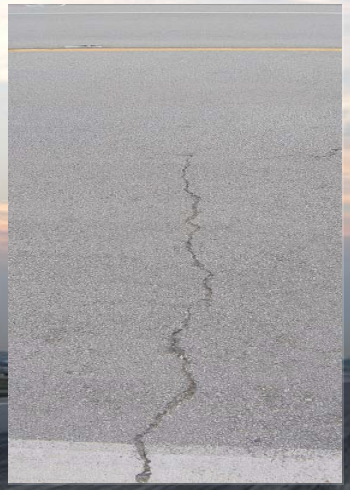
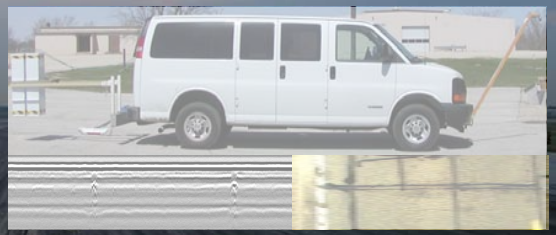
Reflective Cracking Control





Jongeun Beak, Imad L. Al-Qadi, and William G. Buttlar
University of Illinois at Urbana-Champaign

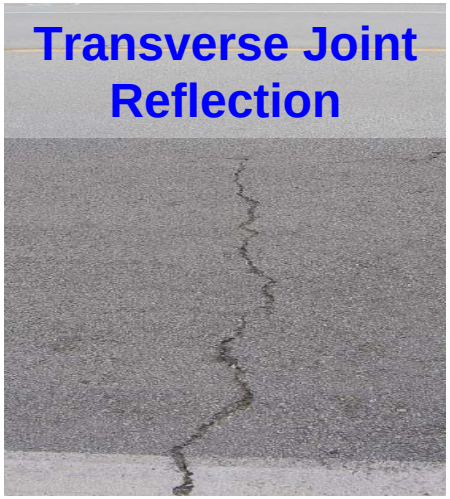
Special Joint Conference
North Central Hot Mix Asphalt Conference
Illinois Bituminous Paving Conference
January 9th, 2008

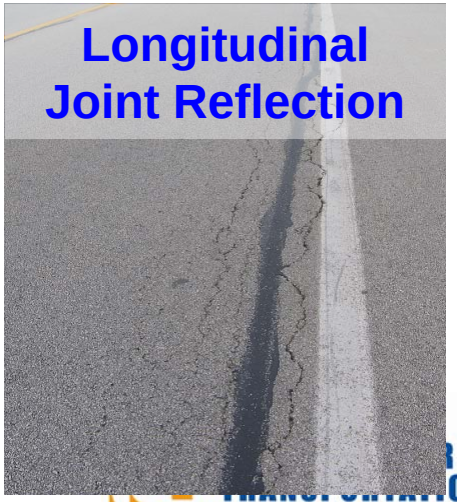
Causes of Cracks

- Fatigue
- Thermal
  - Concrete, flexible, and composite pavements
- Surface stresses
- Lack of bearing support
  - Under-design, poor drainage, or settlement
- Exiting discontinuities
  - Cracks, joints, widening

Reflective Cracking

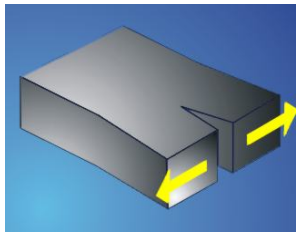
- A major distress in HMA overlays
- Environmental and tire loading
- Premature cracking within 2-3 years
- Transverse and longitudinal directions



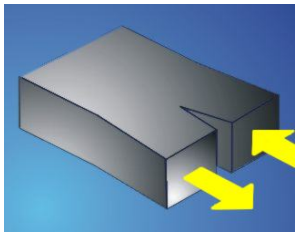


Reflective Cracking Mechanisms

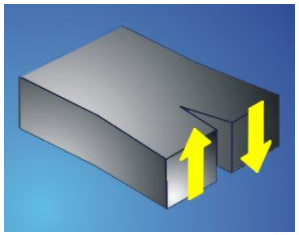
Cause	Result	Type
Tire Loading	Crack opening Shear failure	Mode I Mode II Mixed mode
Seasonal Variation	Crack opening	Mode I



Mode I (Opening)



Mode II (Sliding)



Mode III (Tearing)

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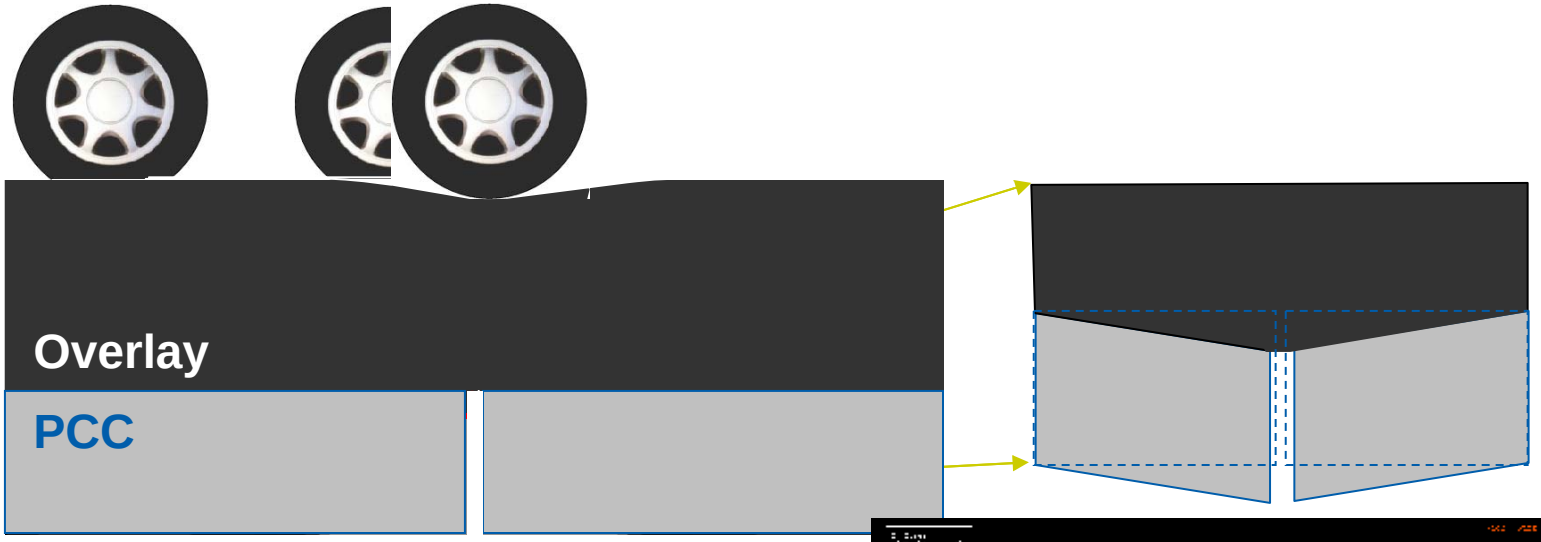
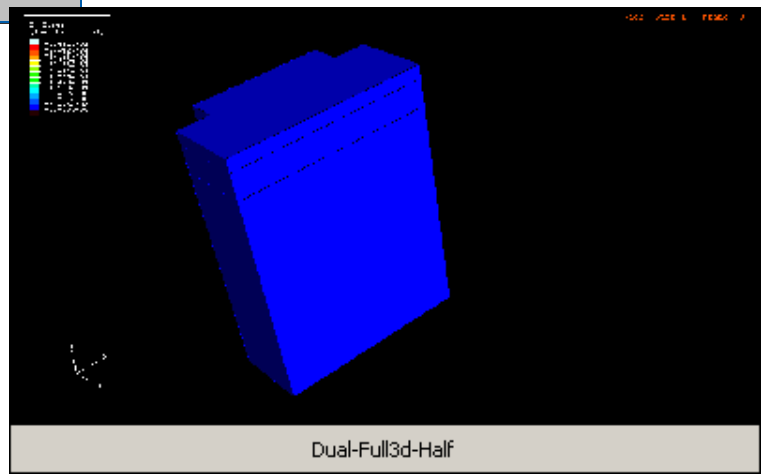
Main Causes: Traffic

- Shear failure (Mode II) Crack opening (Mode I) Mixed mode)

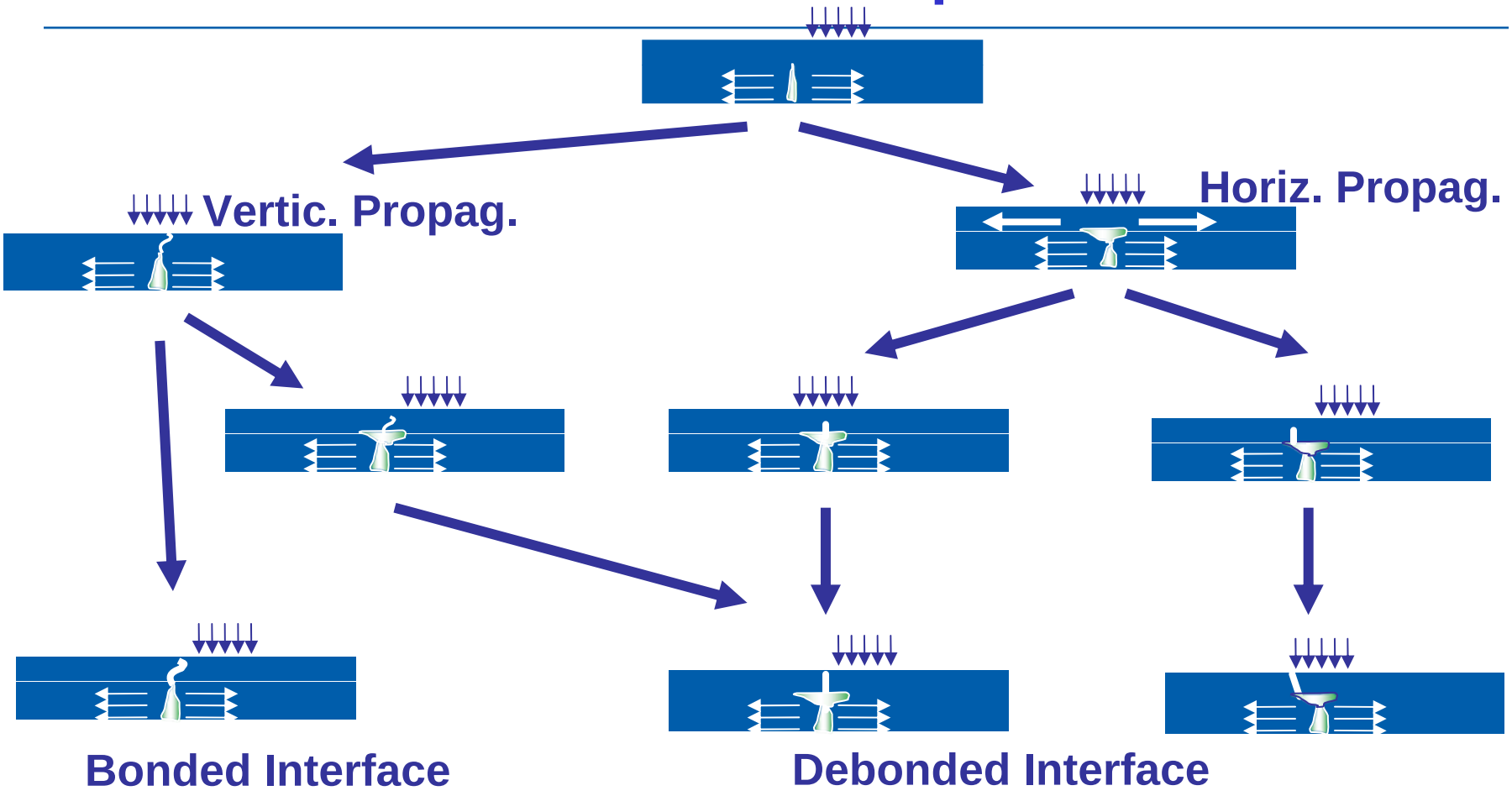


Bending stress

Shear stress



Crack Development



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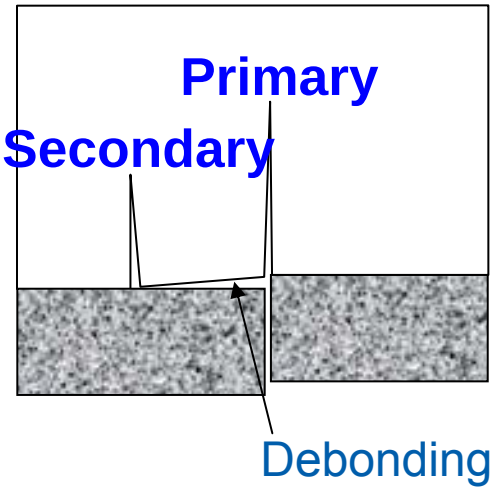
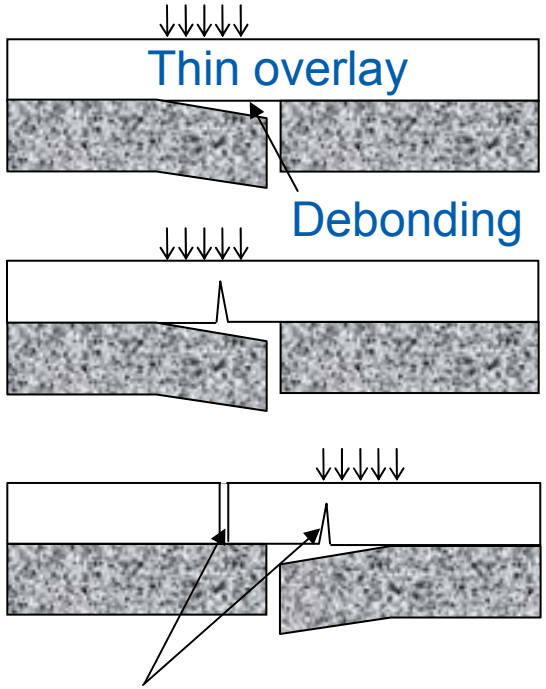
Single or Double RC (Thin Overlay)



Scarpas *et al*. 2000



Double RC, or "Band Cracking"

Zhou and Sun 2002

Single **Double**

In wheelpath **Over whole lane**

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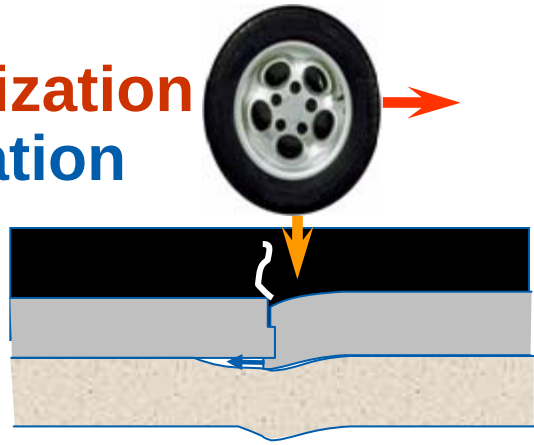
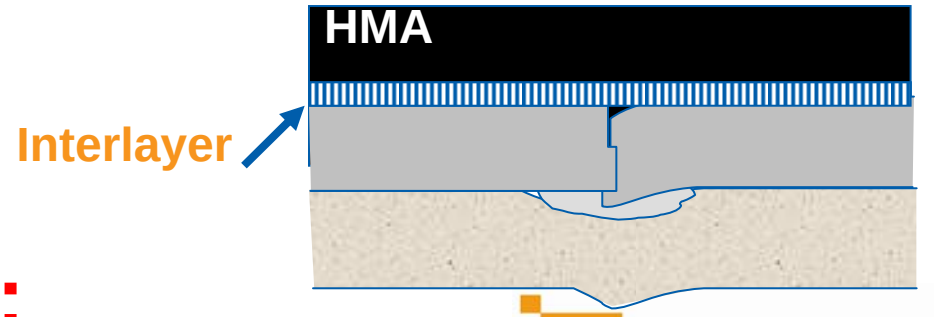
Crack Control Expectation

- Delay cracking occurrence
- Reduce number of cracks
- Control crack severity
- Provide other benefits:
  - Reduce overlay thickness
  - Enhance waterproofing capabilities

Control Measures

- **Typical Solution**
  - **Pre-Overlay Treatment:**
    - **Crack and seat, Break and seat, Rubblization**
    - **Slab stabilization/ load transfer restoration**
    - **Sawing and sealing joints**
  - **HMA Overlay**
  - **Overlay Systems**
    - **Improved mix**
    - **Joint filling/ stabilization**
    - **Leveling course**
    - **Interlayer systems:**





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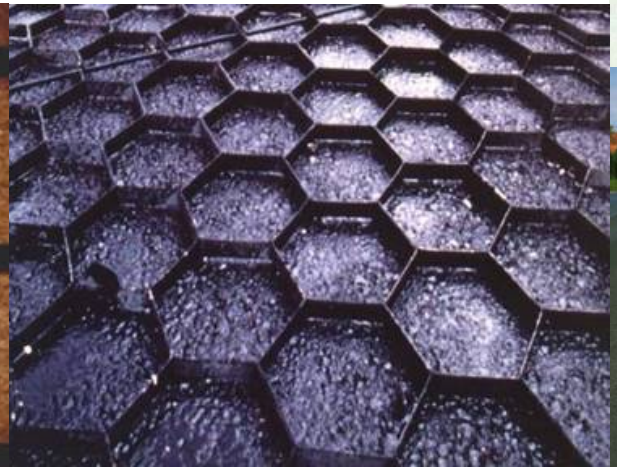
Interlayer Systems

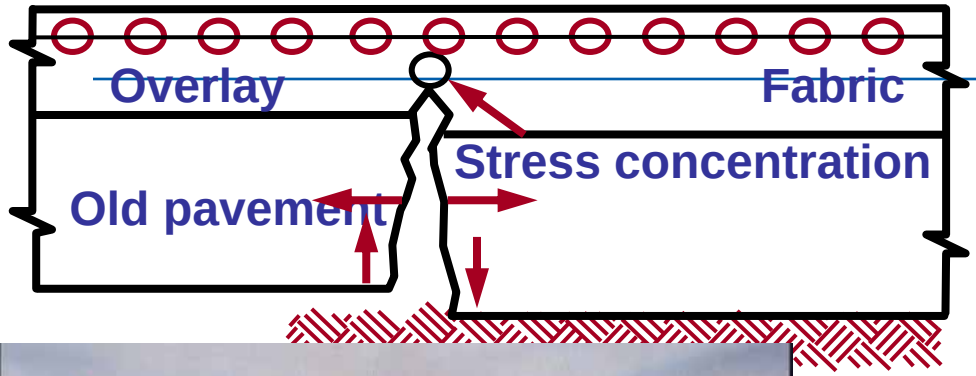
- Cost-effective technique (!)
- Reinforcement:
  - Stiff materials to compensate lack of HMA's tensile strength
- Strain tolerant (Stress relief):
  - Soft materials to dissipate strain energy by deforming itself
- Modified HMA:
  - "Tough" materials to resist cracking

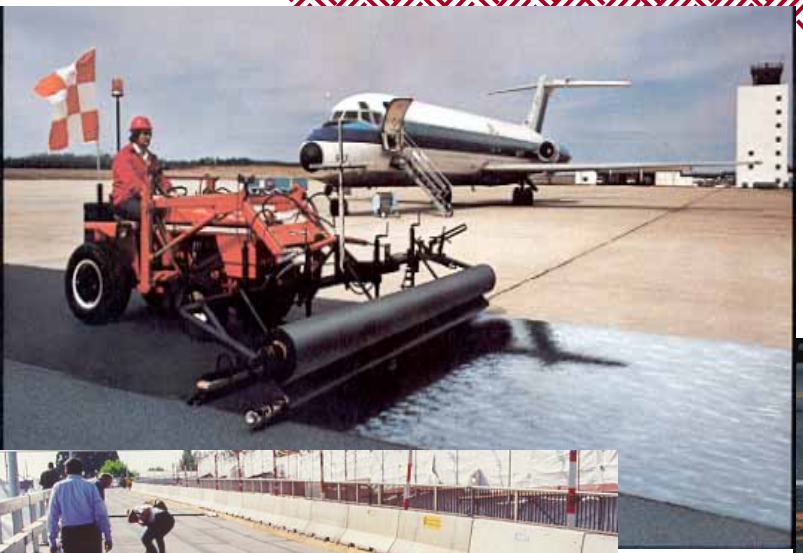
Interlayer Systems

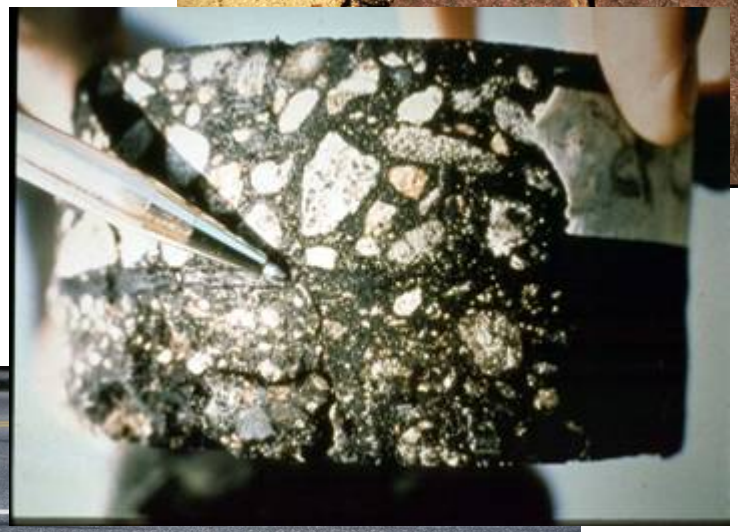
- Sand Asphalt
- SAMI
- Geotextile
- Geomembrane/ Geocomposite
- Grid/ Steel Netting
- 3D Grid



Fabric Interlayer







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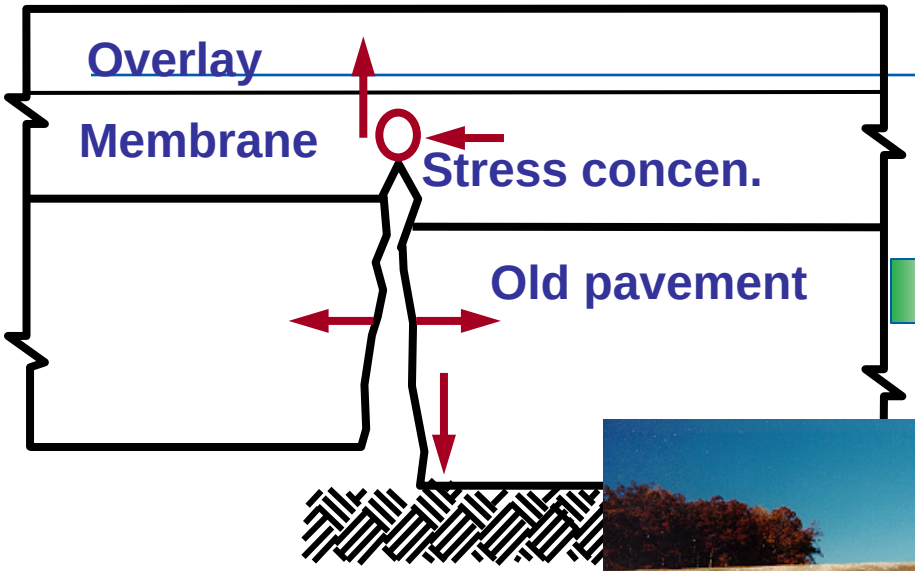
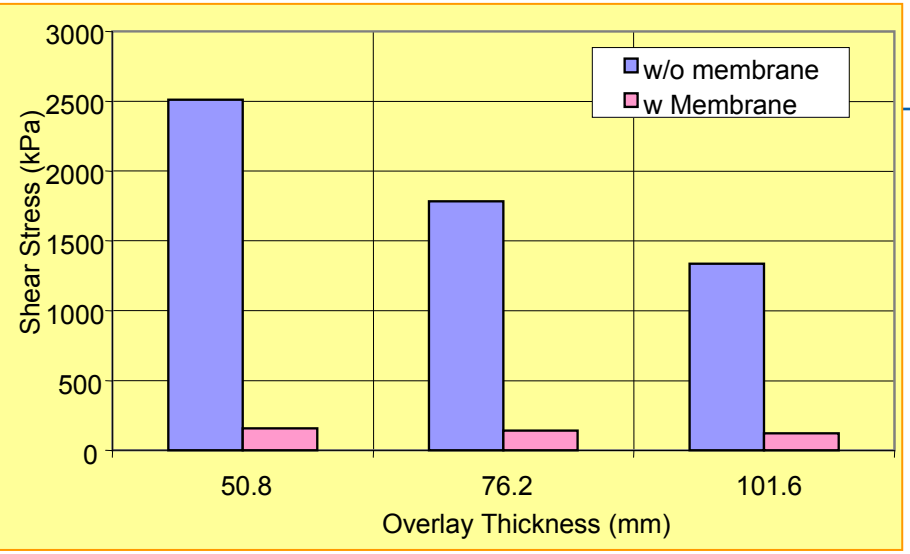
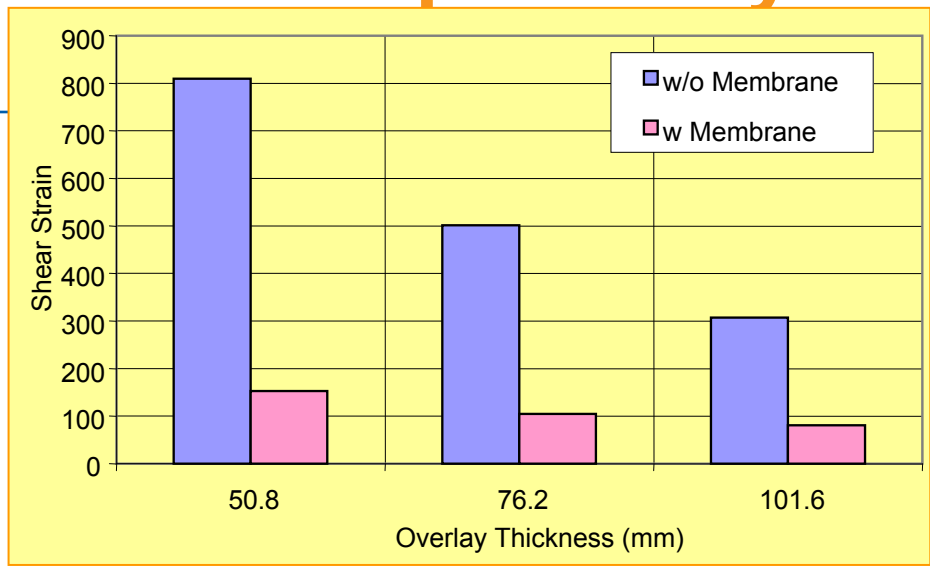
Stress-Absorbing Interlayer

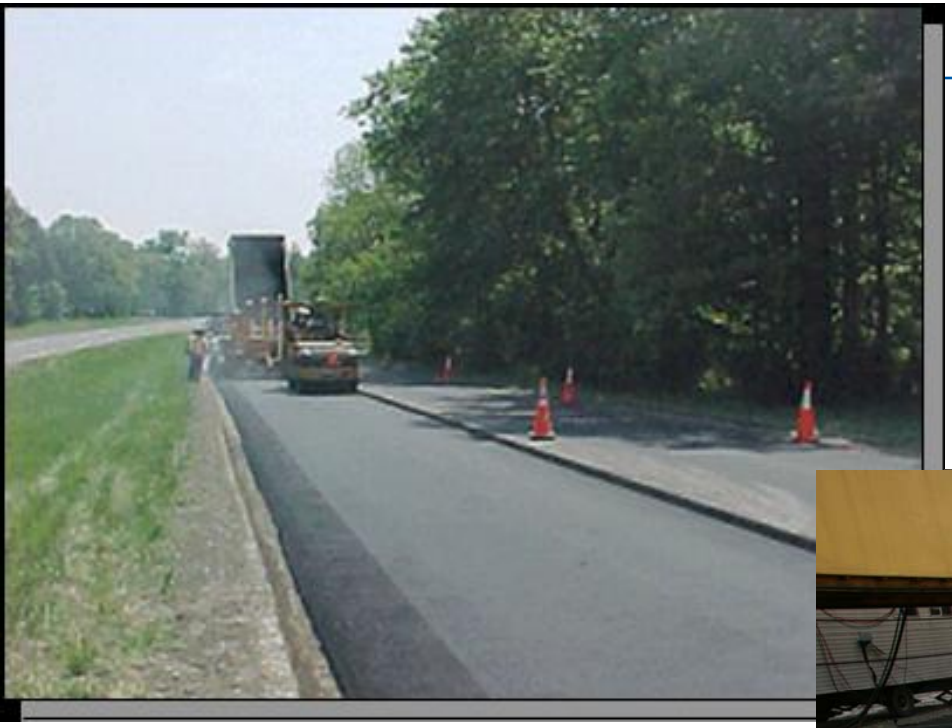


Shear Stress/ Strain at Crack Tip Vicinity





STRATA

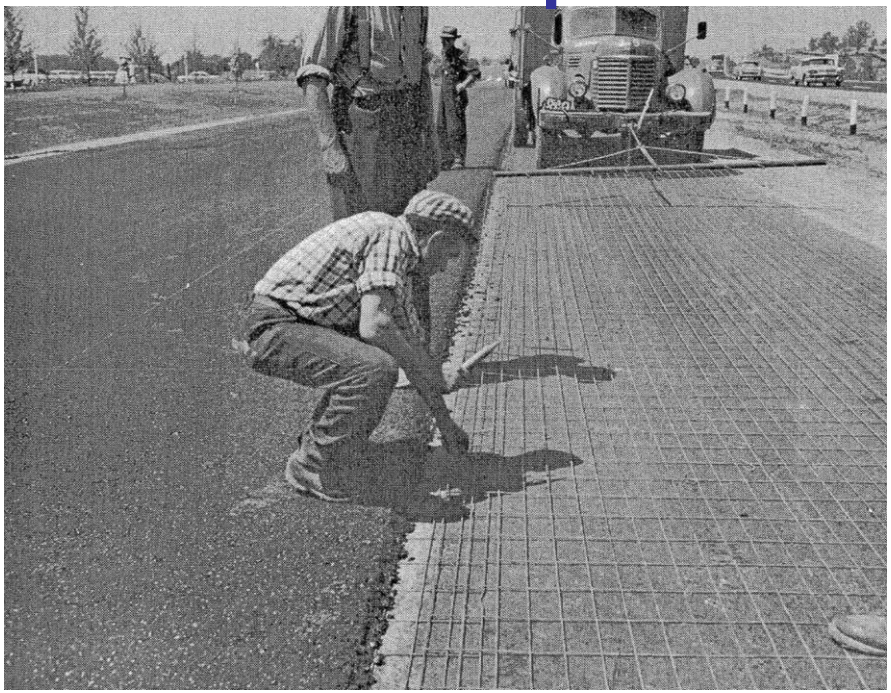


- 1” Thick Strain Tolerant Interlayer, 4.75mm mix, Standard HMA Construction

- UIUC ATLaS Project at ATREL – Full-Scale Validation

Steel Reinforcing Netting

Technology emerged in the early 1950s in the US and Canada, and was re-introduced in the early 1980s in Europe.



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Steel Reinforcement Netting

- The first application in the US was in 1999 by Al-Qadi et al.
- Several states installed trials sections and some are being monitored for long-term performance





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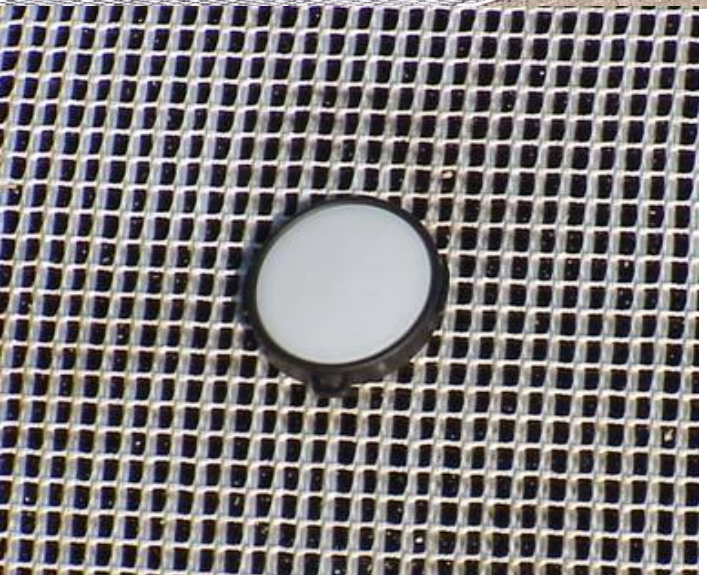
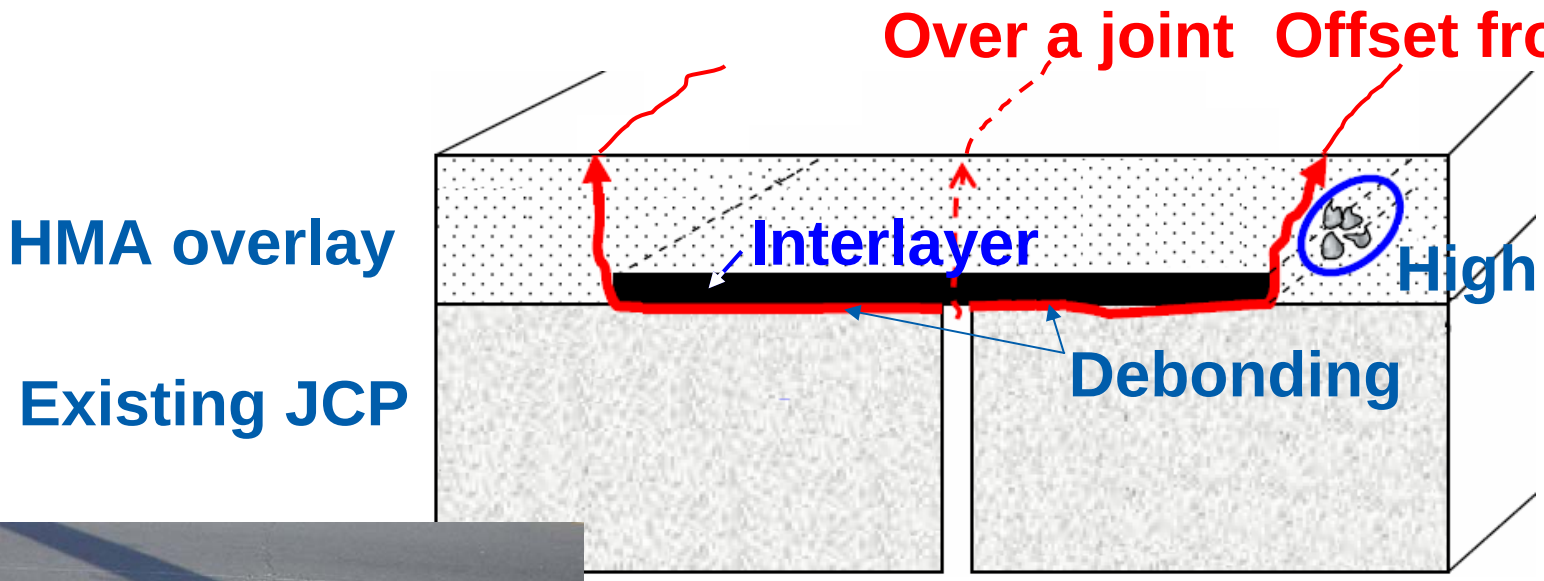
Reinforcing Composite



Interlayer Stress Absorbing Composite, ISAC

Optimum Thickness of Band-Aid



In Less than a Year

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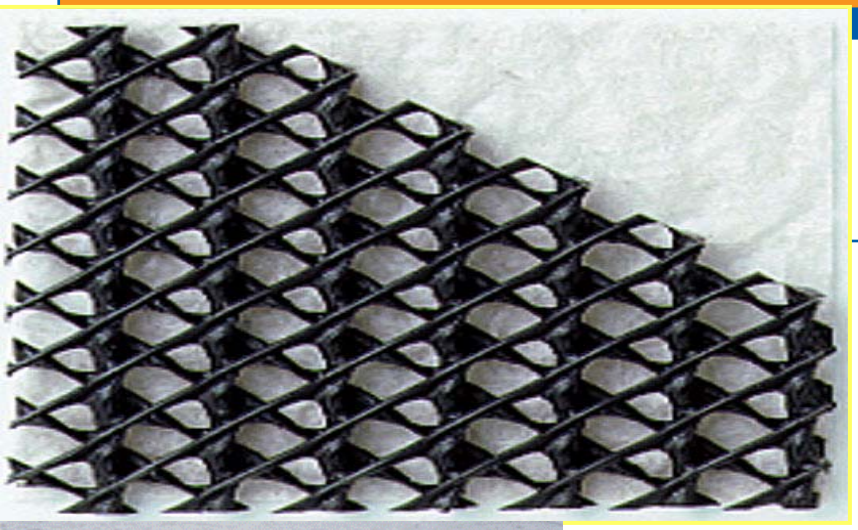
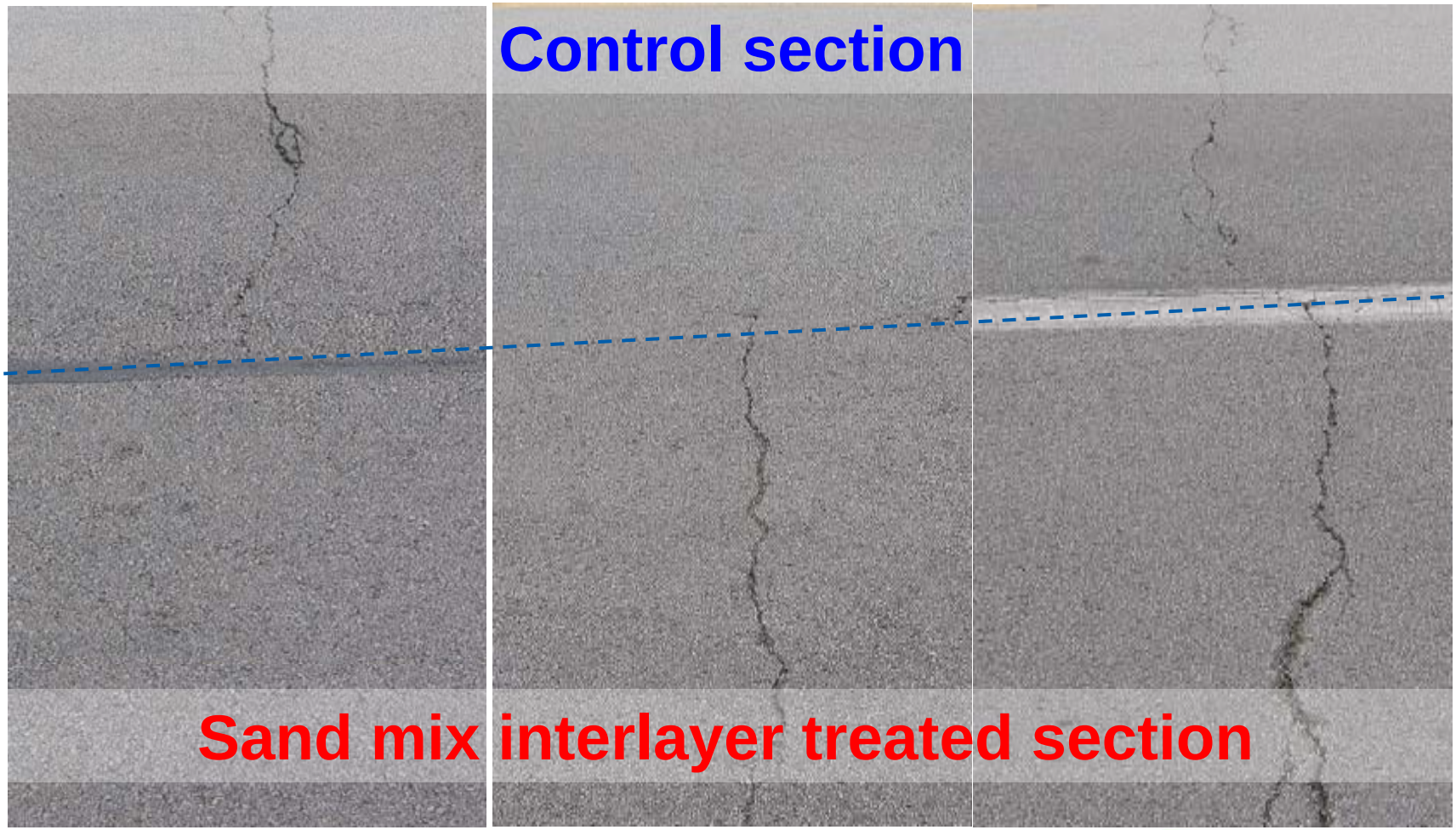
Drainage Layer



Lack of Performance



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Overlay Interlayer Functions

	Reinf.	Resist High Strain	Waterproof
Sand Asphalt		X	X
SAMI (*)		XX	XX
Impregnated Nonwoven		X	XX
Grid Composite	X/XX	X	X/XX*
Steel Netting	XX	X*	X*
3D Grids	XX		
Tri-planar		X	XX
Strain Tolerant Layer		XX	XX

 # Smoothness & Recycling!!

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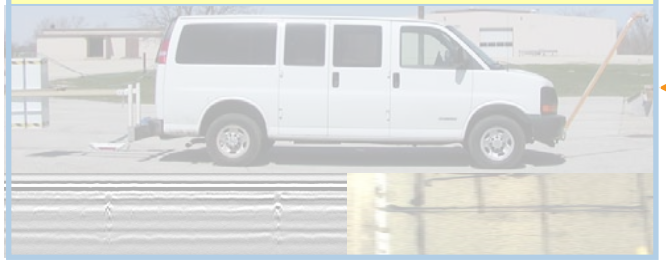
Interlayer System Assessment

Field Survey



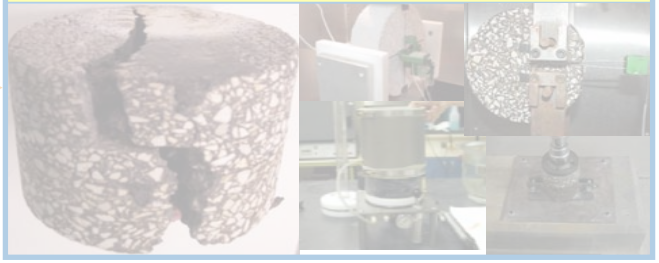
Visual and video:

➡ Pavement surface cracks

Ground penetrating radar:

➡ Joint/patch locations

Forensic Investigation



Field coring:

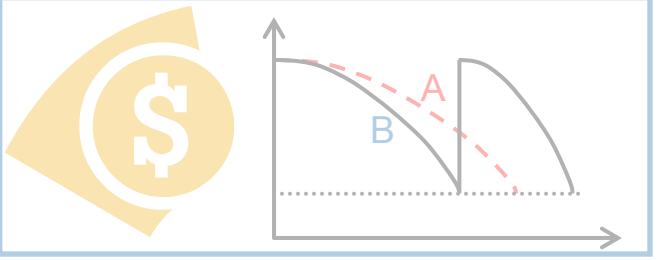
➡ Various reflective crack patterns

➡ Interface failure phenomenon

Laboratory tests:

➡ Fundamental material properties affect reflective cracking

Life-Cycle Cost Analysis



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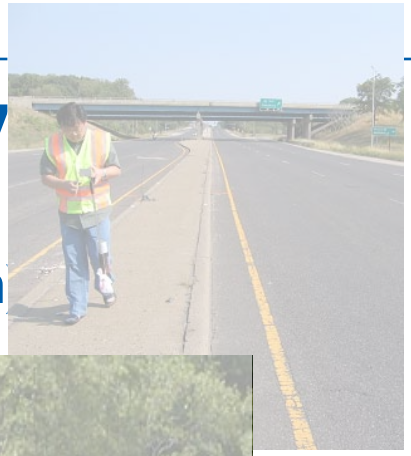
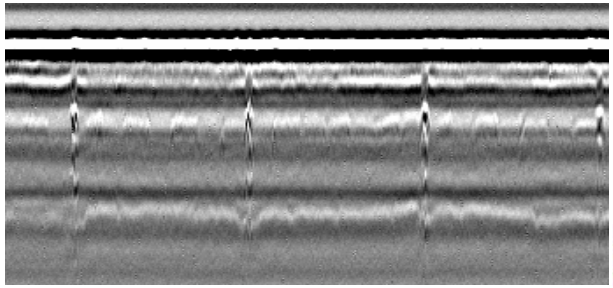
Field Survey Methods

- Surface Pavement Distress Survey
  - Visual (Walk-on) survey
    - Severity (starting, low, medium, and high)
    - Extent (0.0 - 1.0)
  - Video survey
    - Faster and safer operation
    - Link to other distress survey
- Nondestructive Testing
  - Ground penetrating Radar (GPR) survey
    - Overlay thickness
    - Joint/patch location





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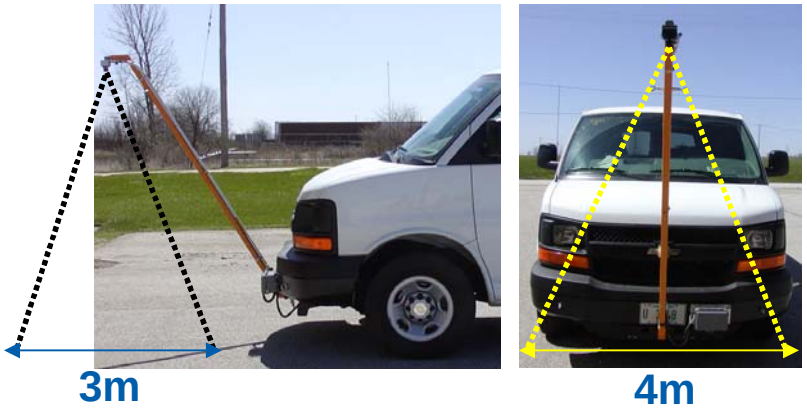
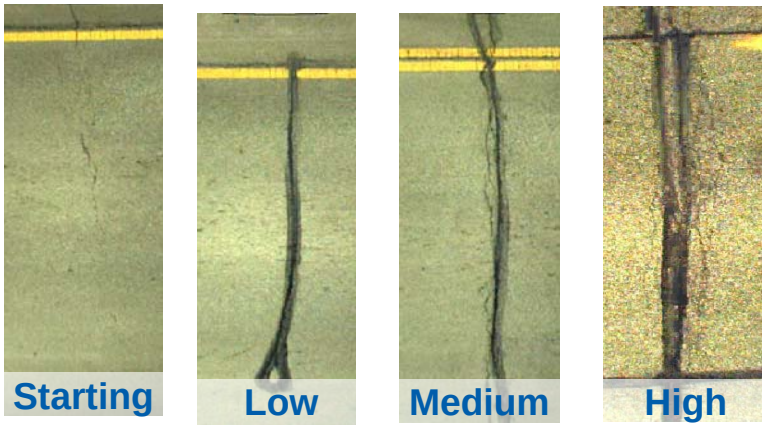
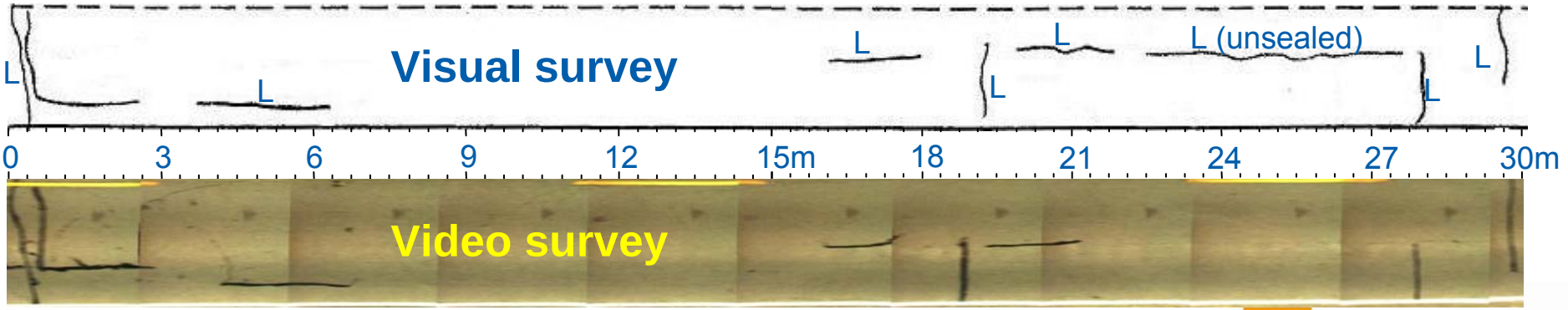
Video Crack Survey

- A high resolution digital video camera: 4m x 3m
- Highway speed up to 30MPH







IL130 northbound (STA. 211+00 to STA. 212+00)

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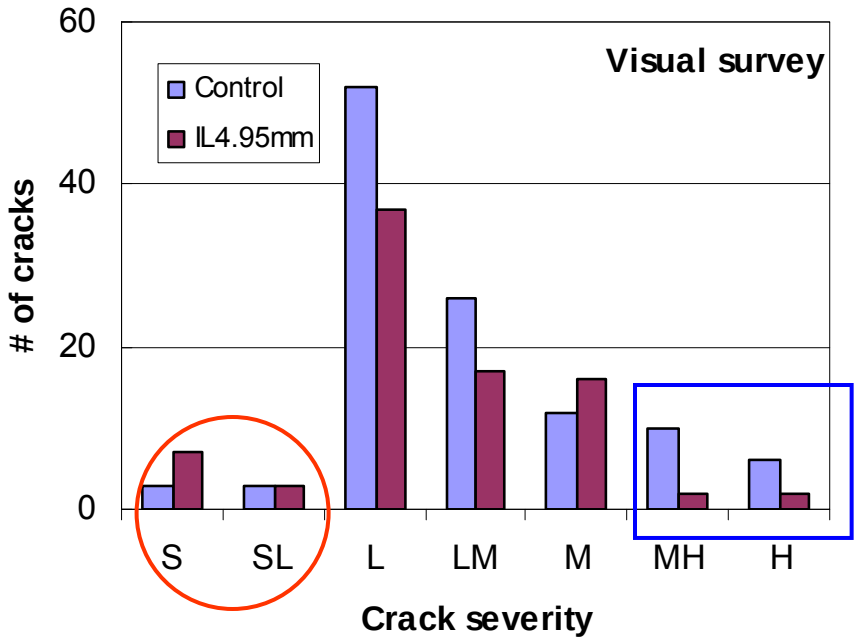
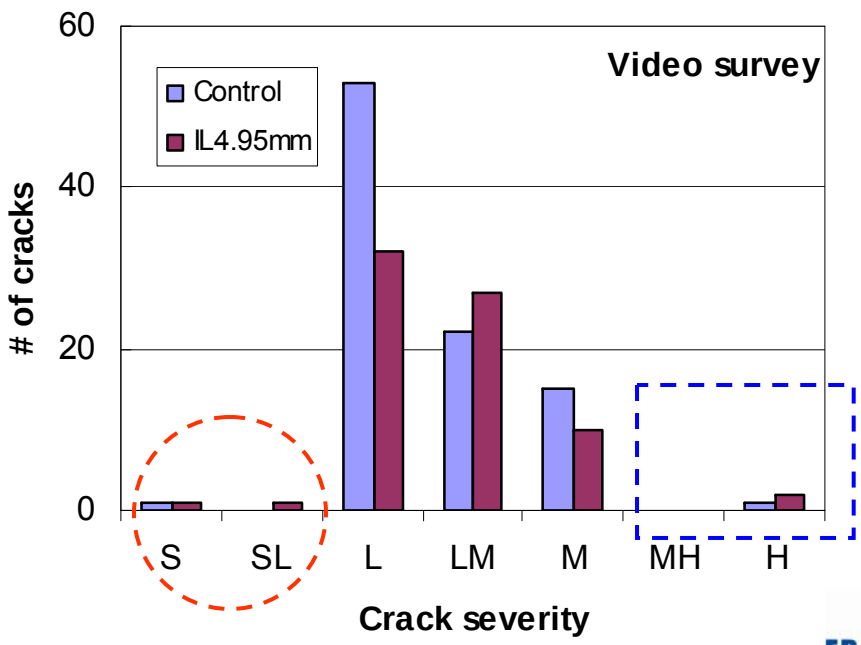
Video Crack Survey

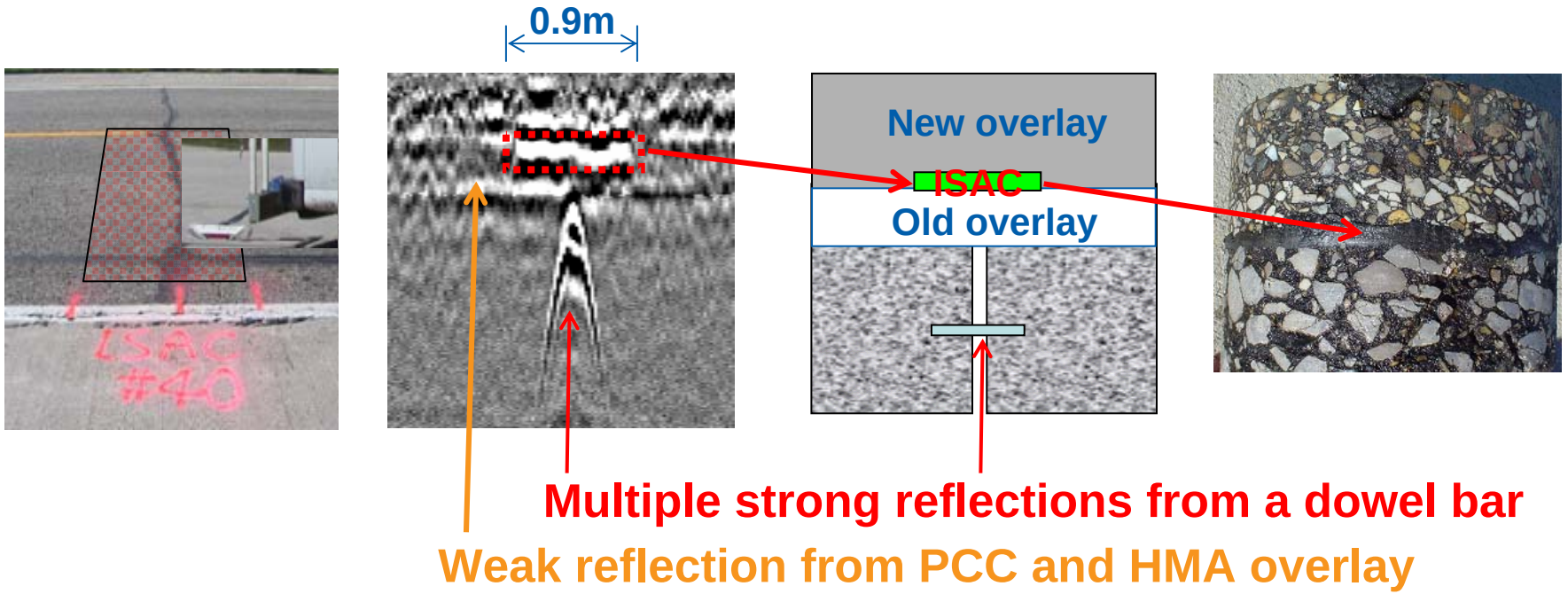
- **Crack detection**
  - 165 out of 195 (84.2%) transverse cracks
  - Shift in severity distribution





GPR Survey

- Using a ground-coupled antenna
- ISAC identification/ accurate width measurement (0.9m)



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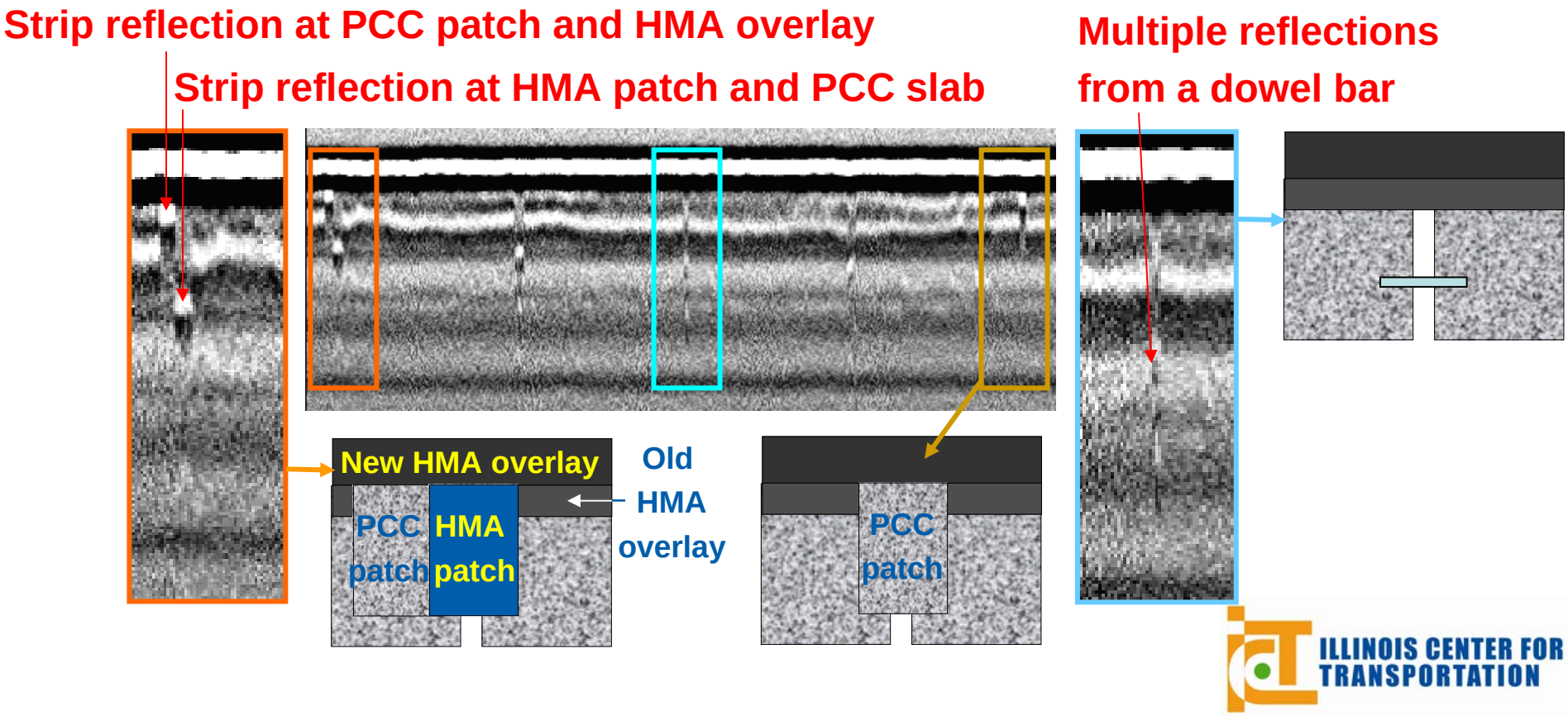
GPR Survey

- Using an air-couple antenna
- Detection of dowel bar at joints and patches



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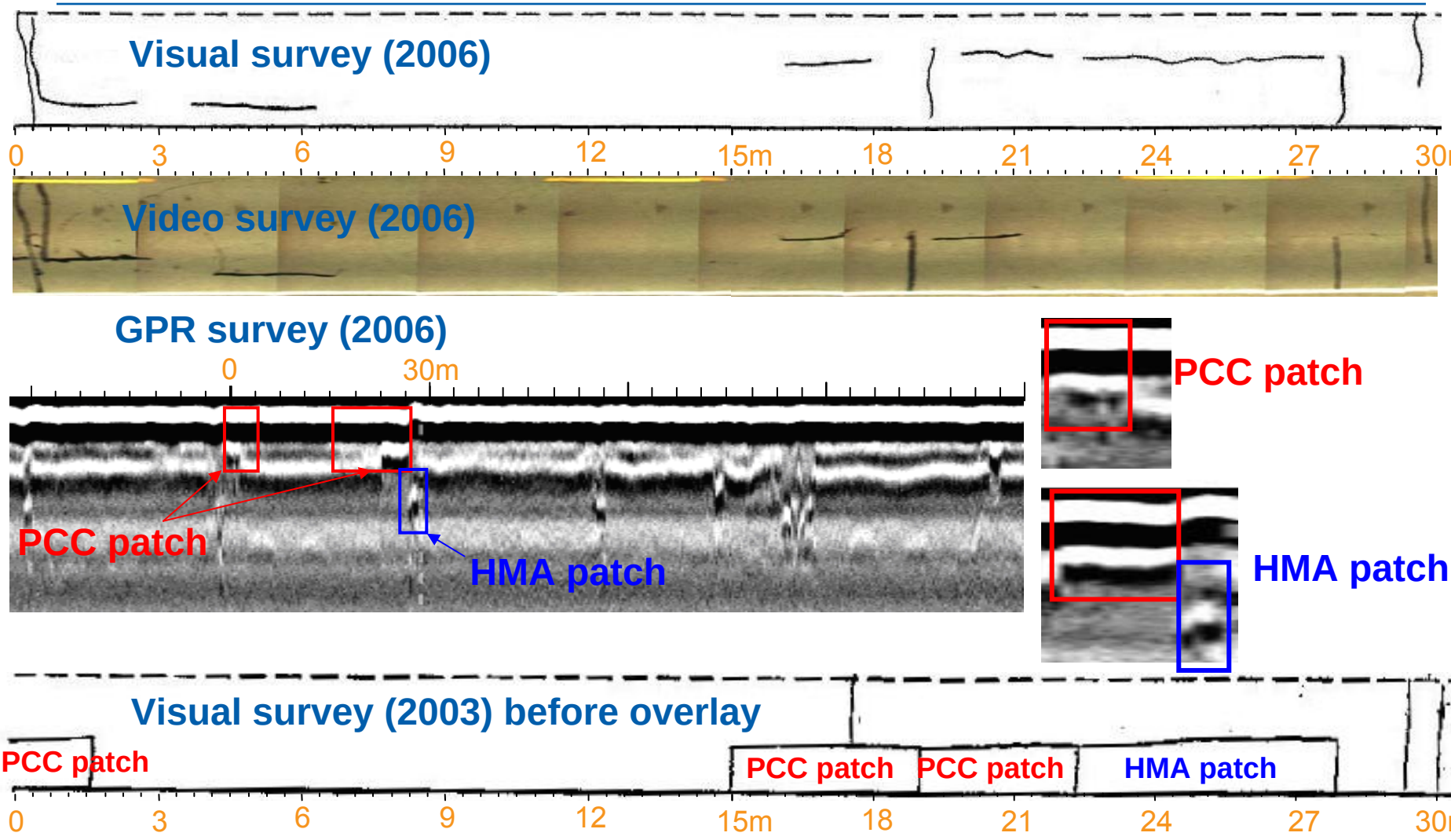
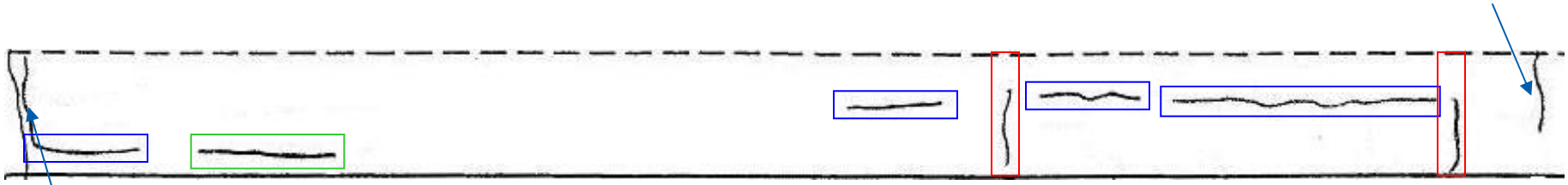
Reflective Cracking Identification



Reflective Cracking Identification

Transverse RC from a joint



Longitudinal RC from patches

Transverse RC from patches

Non Reflective Crack

Double transverse RC from a joint

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Reflective Crack Index

Reflective Cracking Appearance Ratio with joint-associated reflective cracking

$$R_{RCA} = \frac{N_{RC}}{N_J}$$

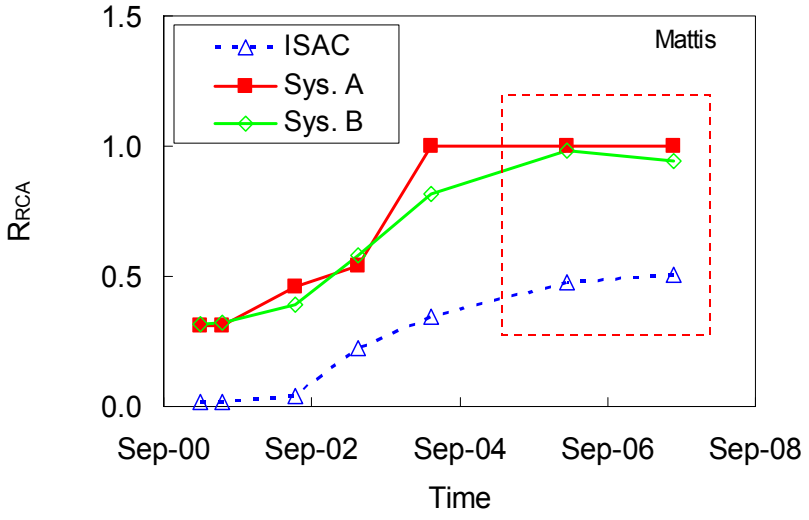
$$R_{RCAW} = \frac{\sum_{i=1}^{4}\left[W_i \times (N_{RC})_i\right]}{N_J}$$

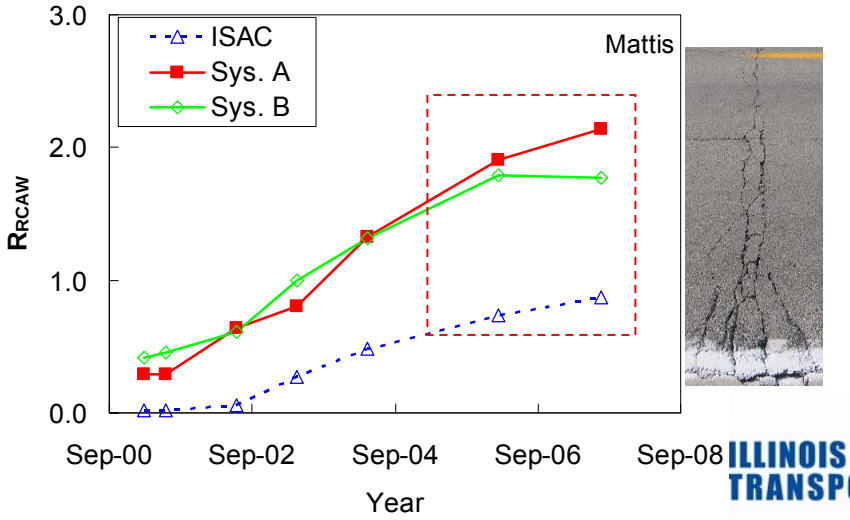
Including crack severity (Weight function, W_i)

Transverse Cracking Appearance Ratio with all transverse cracking

$$R_{TCA} = \frac{N_{TC}}{N_S}$$

$$R_{TCAW} = \frac{\sum_{i=1}^{4}\left[W_i \times (N_{TC})_i\right]}{N_S}$$





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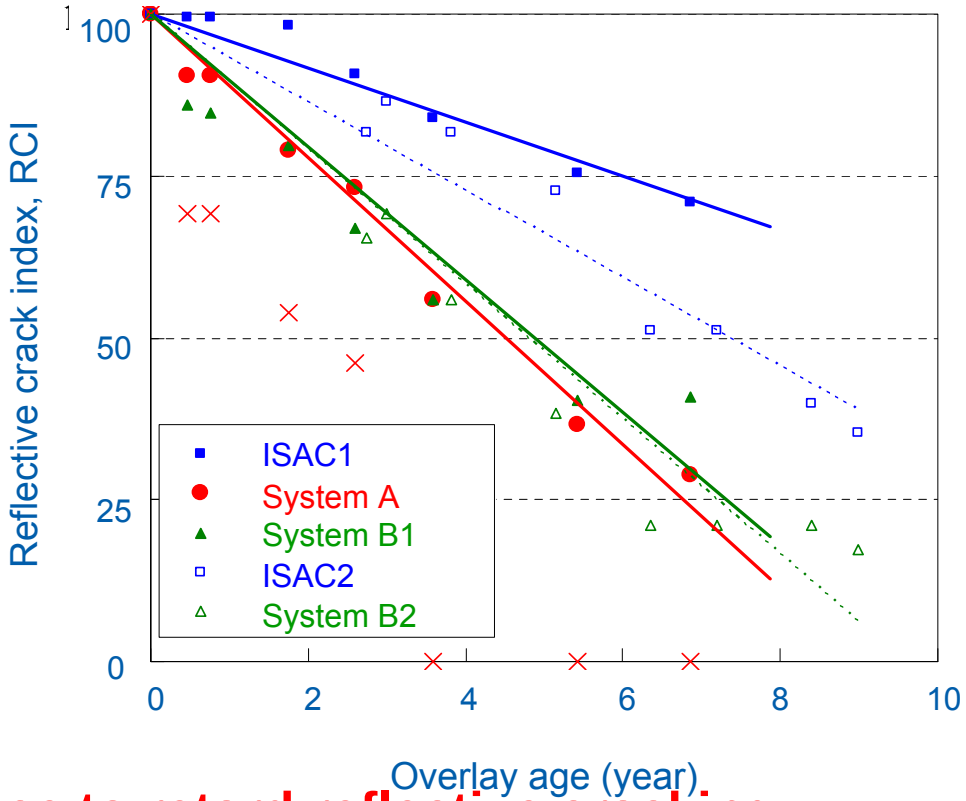
Reflective Crack Index

Reflective Cracking Index with R_{RCAW}: 100 (no RC) to 0 (all high-severity RCs)

$$RCI = 100\left[1 - \frac{R_{RCAW}}{3}\right]$$



➡ **Interlayer systems performance to retard reflective cracking**

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Forensic Investigation

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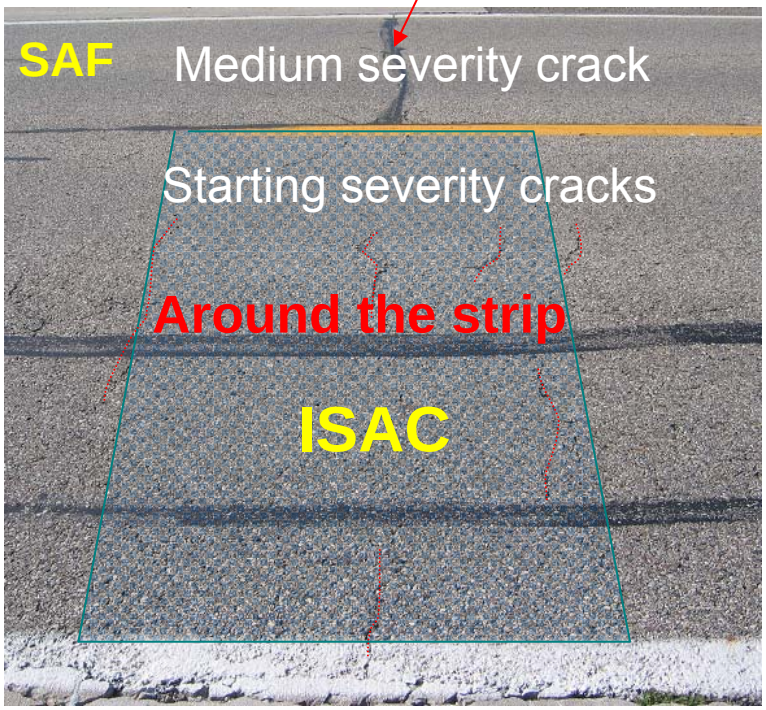
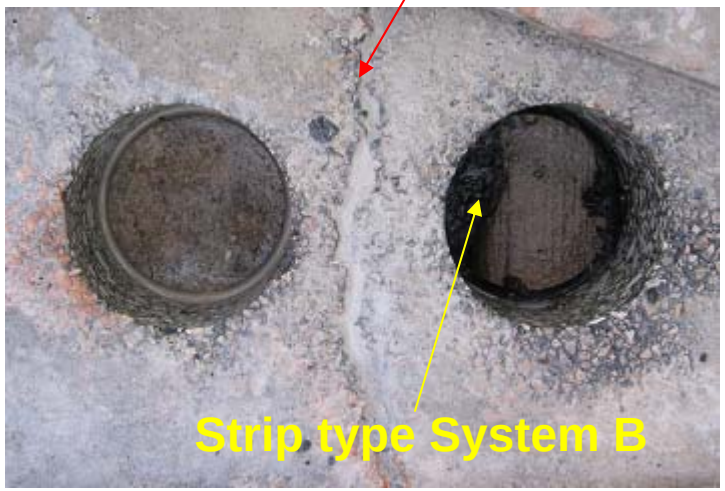
Typical Reflective Crack Path



US136 San Jose



Mattis, Champaign

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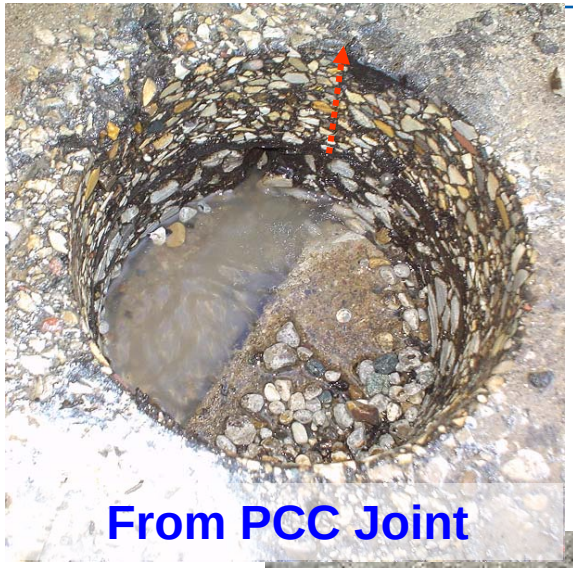
Various RC Paths/Mechanisms



From PCC Joint

Offset from a Joint

Interface of wearing and leveling binder

From HMA Patch

Interface of old and new overlay

Interface Failure Types

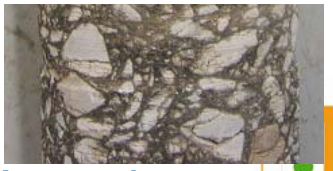
Good bonding

Interface failure

PCC and HMA overlay

PCC and interlayer

Due to lack of bond strength (tack coat) and/or moisture penetration



Interlayer and HMA overlay

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Life-Cycle Cost Analysis

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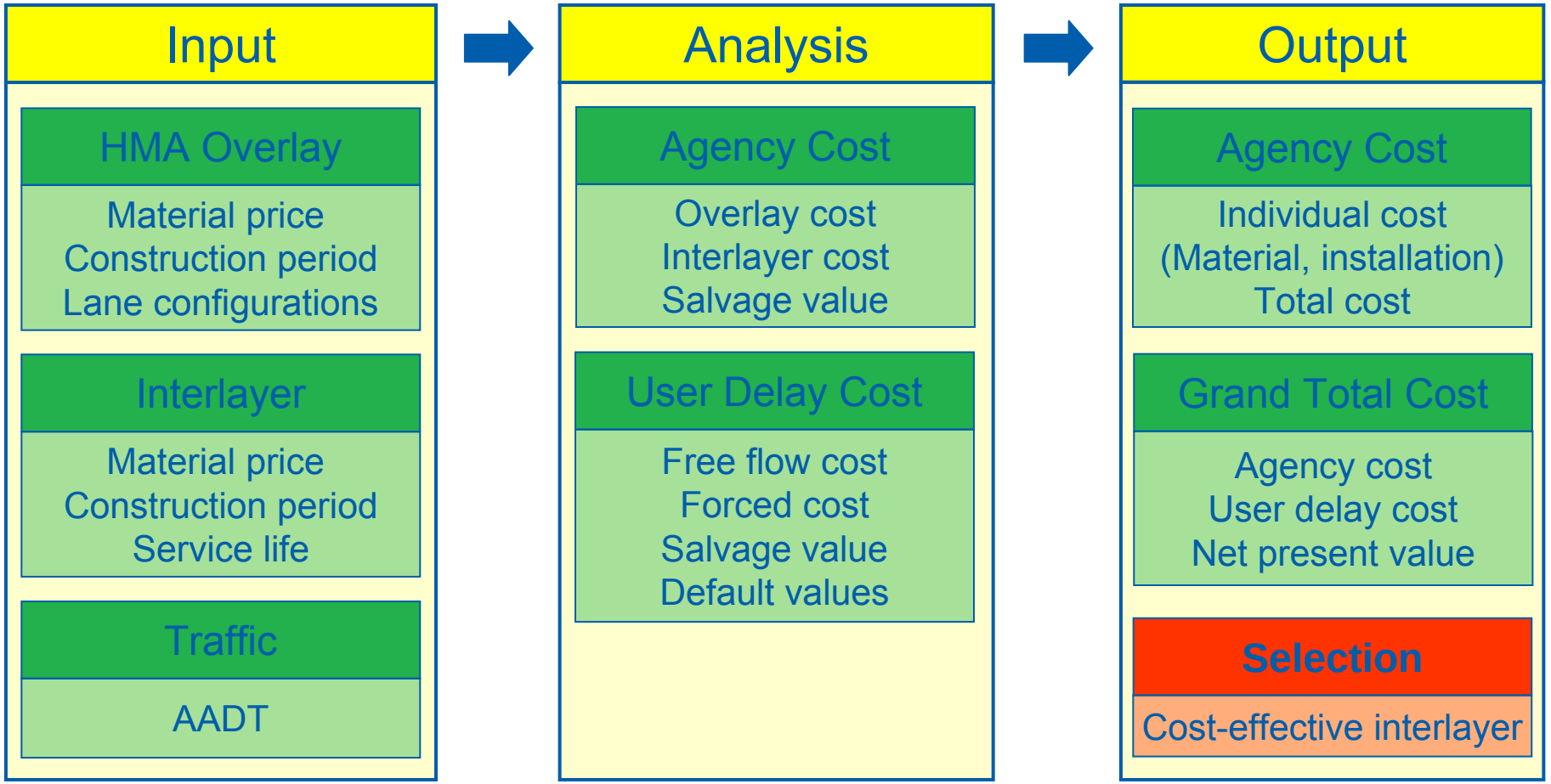
Overall Process



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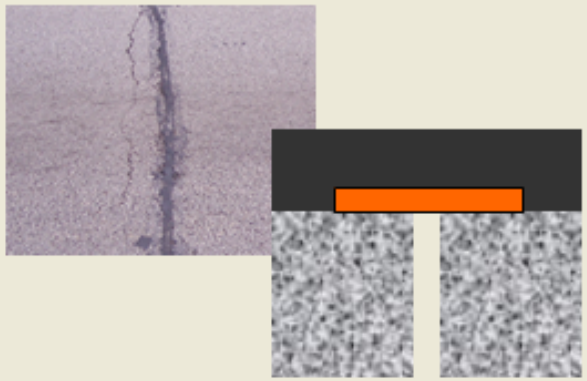
Cost-Effective Interlayer System Decision Program

CEISDP

(COST-EFFECTIVE INTERLAYER SYSTEM DECISION PROGRAM)

Version 0.8



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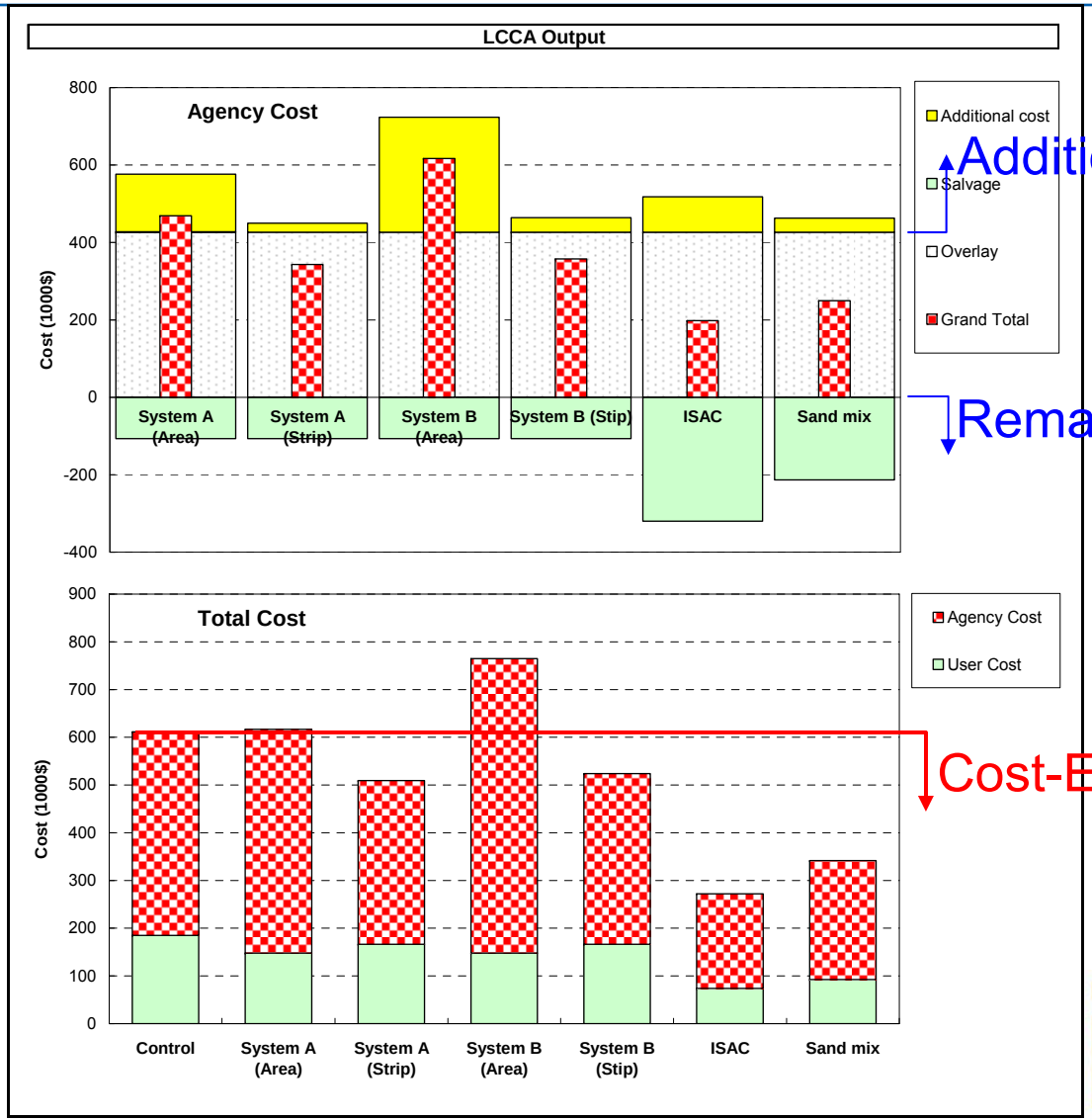
Example (Output)



Additional cost

Remaining capacity

Cost-Effective method

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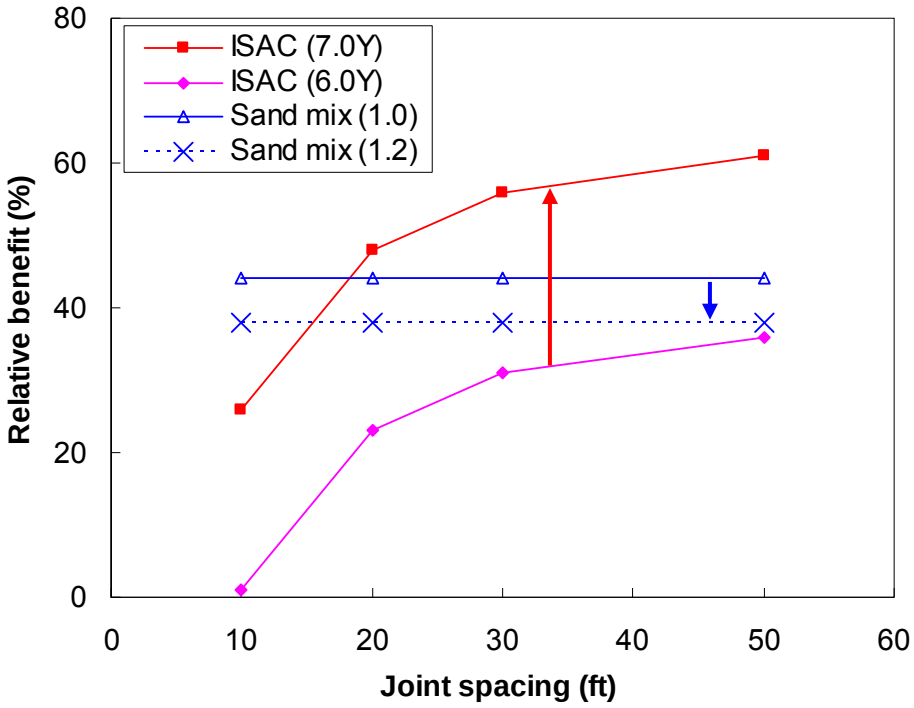
Major Variables

- Joint spacing
- Interlayer system performance
- Interlayer cost



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Considerations When Using Interlayer Systems to Abate Reflective Cracking

- Interlayer systems MAY NOT prevent crack movement
- Not all interlayer systems are the same! (reinforcement, strain tolerant, moisture barriers)
- Joints/cracks must be stable (Prepare Pavement!)
- Minimum overlay thickness needs to be identified
- Successful installation is a key for good performance:
  - No wrinkles
  - Pretensioning/ fixation
  - Interlayer system joints
  - Bonding issues
  - Overlay characteristics

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Summary

- Joint-associated reflective cracking can be successfully identified using ground-penetrating radar (GPR) and crack surveys.
- Reflective crack indices are proposed to evaluate crack extent and severity.
- Criteria to select an interlayer system:
  - Performance ◄ Interlayer system assessment
  - Cost ◄ Life-cycle cost analysis (LCCA)
- *Proper installation is very important!*

Thank You?

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Sixth RILEM International Conference on CRACKING IN PAVEMENTS

Chicago, Illinois

June 16-18, 2008

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