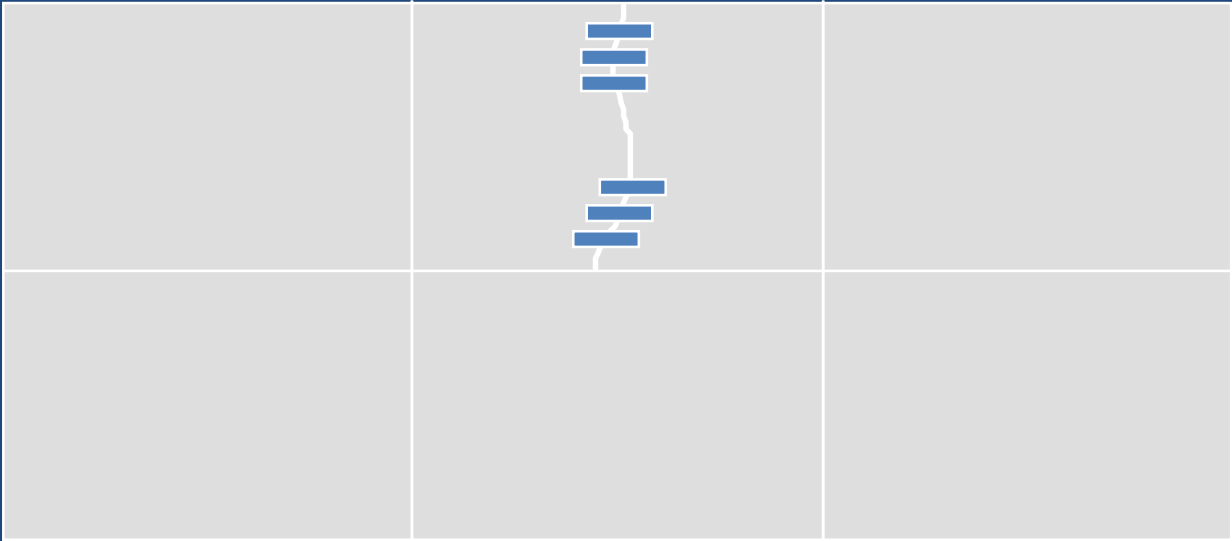
Recreation: Blowing



- Partially Penetrates Slab Depth

# REPAIRING PAVEMENT DEFECTS

Alignment, Joint, Slab, Dowel Bars







# REPAIRING PAVEMENT DEFECTS

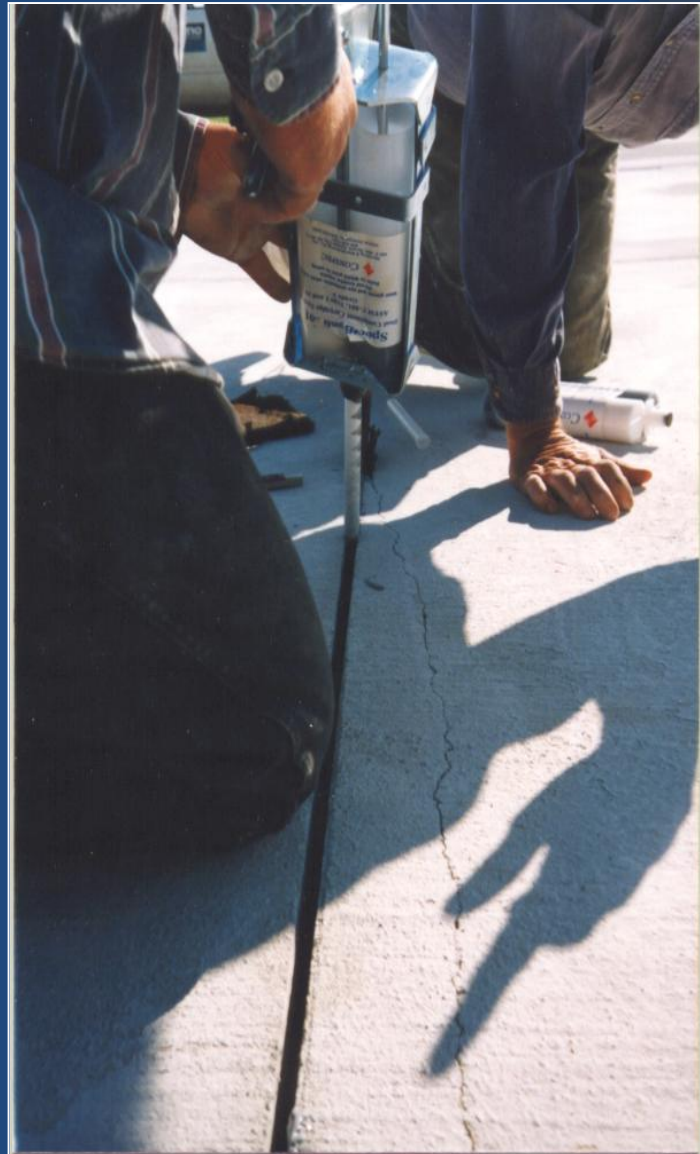
Recommend: Saw & Seal Crack - Epoxy Saw Cut



- Cracks Fully Penetrate Slab Depth
- Joints Not Cracked where Cracks Exist

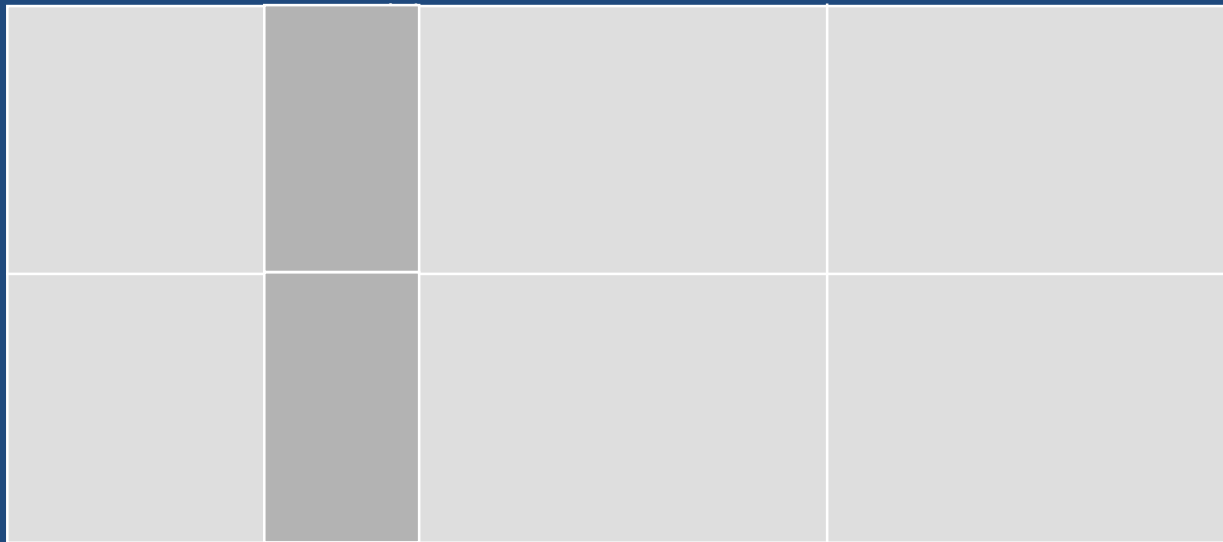
# EPOXYING JOINT RESERVOIR

The crack  
becomes the  
“working joint”



# REPAIRING PAVEMENT DEFECTS

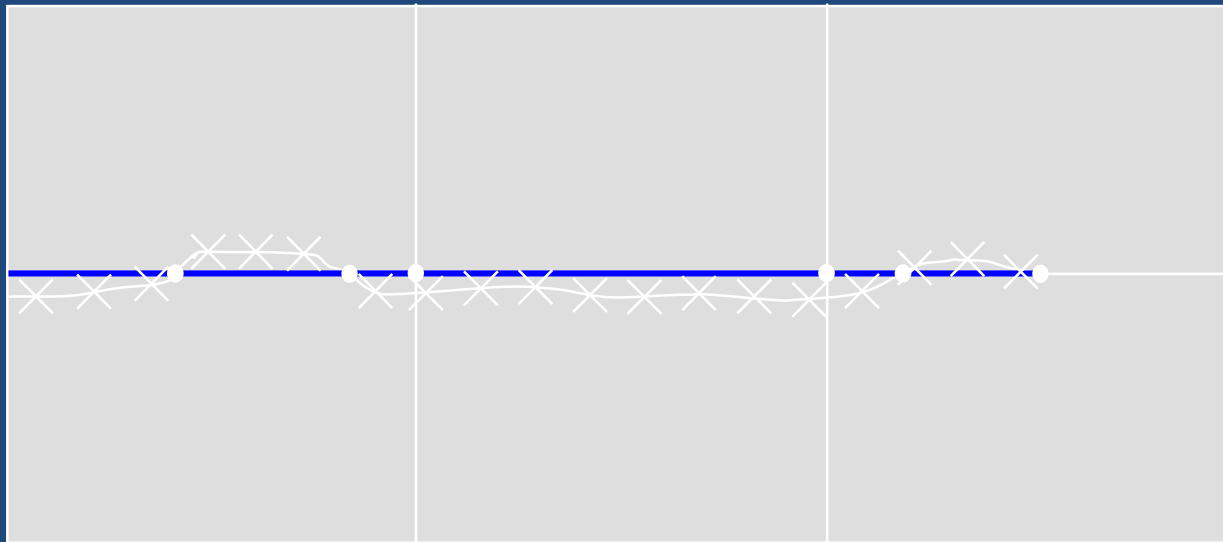
Recommended Alternative Slab Depth Repair Epoxy Saw Cut



- Crack Fully Penetrates Slab Depth
- Crack within 4.5 ft of Joint
- Joints Not Cracked where Crack Exists

# REPAIRING PAVEMENT DEFECTS

Alternative Saw Cuts & Seal Cracks with Epoxy Saw Cut



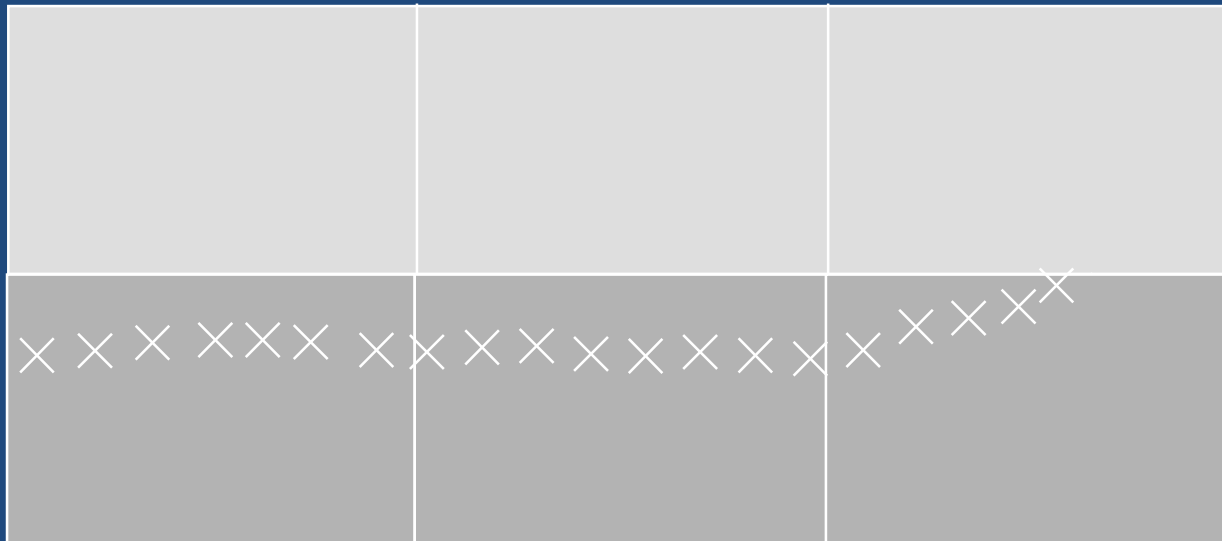
- Crack Fully Penetrates Slab Depth
- Crack within 1 ft of Joint
- Joints Not Cracked where Cracks Exist

# PAVEMENT CROSS-STITCHING



# REPAIRING PAVEMENT DEFECTS

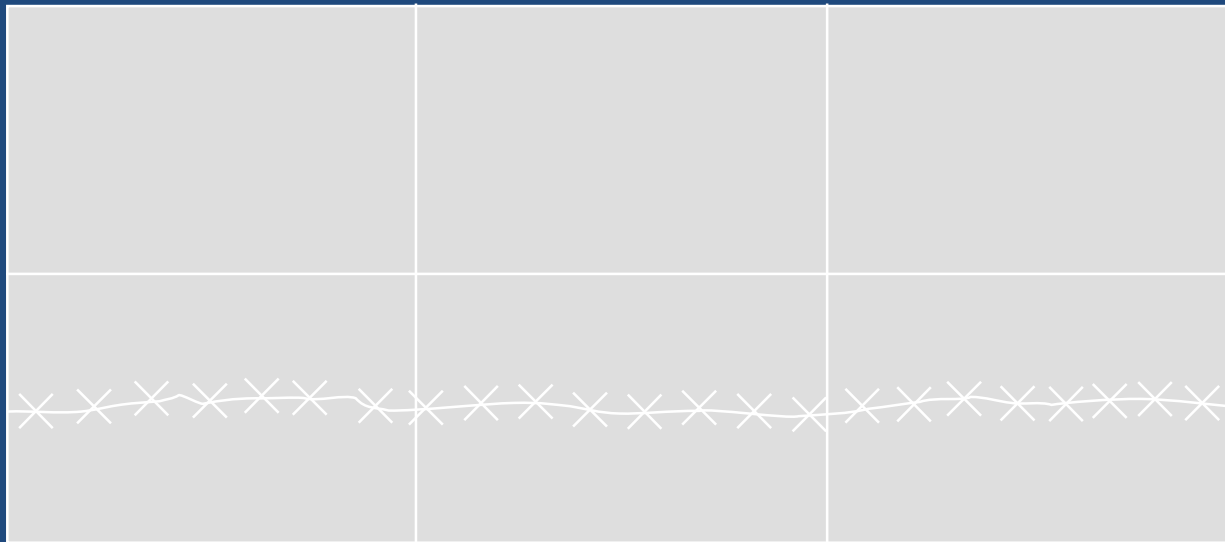
Reinforcement: Cross Slabs Full Depth



- Crack Fully Penetrates Slab Depth
- Crack Relatively Parallel in Wheelpath (1 ft to 4.5 ft) from Joint

# REPAIRING PAVEMENT DEFECTS

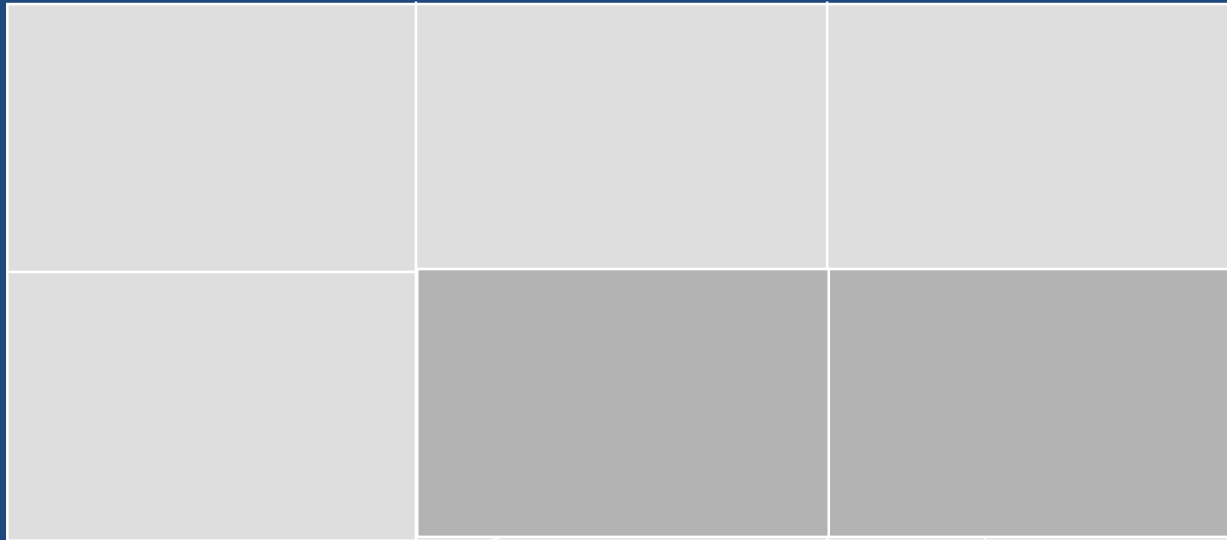
Recommend: Cross-Stitch the Crack



- Crack Fully Penetrates Slab Depth
- Crack Relatively Parallel in Mid-slab (>4.5 ft) from Joint or Edge

# REPAIRING PAVEMENT DEFECTS

Recommend: Replace Slabs Full-Depth

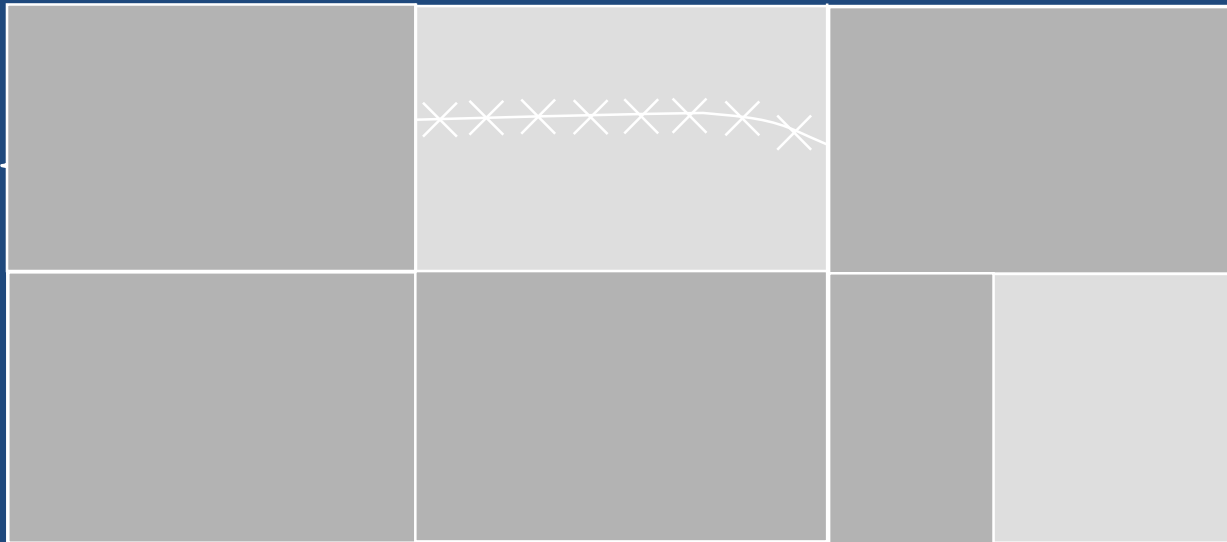


- Crack Fully Penetrates Slab Depth
- Crack Runs Diagonally



# REPAIRING PAVEMENT DEFECTS

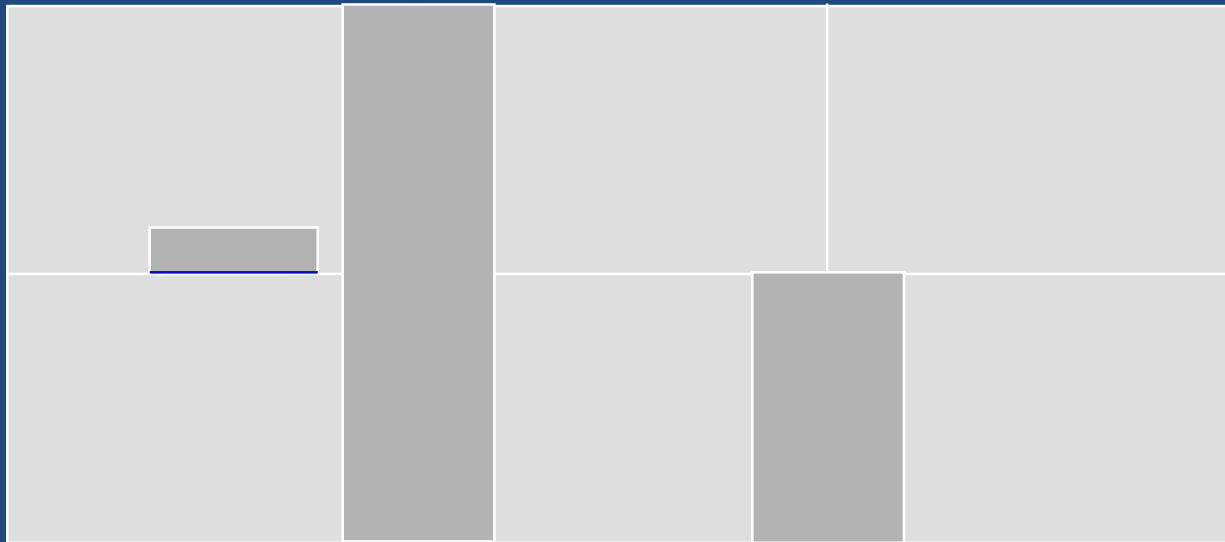
Recommend: Replace Slabs Full-Depth



- Crack Fully Penetrates Slab Depth
- Cracks Divide Slabs into Three or More Pieces

# REPAIRING PAVEMENT DEFECTS

## Alternate: Full-Depth Repair

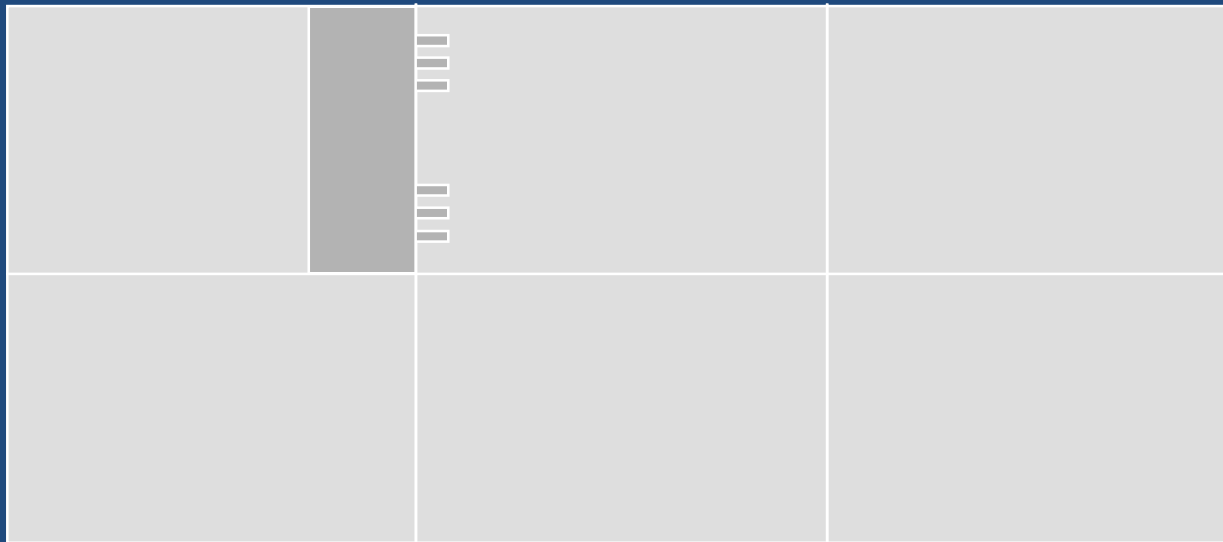


- Spalls less than about 1/3 slab depth
- Spalls either on one side or on both sides of joint

# HUMAN ERROR

## MISPLACED DOWELS / SAWCUTS

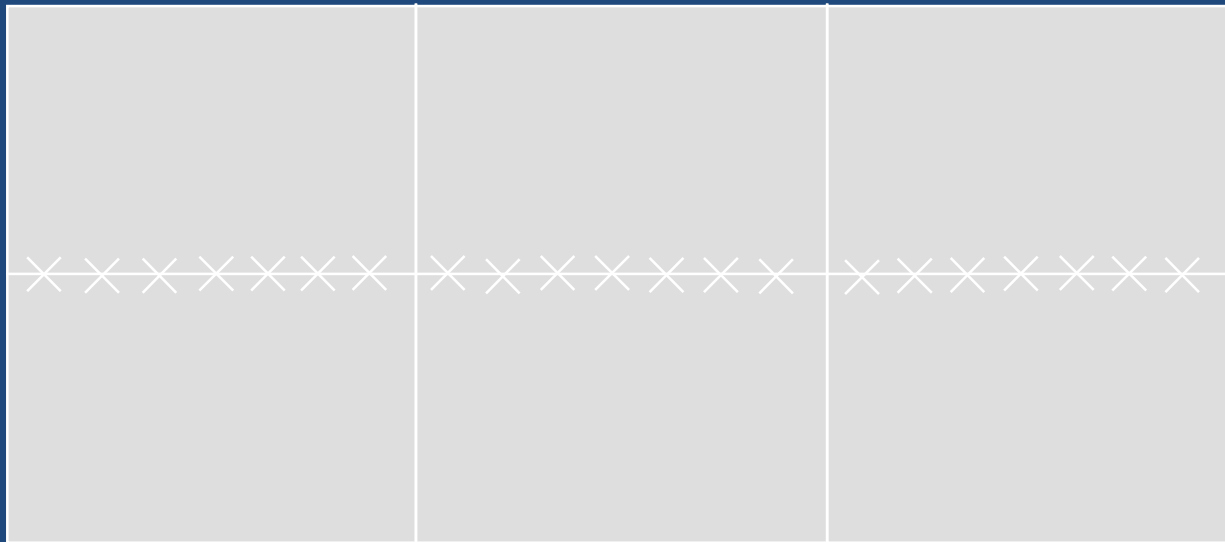
Ratio of Material Depth Bar Retrofit



# *HUMAN ERROR*

## *MISPLACED TIEBARS / SAWCUTS*

Recommend: Cross Stitching

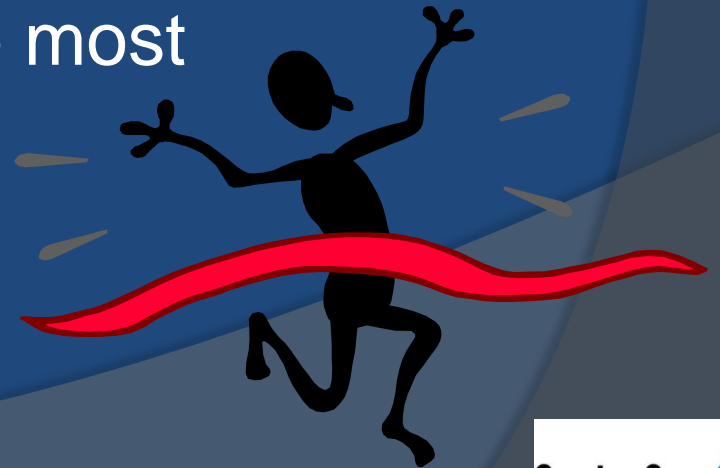


# *CONCLUSIONS*

- ◎ Early pavement distresses are influenced by:
  - Design features
  - Jointing techniques  
(design, layout, sawing)
  - Environmental circumstances
  - Human error

# *CONCLUSIONS*

- ◎ Many cracks are uncontrolled joints – fix only those that will likely impact pavement performance.
- ◎ Remedies are available to repair uncontrolled cracks and other defects
- ◎ Standardized approaches are most effective





# RESOURCES

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ACPA TB016 – Early Cracking of Concrete Pavement – Causes and Repairs

CP TECH CENTER -IMCP Manual

FHWA /TRANSTEC – HYPERPAVE

NRMCA – CIP Series

PCA – Design and Control of Concrete Mixtures

