SEMINARIO INTERNACIONAL DE PAVIMENTOS DE HORMIGÓN
24 y 25 DE OCTUBRE 2012 • CIUDAD DE CÓRDOBA - ARGENTINA

Advances in Materials, Design and Construction Technologies for Concrete Paving Systems

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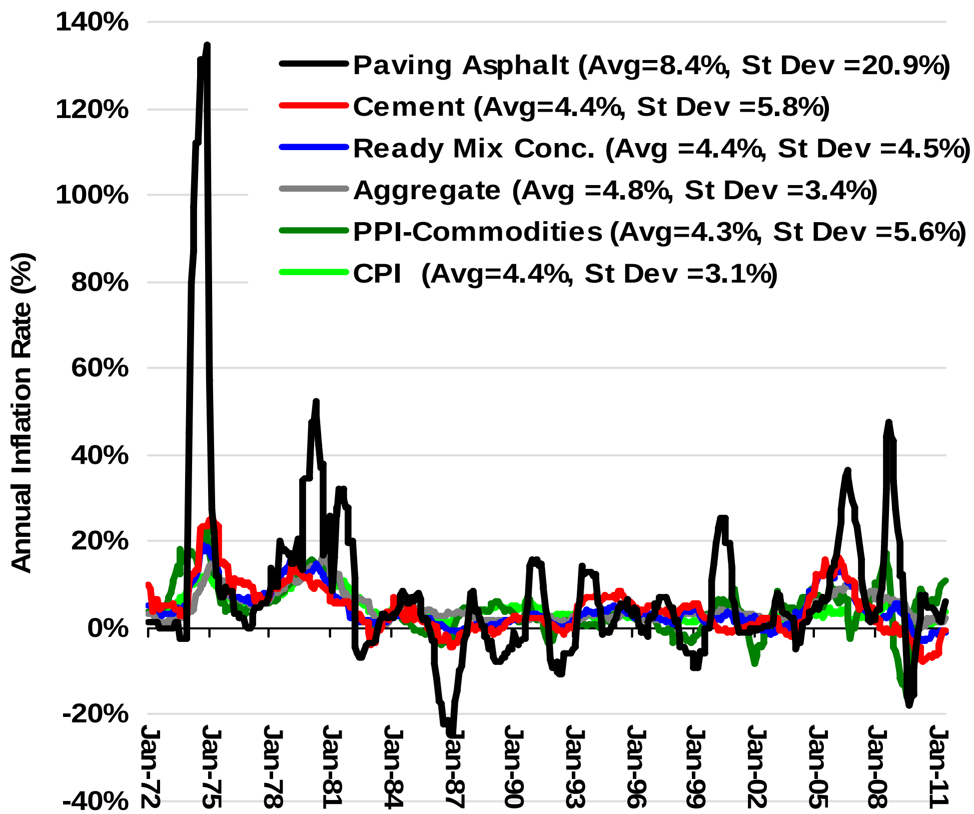
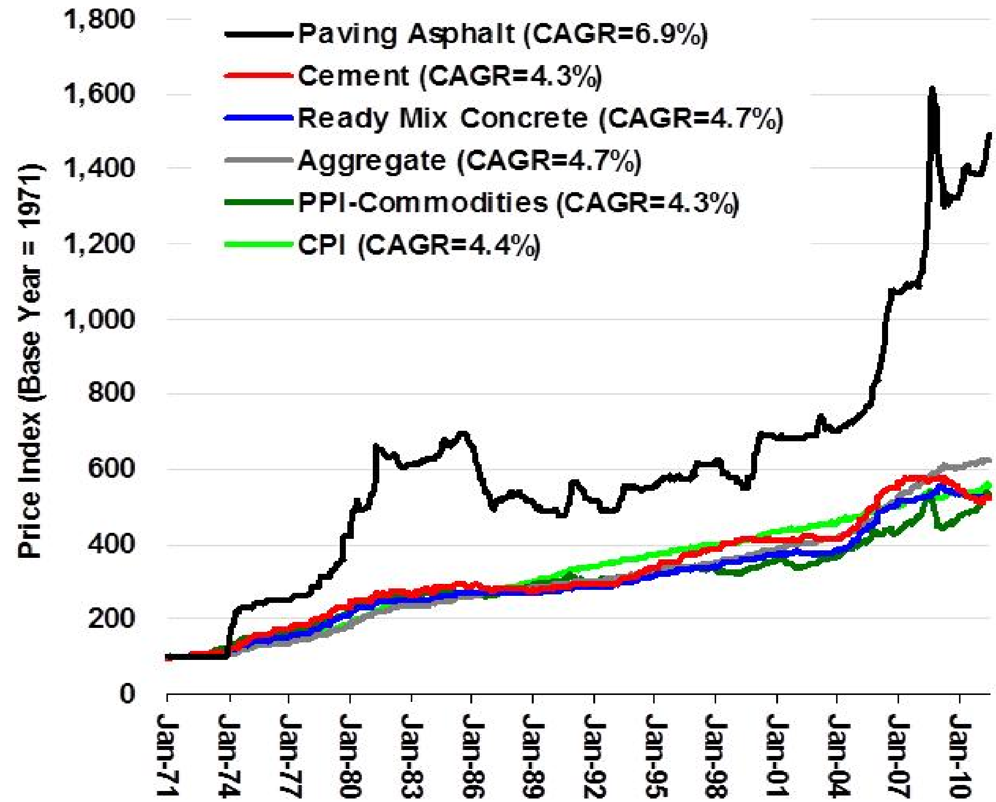
Increased Demand for Concrete Roads and Streets – Driven by Sustainability's "Triple Bottom Line "

- Economic
- Environmental
- Societal

U.S. Annual Price Increase/Inflation *Rates*



U.S. Price and Inflation *Indexes* since 1971



Average Annual Cost Increase for Paving Asphalt is 4 – 5 percent higher than for Cement, Concrete and the Consumer Price Index!

It is also much more volatile.

Environmental factors:

Primarily “Operational-Phase” Impacts:

- **Vehicle fuel consumption rates**
  - Pavement rigidity
  - Pavement smoothness
- **Pavement surface reflectivity (albedo)**
  - Urban heat island mitigation
  - Lighting need
  - Global cooling potential

Also Conservation of Materials

U.S. Definition of Long-Life Concrete Pavements

- Service life of original PCC surface = 40+ years
- No premature failures or materials-related distress
- Reduced potential for cracking, faulting, spalling, etc.
- Maintain desirable ride and surface texture characteristics with minimal M&R

Design and Build it Right

&

Stay Out As Long As Possible

LLCP Design Concept

1) Structural design for 40+ years of loads

2) Improve materials and construction practices so that it will last that long (durability).

General LLCP Design Concepts

- Match performance potential for design components (strengthen “weak links”)

- “a la carte” approach may not produce LLCP

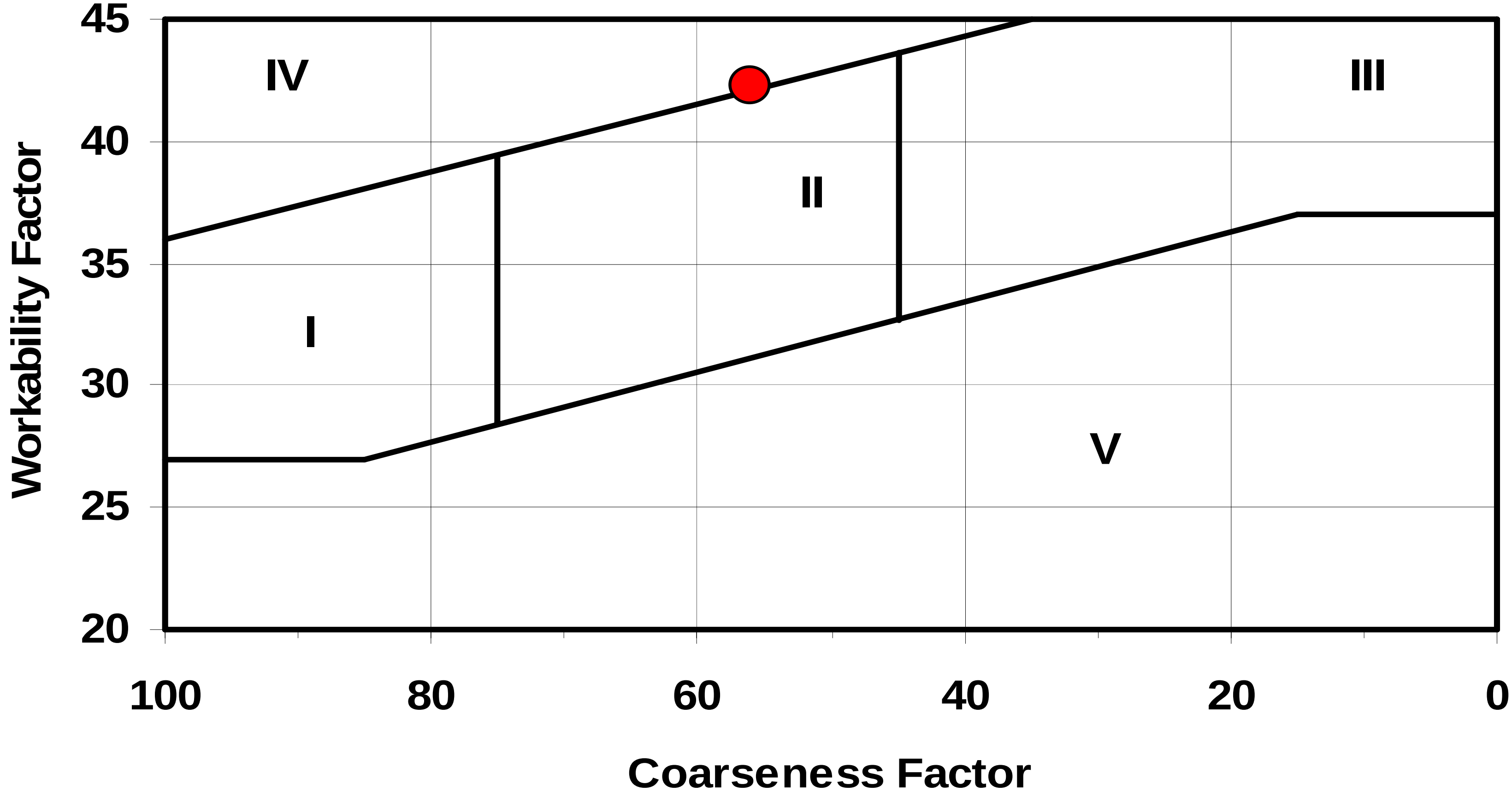
Advances in Concrete Pavement Materials

Concrete Mixture Improvements: Aggregate

- Require more durable aggregate
  - Screen for freeze-thaw, ASR problems
  - Limit limestone content of gravels to 20%, with incentives to reduce to 10%
  - Incentives for use of Class A aggregate (quarried igneous, metamorphic, e.g., granite, basalt)
- Require well-graded aggregate
  - Reduced paste content (more economical)
  - Improved workability without using excessive amounts of water reducer

Source: Portland Cement Association

Shilstone Coarseness Chart



(% passing 2.36-mm)

$$\frac{(\%\ \text{retained on 2.36-mm})}{(\%\ \text{retained on 9.5-mm})}$$

SEMINARIO INTERNACIONAL
DE PAVIMENTOS DE HORMIGÓN


1
2
3
4
5
Source: Doug Schwartz, MnDOT

ACPA

Description

By inputting sieve size analysis (gradation) information for up to three coarse aggregates and two fine aggregates, and the relative percent of each aggregate to be used in the mixture, this web applet allows you to view plots of the percent passing, percent retained, workability chart, ASTM C33 curve, and 0.45 power curve for the combined aggregate gradation.

Terms of Use

The user accepts ALL responsibility for decisions made as a result of the use of this design tool. American Concrete Pavement Association, its Officers, Board of Directors and Staff are absolved of any responsibility for any decisions made as a result of your use. Use of this design tool implies acceptance of the terms of use.

go to APP HOME

CONTACT

Percent Blend

Stone 1	Stone 2	Stone 3	Sand 1	Sand 2	Combined
60 %	0 %	0 %	40 %	0 %	100 %

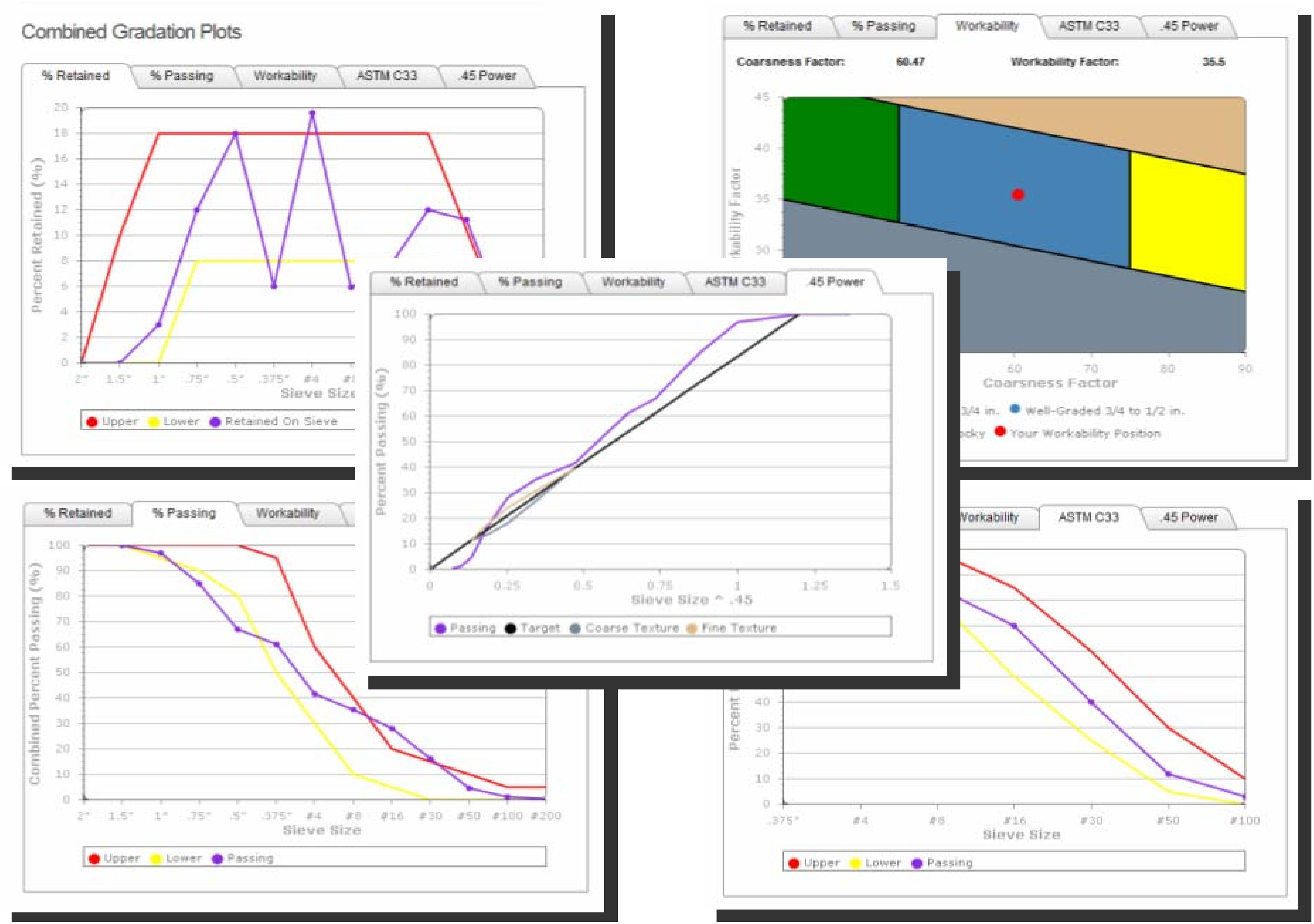
*Combined must total 100% before a calculation can be run

Percent Passing (Gradation)

Metric

Sieve	Stone 1	Stone 2	Stone 3	Sand 1	Sand 2	Combined
2 in.	100 %	0 %	0 %	100 %	0 %	100 %
1.5 in.	100 %	0 %	0 %	100 %	0 %	100 %
1 in.	95 %	0 %	0 %	100 %	0 %	97 %
.75 in.	75 %	0 %	0 %	100 %	0 %	85 %
.5 in	45 %	0 %	0 %	100 %	0 %	67 %
.375 in.	35 %	0 %	0 %	100 %	0 %	61 %
#4	5 %	0 %	0 %	96 %	0 %	41.4 %
#8	2.5 %	0 %	0 %	85 %	0 %	35.5 %
#16	0 %	0 %	0 %	70 %	0 %	28 %
#30	0 %	0 %	0 %	40 %	0 %	16 %
#50	0 %	0 %	0 %	12 %	0 %	4.8 %
#100	0 %	0 %	0 %	3 %	0 %	1.2 %
#200	0 %	0 %	0 %	1 %	0 %	0.4 %

apps.acpa.org

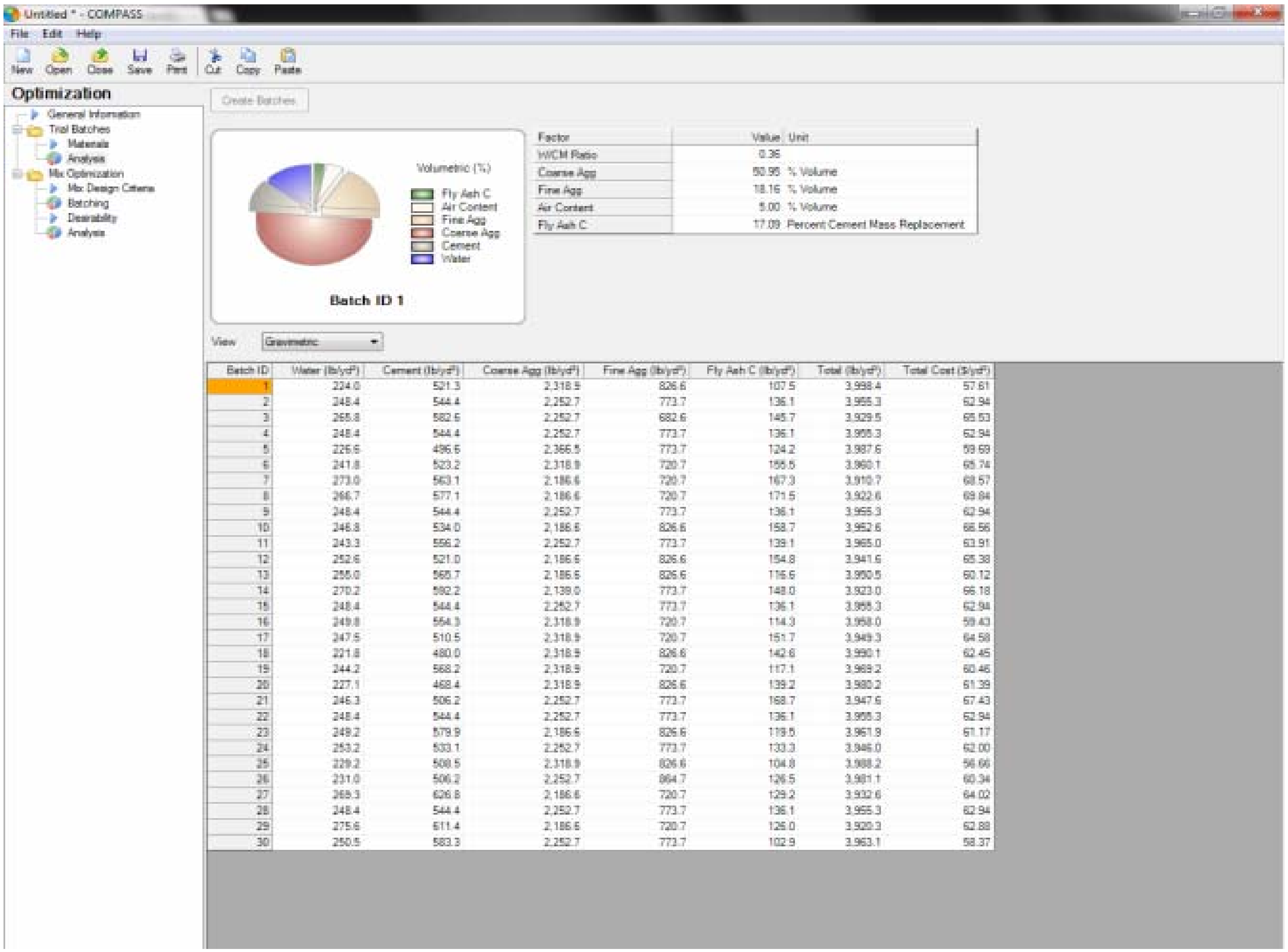


Combined Gradation Plots
% Retained
% Passing
Workability
ASTM C33
.45 Power
Percent Retained (%)
Sieve Size
Upper
Lower
Retained On Sieve
Coarseness Factor: 60.47
Workability Factor: 35.5
Coarseness Factor
Well-Graded 3/4 to 1/2 in.
Your Workability Position
Percent Passing (%)
Sieve Size ^ .45
Passing
Target
Coarse Texture
Fine Texture
Combined Percent Passing (%)
Sieve Size
Upper
Lower
Passing

Concrete Mixture Improvements: Durability and Quality Assurance

- Reduced Cementitious Content
  - 300 - 360kg/m^3
  - 15 – 40% SCMs (fly ash, slag cement, etc.)
- W/(C + P) < 0.42 (or less)
  - Incentives to lower values
  - Field QA using microwave oven
- Increased air content
  - Typical Standard: 6.5% +/- 1.5%
  - Typical LLCP: 8.0% +/- 1.5%.

COMPASS: A *Free* Mixture Optimization Tool



Factor	Value	Unit
W/CM Ratio	0.36	
Coarse Agg	50.95	% Volume
Fine Agg	18.16	% Volume
Air Content	5.00	% Volume
Fly Ash C	17.09	Percent Cement Mass Replacement

Batch ID	Water (lb/yd³)	Cement (lb/yd³)	Coarse Agg (lb/yd³)	Fine Agg (lb/yd³)	Fly Ash C (lb/yd³)	Total (lb/yd³)	Total Cost ($/yd³)
1	224.0	521.3	2,318.9	826.6	107.5	3,998.4	57.61
2	248.4	544.4	2,252.7	773.7	136.1	3,955.3	62.94
3	265.8	582.6	2,252.7	682.6	145.7	3,929.5	65.53
4	248.4	544.4	2,252.7	773.7	136.1	3,955.3	62.94
5	226.6	496.6	2,366.5	773.7	124.2	3,987.6	59.69
6	241.8	523.2	2,318.9	720.7	155.5	3,960.1	65.74
7	273.0	563.1	2,186.6	720.7	167.3	3,910.7	68.57
8	266.7	577.1	2,186.6	720.7	171.5	3,922.6	69.84
9	248.4	544.4	2,252.7	773.7	136.1	3,955.3	62.94
10	246.8	534.0	2,186.6	826.6	158.7	3,952.6	66.56
11	243.3	556.2	2,252.7	773.7	139.1	3,965.0	63.91
12	252.6	521.0	2,186.6	826.6	154.8	3,941.6	65.38
13	255.0	565.7	2,186.6	826.6	116.6	3,950.5	60.12
14	270.2	592.2	2,139.0	773.7	148.0	3,923.0	66.18
15	248.4	544.4	2,252.7	773.7	136.1	3,955.3	62.94
16	249.8	564.3	2,318.9	720.7	114.3	3,958.0	59.43
17	247.5	510.5	2,318.9	720.7	151.7	3,949.3	64.58
18	221.8	480.0	2,318.9	826.6	142.6	3,990.1	62.45
19	244.2	568.2	2,318.9	720.7	117.1	3,969.2	60.46
20	227.1	468.4	2,318.9	826.6	139.2	3,980.2	61.39
21	246.3	506.2	2,252.7	773.7	168.7	3,947.6	67.43
22	248.4	544.4	2,252.7	773.7	136.1	3,955.3	62.94
23	249.2	579.9	2,186.6	826.6	119.5	3,961.9	61.17
24	253.2	533.1	2,252.7	773.7	133.3	3,946.0	62.00
25	229.2	508.5	2,318.9	826.6	104.8	3,988.2	56.66
26	231.0	506.2	2,252.7	864.7	126.5	3,981.1	60.34
27	269.3	626.8	2,186.6	720.7	129.2	3,932.6	64.02
28	248.4	544.4	2,252.7	773.7	136.1	3,955.3	62.94
29	275.6	611.4	2,186.6	720.7	126.0	3,920.3	62.88
30	250.5	583.3	2,252.7	773.7	102.9	3,963.1	58.37

www.pccmix.com

Dowel Corrosion

Adverse Effects:

- Loss of Cross-Section at Joint
  - *Poor Load Transfer*
  - *Reduced Curl-Warp Restraint*

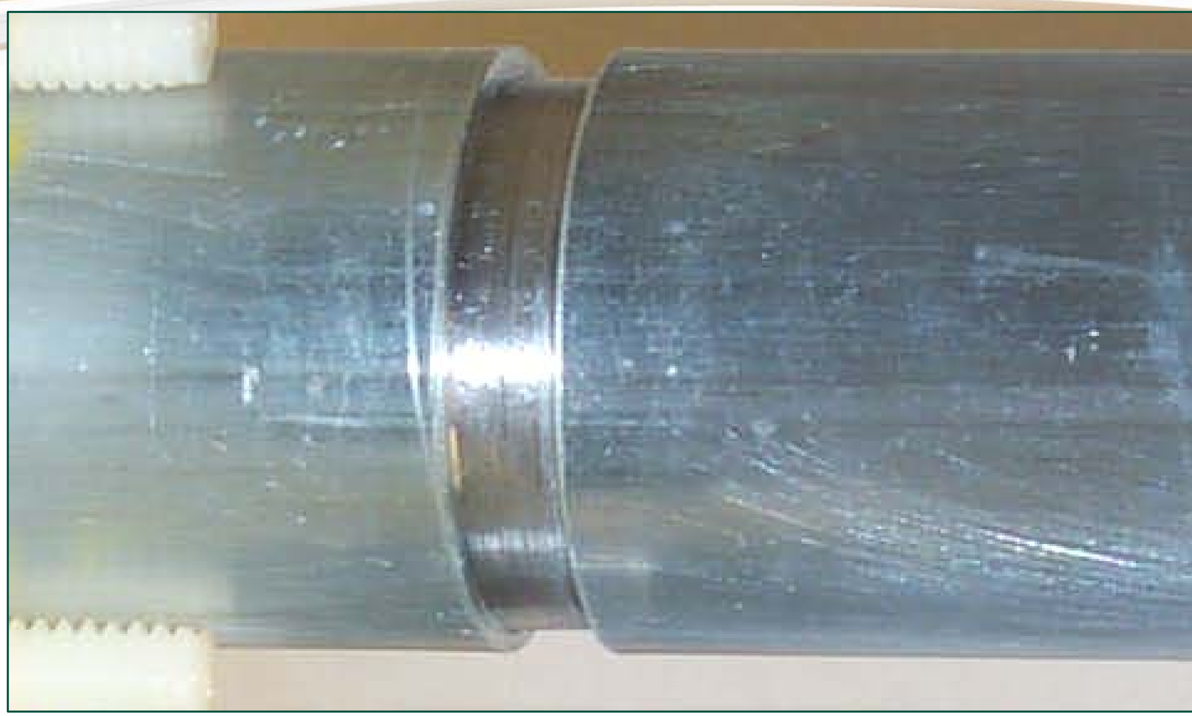
- Joint Lockup (Corrosion Products)
  - *Spalling*
  - *Crack Deterioration*
  - *Premature Failure*

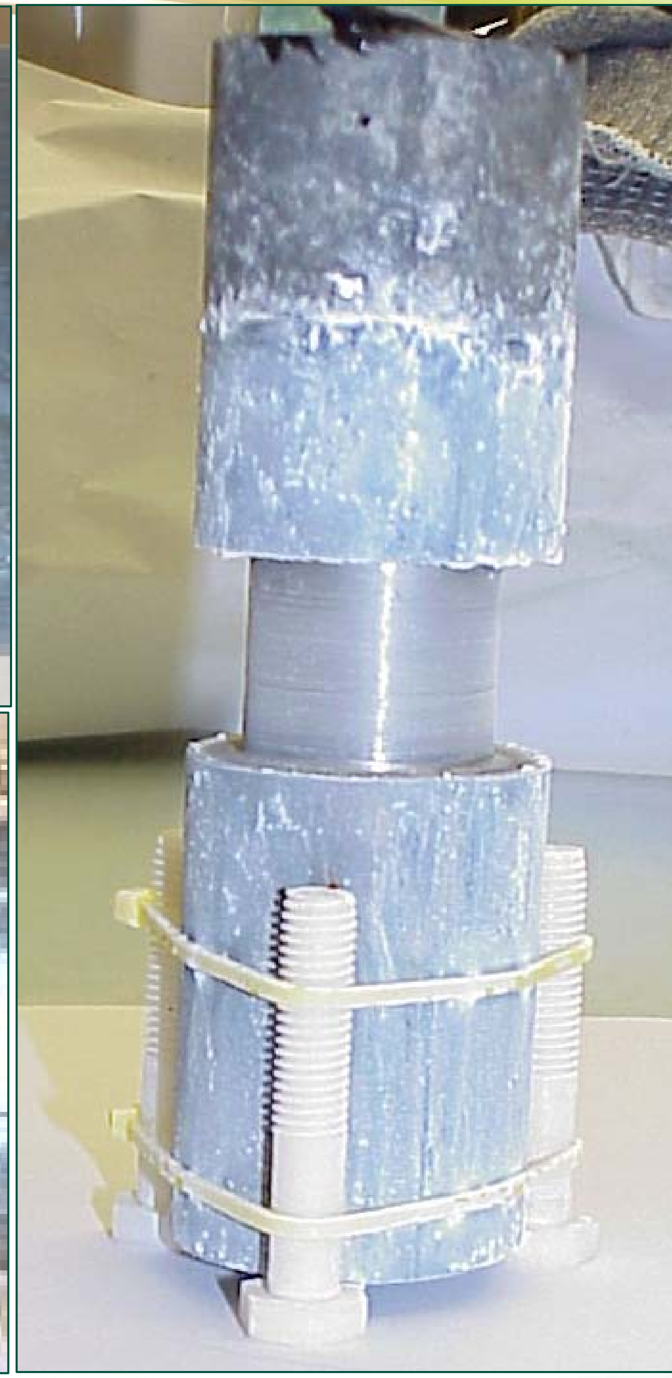
Photo credit: Washington State DOT

Photo credit: Tom Burnham, MnDOT

Dowel Bar Materials

Many materials/products are available





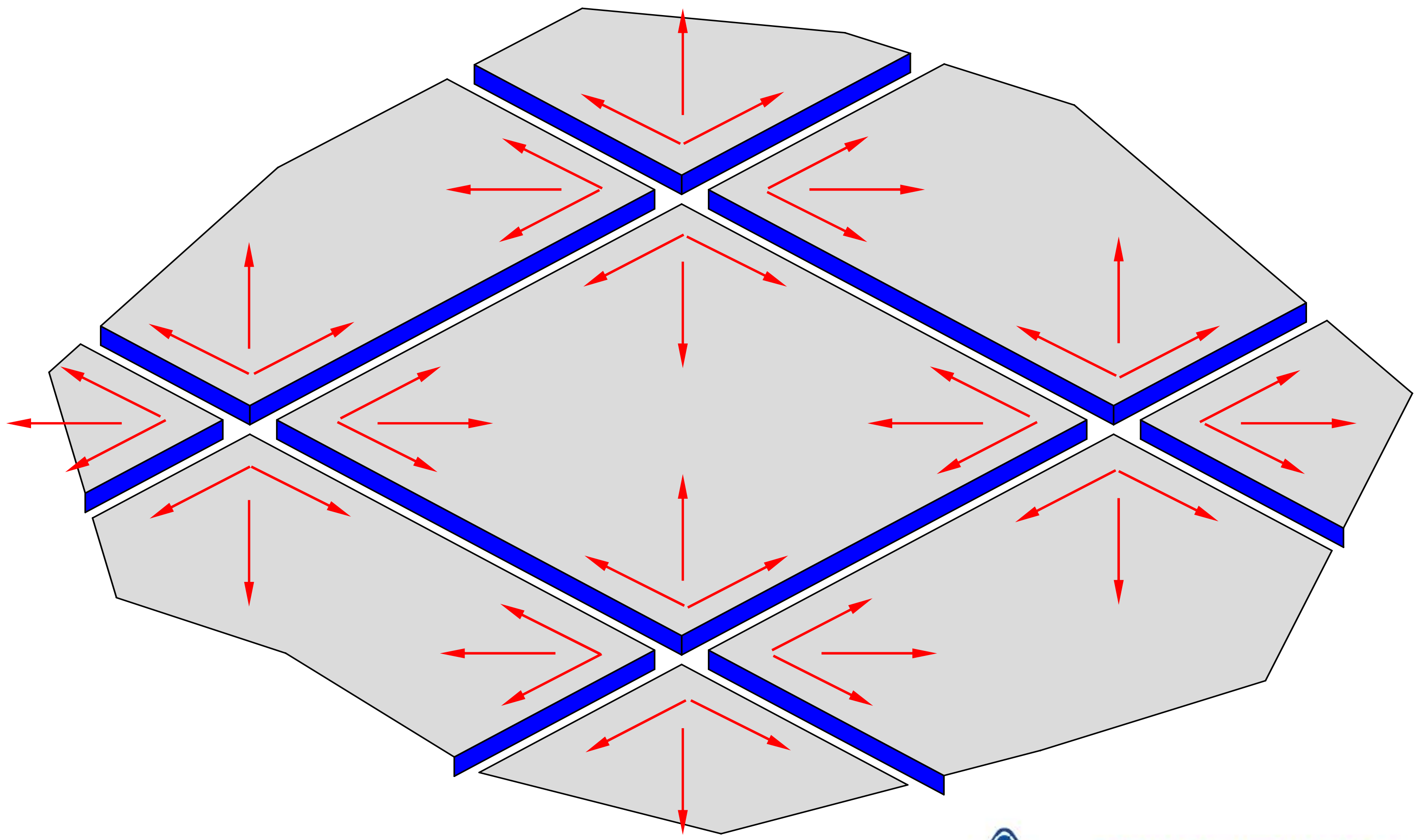
Dowel Structural Behavior: Fiber-Reinforced Polymer vs. Metallic

Dowel Type	Diameter (in)	Dowel Modulus, E (psi)	Applied Shear Force (lb)	Dowel Deflection at Joint Face (in)	Bearing Stress (psi)
Metallic	1.5	29,000,000	1940 (12" spacing)	0.0009	1421.4
FRP	1.5	5,600,000	1940 (12" spacing)	**0.0015**	**2185.8**
FRP	**1.92**	5,600,000	1940 (12" spacing)	0.0009	1405.5
FRP	1.5	5,600,000	**1260 (8" spacing)**	0.0009	1419.7

There is additional deflection across the joint …

FRP/Steel Composite Dowels

Restraint of Movements in Area Pavements



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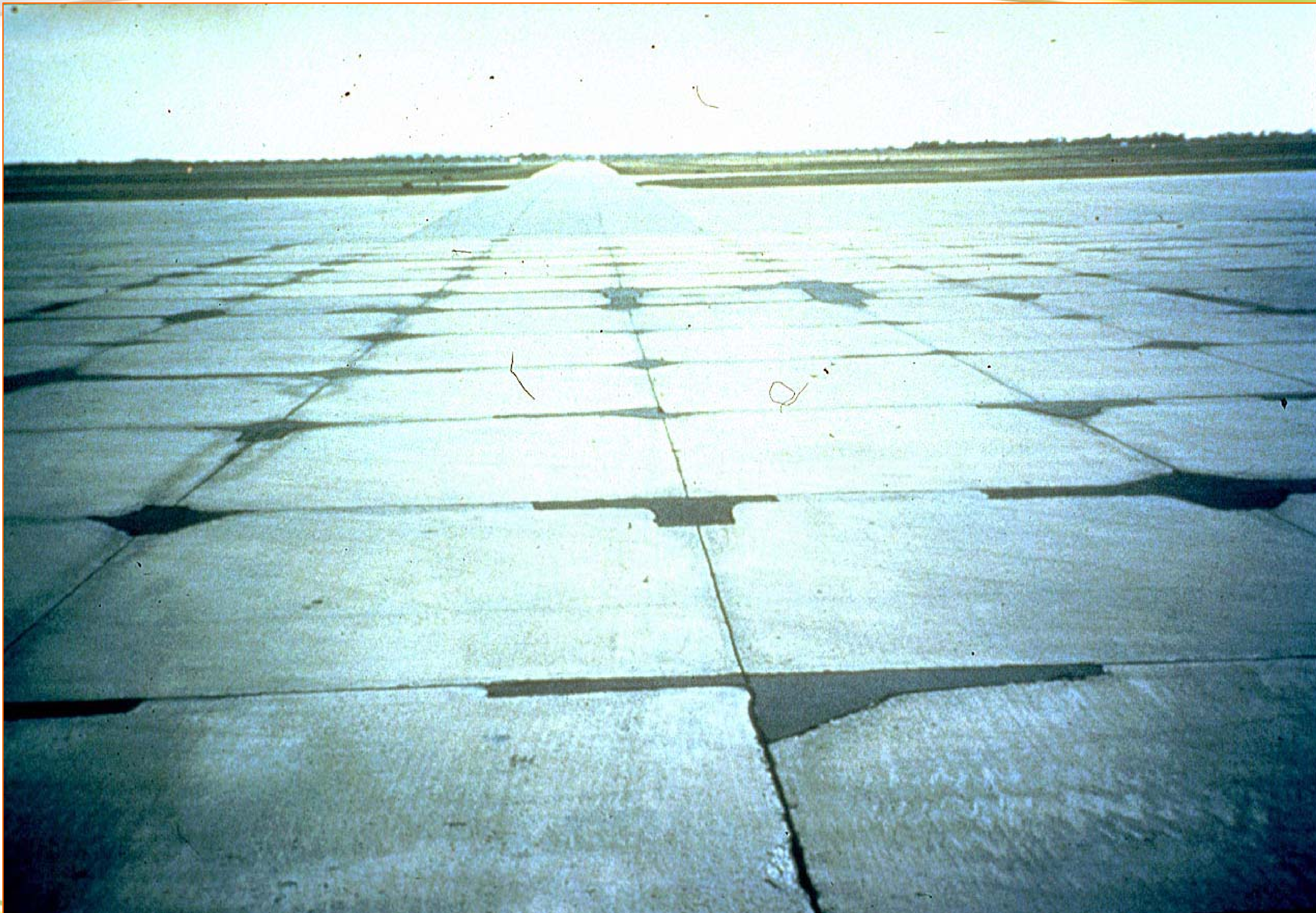


Restraint of Odd-shaped Panels and Roundabouts

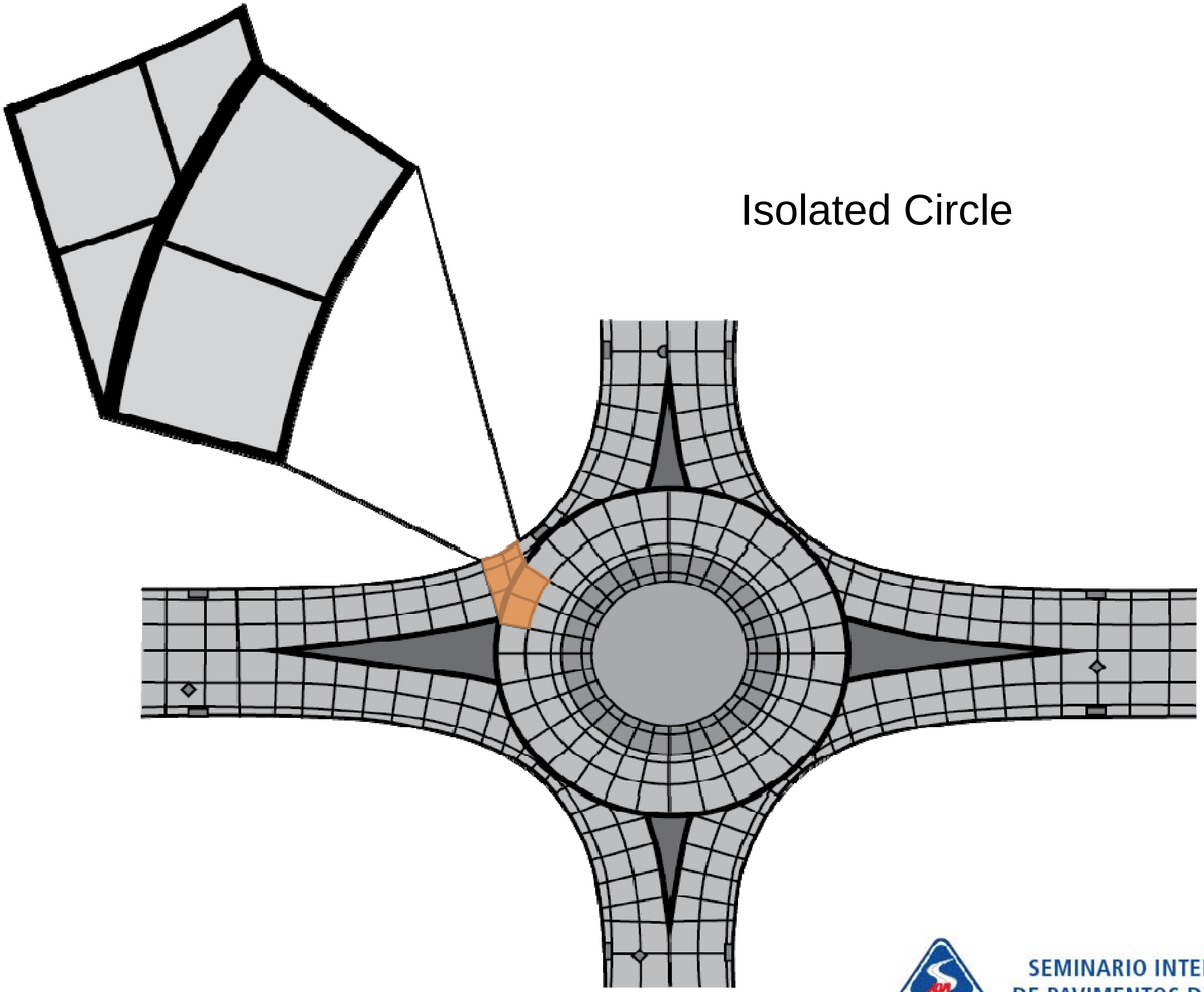
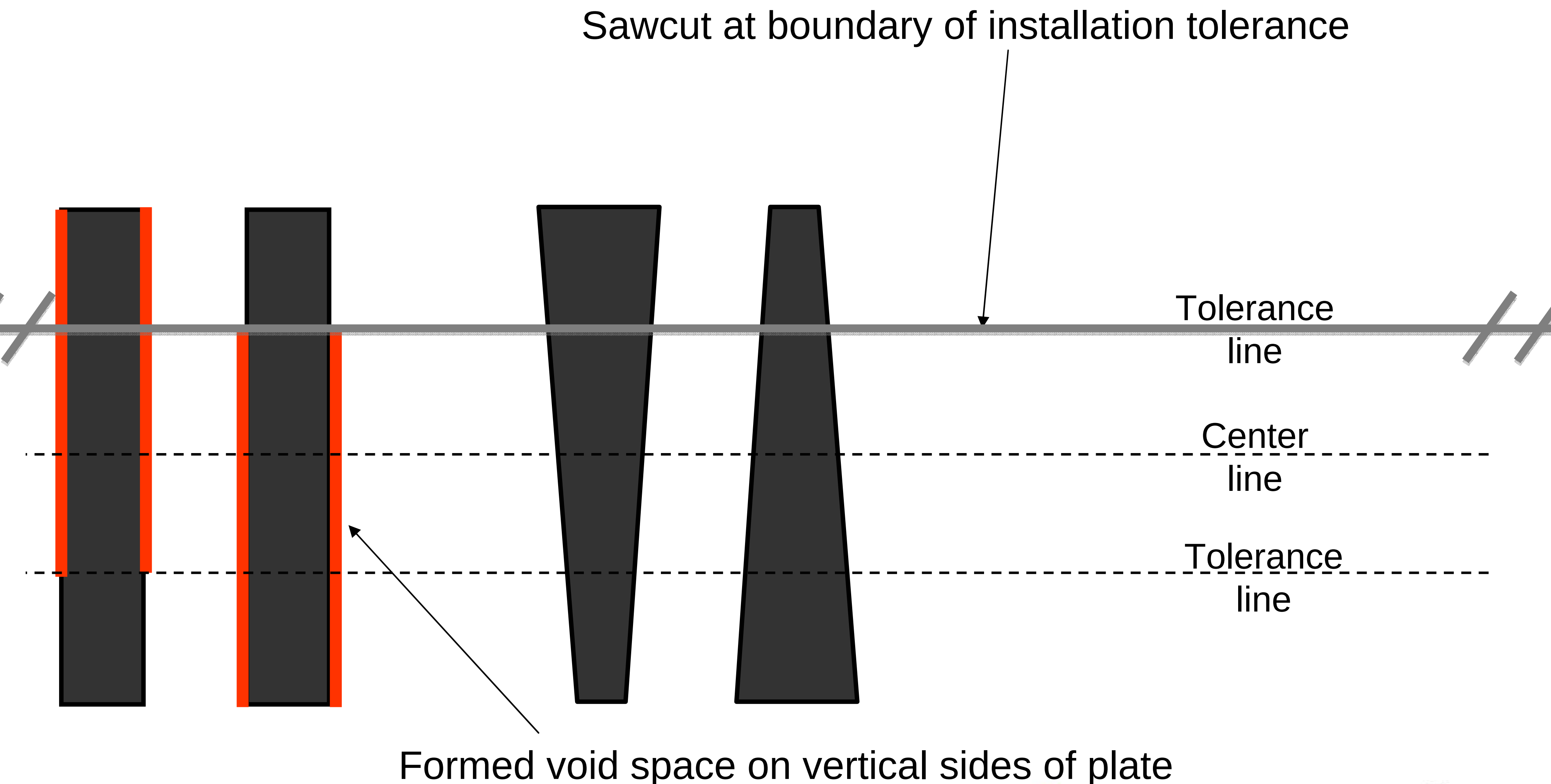
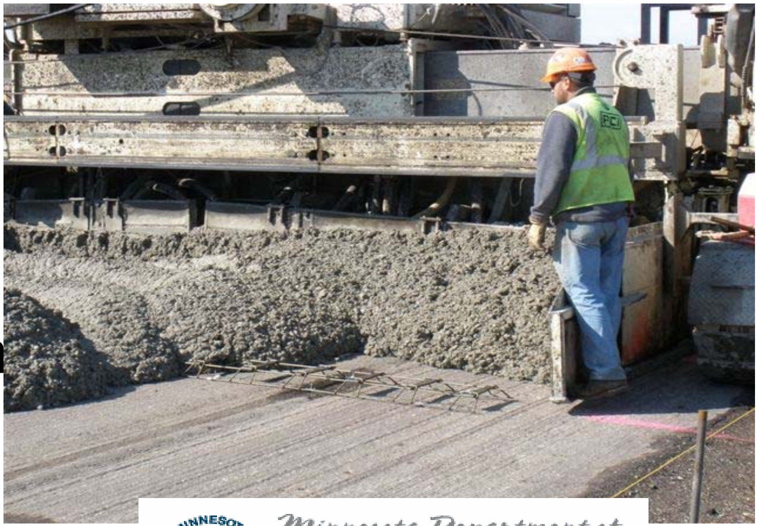


Plate Dowel Geometries for Contraction Joints



MnRoad Testing: How thin Can you go?

- Study initiated in 2008
  - Focus: section thickness
- Proof of concept
  - Plate dowel performance and
  - Plate dowel performance in thin paven



- Testing bonded overlays
  - 125, 150 and 175mm pavements
- Joint spacing: 3.8m and 4.6m
- Direct comparison
  - 9.5mm x 400mm PD^3 Basket® assemblies at 300mm
  - 25mm x 400mm round dowels at 300mm

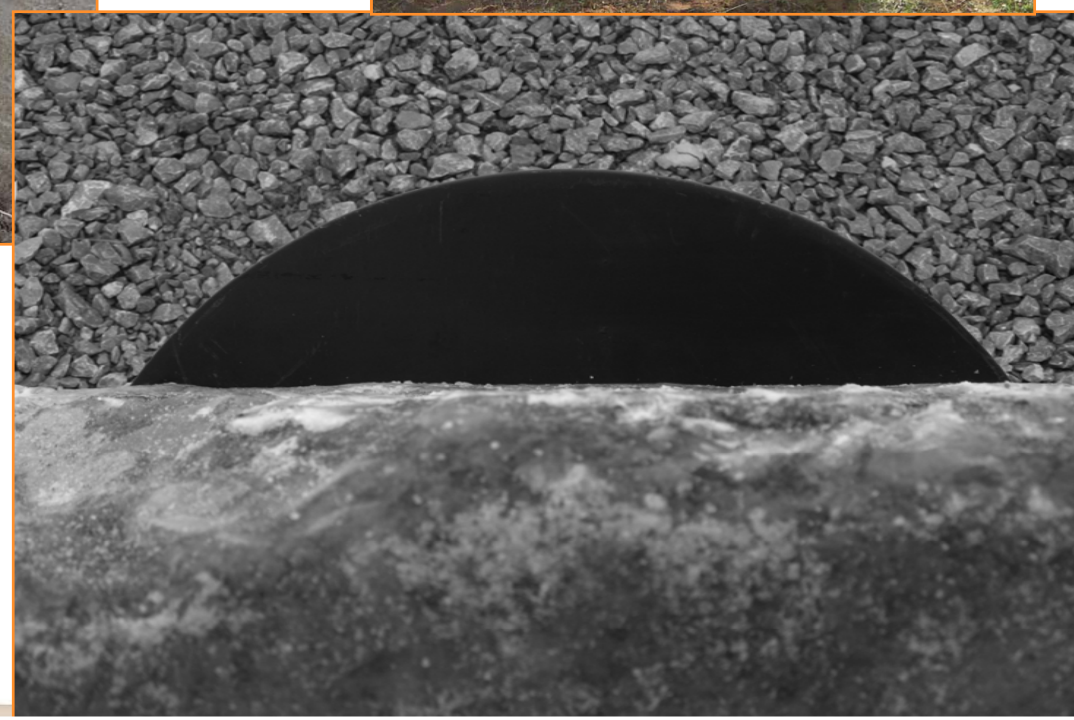
Preliminary Findings – Plate Dowels Perform

- 2.5 million ESALs to date
- Performance Summary
  - Joint performance is good
  - Joint deflection less than round dowels
  - Consolidation is good
  - LTE in acceptable range
  - Less cracking

Core sample showing consolidation above and below plate

3/8" x 12" PD^3 basket assembly

Plate dowels for slip-formed or 'new-to-existing' joints



Epoxy-grout CoVex™ Plates into place

Plastic debonding sleeves installed

Another "Construction Material": Precast Concrete Pavement Systems:

A concrete solution for durable repairs in short work windows

Super-Slab® System (Proprietary)

- Simple slab-on-grade system
- Standard dowels and tie bars
- Built-in bedding grout distribution
- Precision grading equipment
- Warped Slabs for non-planar surfaces

(>70 projects, 40 lane-km completed in 14 States + Provinces)
(10,000 + Slabs = over 100,000 m^2)

Source: Fort Miller Company, Inc.


Source: Fort Miller Company, Inc.

Various Jointed Precast Concrete Pavement Systems

Roman Stone System

Michigan System

Fort Miller System

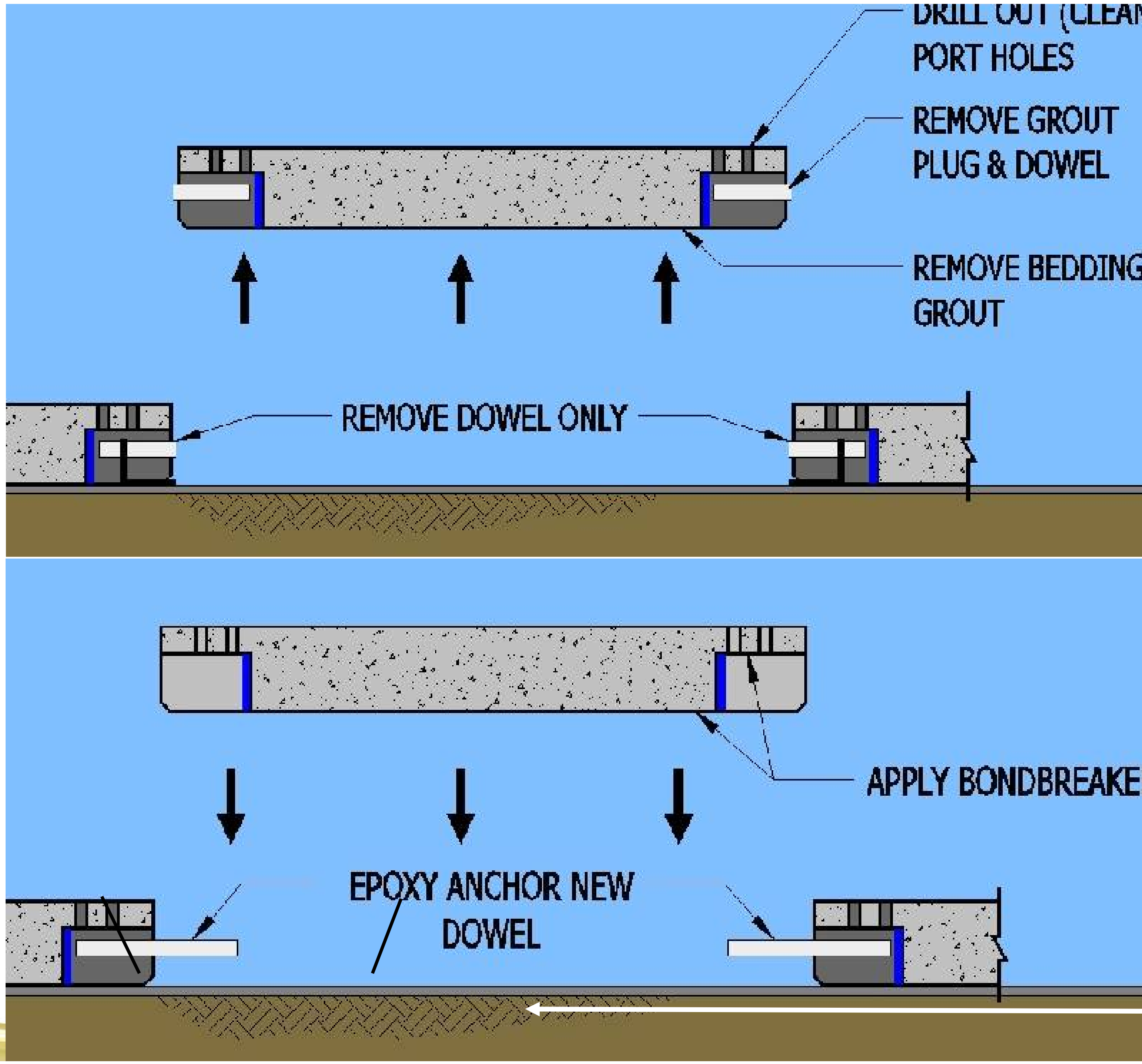
Source: Shiraz Tayabji, Fugro Consultants, Inc.

Super-Paver – A Re-usable Urban Pavement (RUP) System

- Light weight
  - 2m x 2m weighs 2 T
- Vertically removable & replaceable
- Warped as required to fit any surface
- **Removable and reusable**

(Designed specifically for utility-intensive urban highways and intersections)

Slab Removal & Replacement



Removable/reusable pavement made possible by easily cut but structurally adequate Super-Dowel® System (Proprietary)

SuperPaver Reusable Urban Pavement System (RUPS)

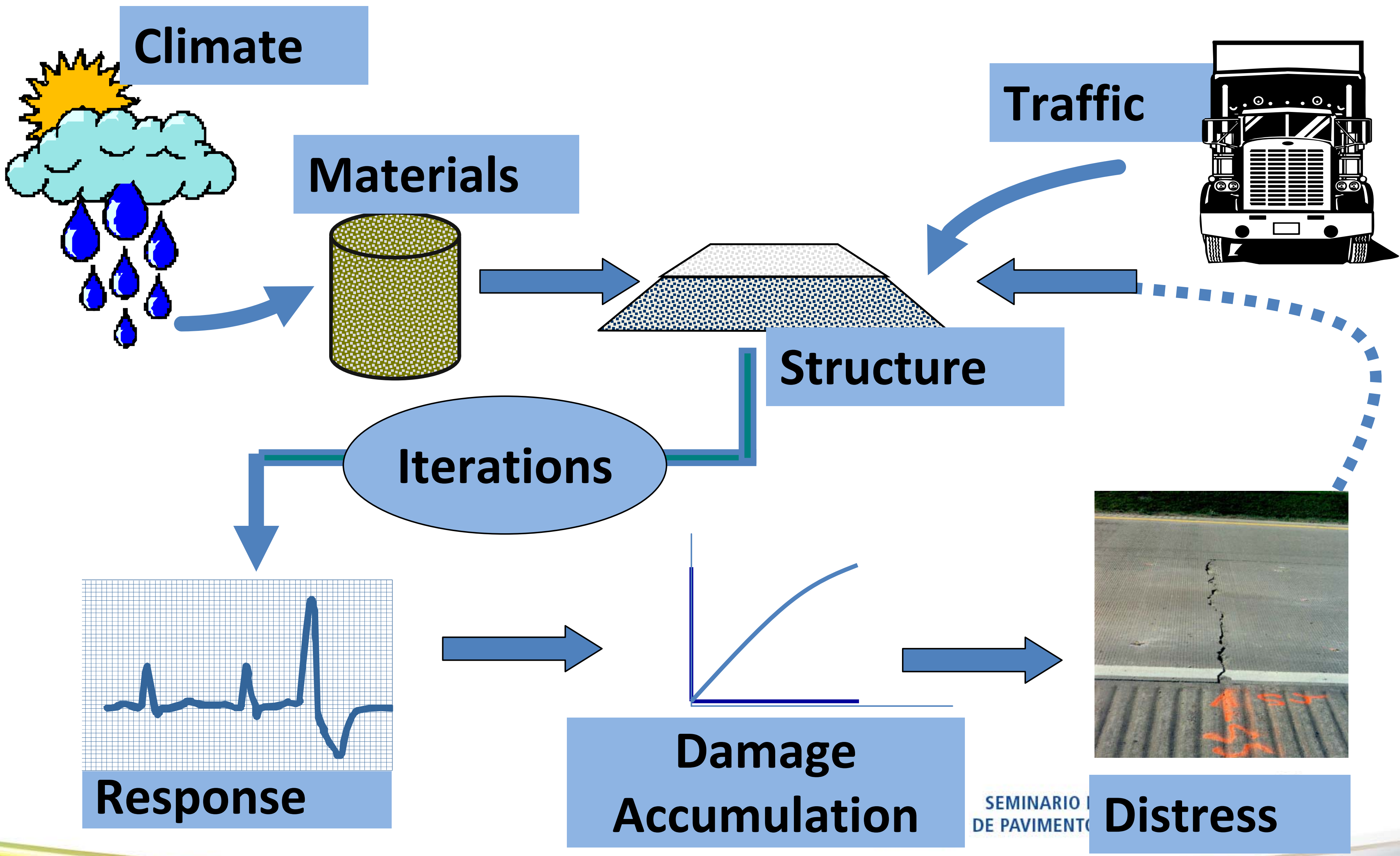
Advances in Concrete Pavement Design

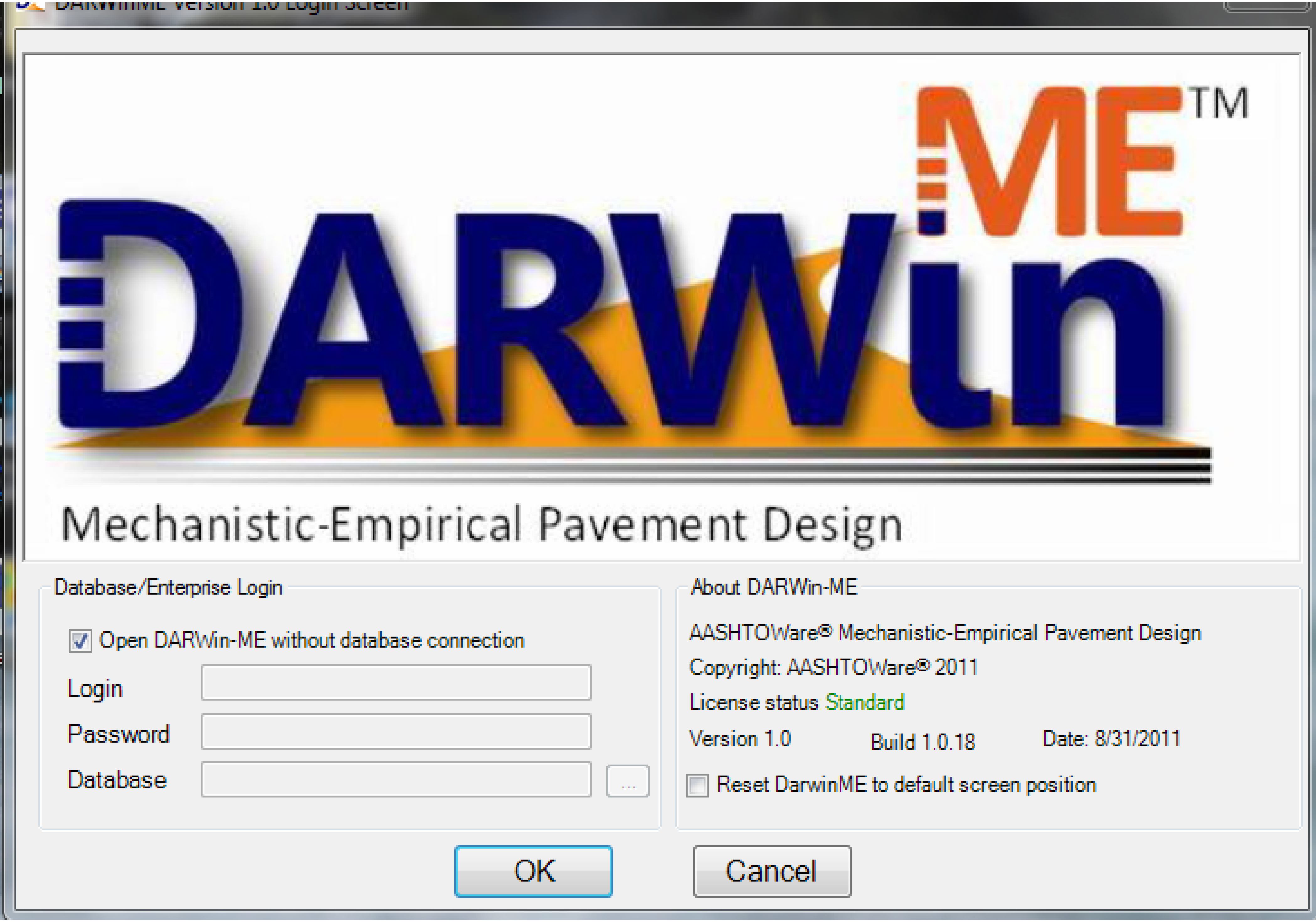
Tradition: Empirical Design

- Models based mainly on experience and observation
- Dependent on design conditions
  - Climate
  - Traffic
  - Materials
- Primary focus on structural (thickness) design
- Limited attention to specific failure modes (e.g., cracking, faulting, roughness, etc)
- Limited attention to design features

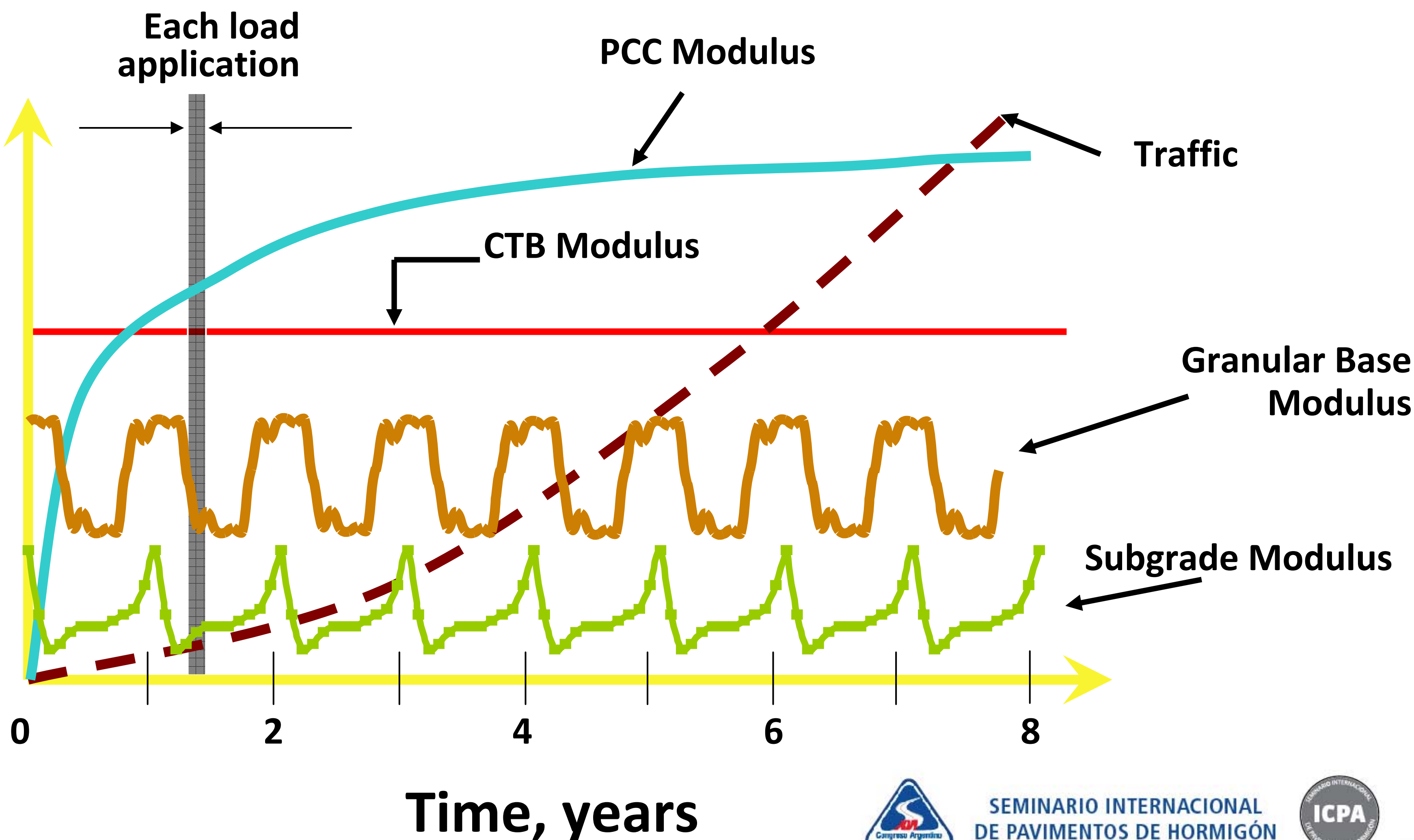
Most common: Interim AASHTO Guides

The Mechanistic-Empirical Design Process



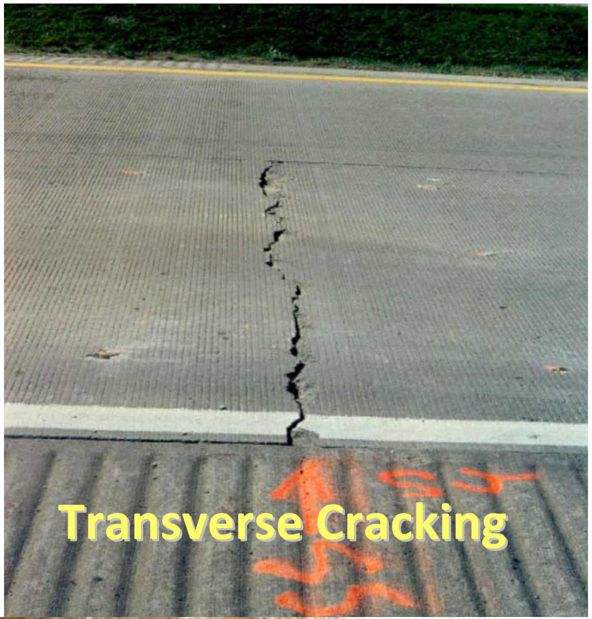

DARWin ME™
Mechanistic-Empirical Pavement Design
Database/Enterprise Login
Open DARWin-ME without database connection
Login
Password
Database
About DARWin-ME
AASHTOWare® Mechanistic-Empirical Pavement Design
Copyright: AASHTOWare® 2011
License status Standard
Version 1.0
Build 1.0.18
Date: 8/31/2011
Reset DarwinME to default screen position
OK
Cancel

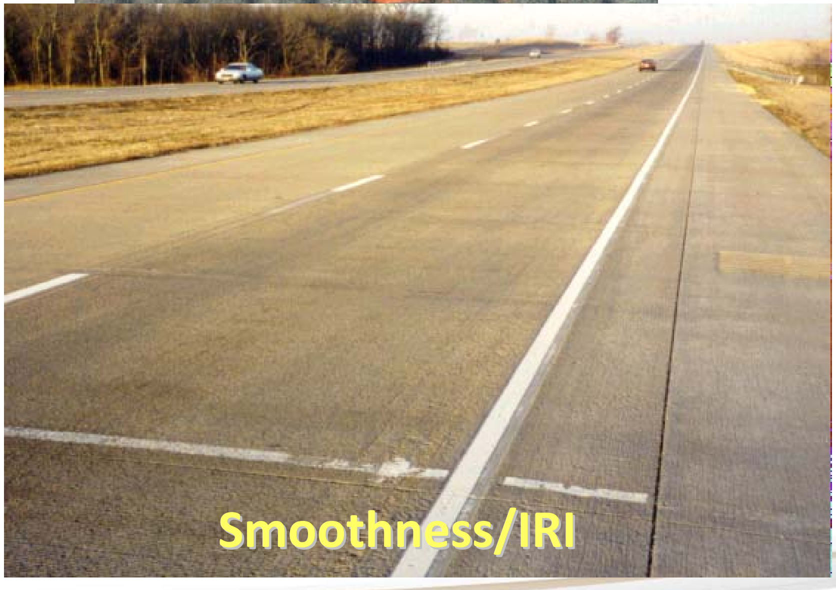
Design Parameters Over Pavement Life



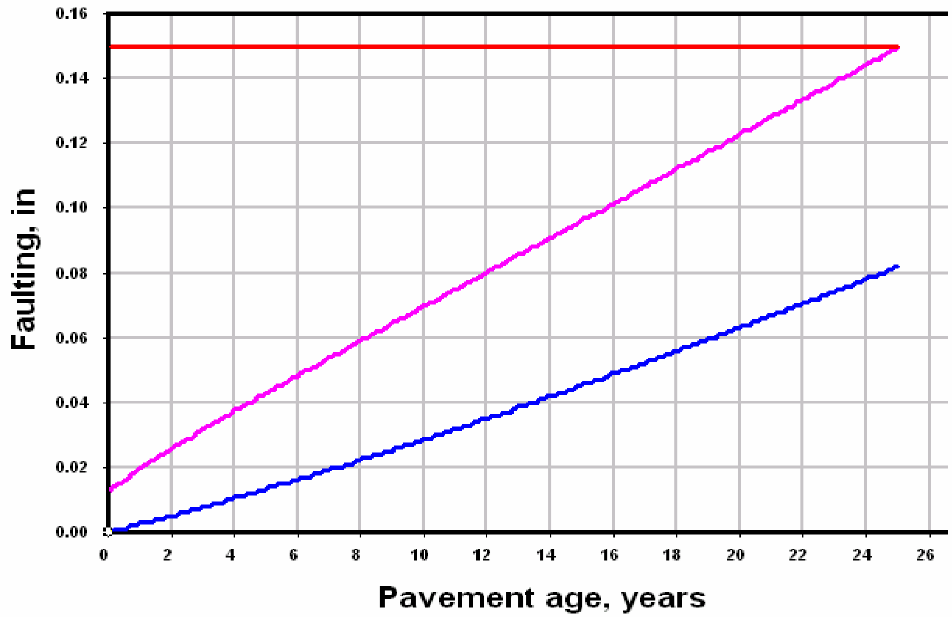
Performance Prediction

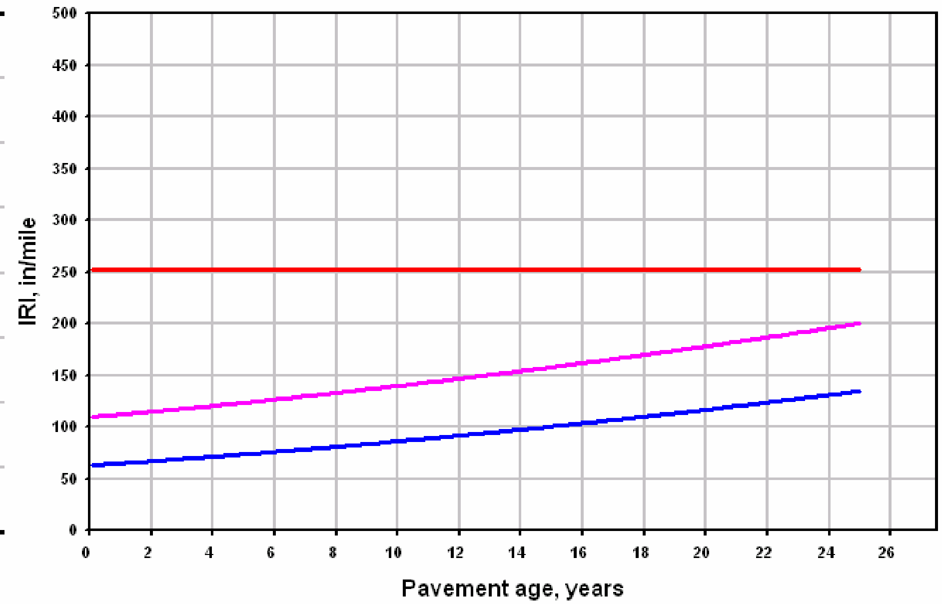
- Faulting
- Transverse cracking (top-down/bottom-up)
- Punchout (CRCP)
- IRI
  - Based on prediction of other distresses

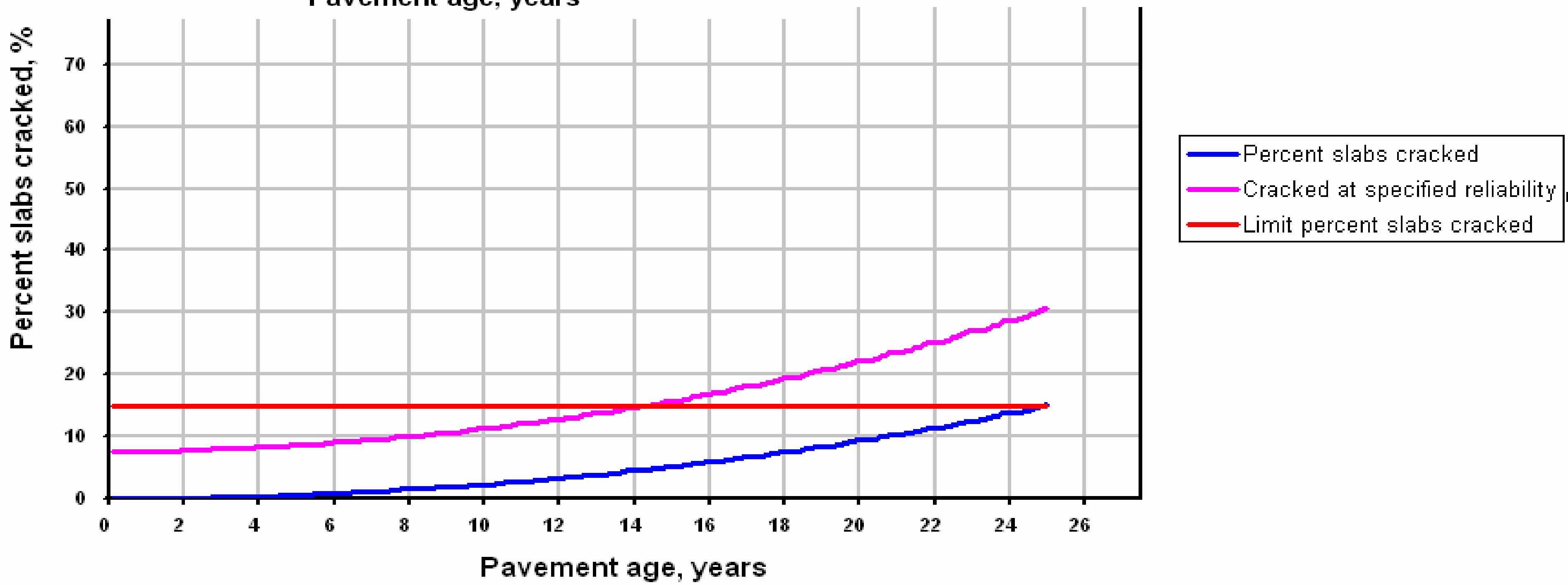




DARWin-ME Design Guide Results





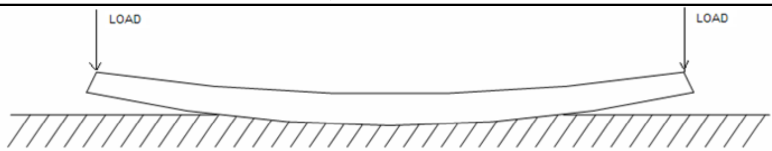
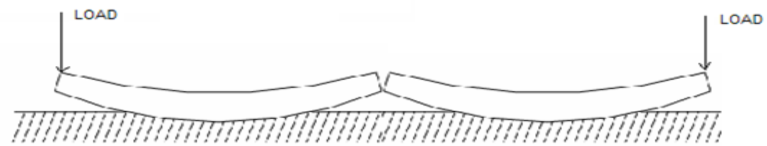
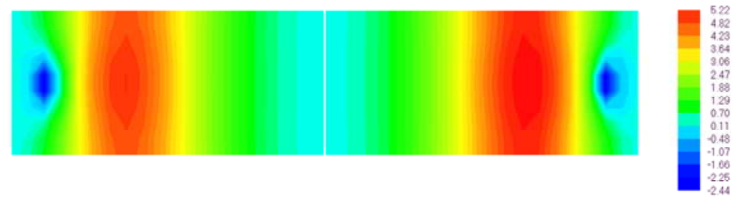
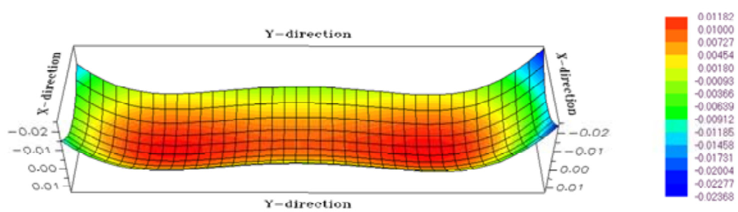
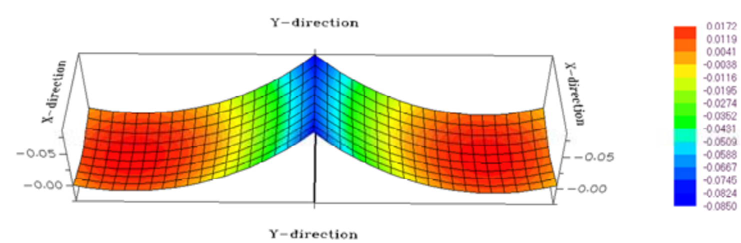


Advantages/Limitations

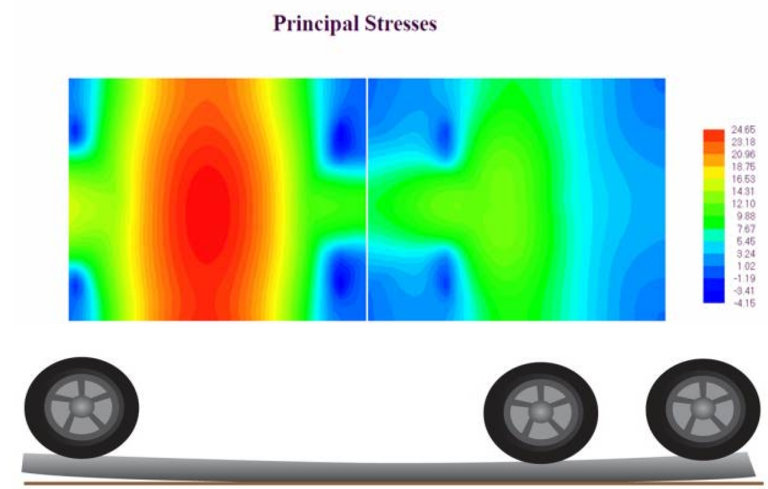
- Advantages
  - Accounts for many factors that change over time (traffic, climate, materials).
  - Improved traffic/materials characterization
  - Improved structural modeling capabilities
  - More versatile procedure
- Limitations
  - Can involve more complex calculations
  - Requires long-term performance data
  - Requires reliable performance models

TCPavements® - Optimizing slab geometry

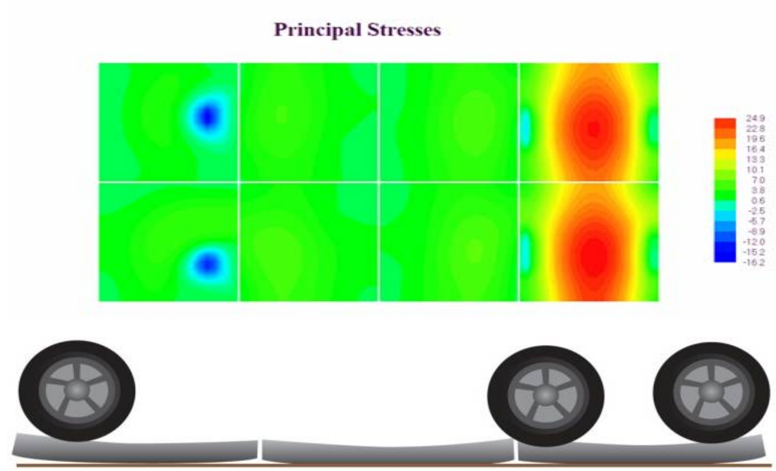
Influence of slab geometry on stresses, deflections

4,5m x 1m	2.25 m x 1 m
	
	
Maximun tensile stress = 24.65 Kg/cm2	Maximun tensile stress = 5.22 Kg/cm2
Principal stresses on the top of the slab, Red is tensile stress	
	
Deformation of the slab	

Slab sizes and thicknesses for same top stress (2.5MPa)



Thickness: 25cm
Concrete
Slabs 4.5m x 3.6m



Thickness: 16cm
Concrete
Slabs 1.8m x 1.8m

Example Installation – Antigua Guatemala

www.tcpavements.com

Advances in
Concrete Pavement Construction

Typical Paving Clearance Zone

- The minimum clearance zone needed for a standard concrete paver operation is ~1.2 m per machine side:
  - ~0.9 m for the paver track and workers
  - ~0.3 m for paver control string line

Modified Paver for “Zero Clearance”

Stringless Paving Example

G&Z's S600 is available with G&Z's NoLine: Stringless Preparation Package which allows Leica's "Direct Connect" 3D Control System Software to communicate directly with G&Z's networked Microprocessor Control System.

Concrete Overlay Systems

Thinner

Thicker

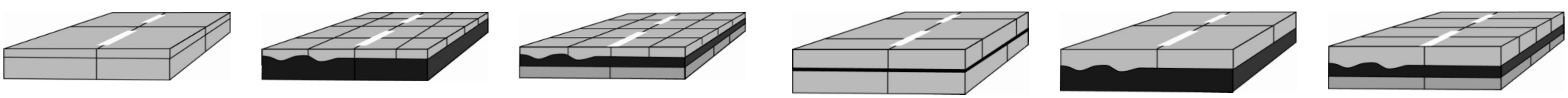
Concrete Overlays

Bonded Overlay Systems

- Bonded Concrete Overlay of Concrete Pavements
- Bonded Concrete Overlay of Asphalt Pavements
- Bonded Concrete Overlay of Composite Pavements

Unbonded Overlay Systems

- Unbonded Concrete Overlay of Concrete Pavements
- Unbonded Concrete Overlay of Asphalt Pavements
- Unbonded Concrete Overlay of Composite Pavements



Bond is integral to design

Old pavement is base

Bonded Overlays of ACP

- Thickness: 100 – 150 mm (*moderately loaded*)
  - State/county highways
  - Secondary routes
  - Collectors

- Thickness: 50 – 75 mm (*lightly loaded*)
  - City streets
  - Urban intersections
  - Parking lots

Design Issues

- ACPA (www.acpa.org) provides guidance on suitable thickness and joint spacing combinations
  - 1.8m by 1.8m joint spacing widely used
- Dowel bars not used
- Tie-bars may be used

Surface Preparation

- Some pre-overlay repairs
- Milling AC surface
  - Remove rutting
  - Restore profile
  - Enhance bond
- Minimum AC thickness remaining after milling: >75mm
- Surface cleaning

PCC Placement and Finishing

- Same as conventional PCC paving
  - Slipform
  - Fixed form
- Avoid surface contamination
- <u>Effective curing is critical</u>

PCC Joint Sawing

<u>Timely joint sawing is critical</u>

Completed Bonded Overlay Projects - Colorado

S.H. 119 – Longmont, CO

Over existing AC pavements

Parker Av. A, Denver, CO - 1997

What is Roller-Compacted Concrete (RCC) Pavement?

– Definition: “Roller-Compacted Concrete (RCC) is a no-slump concrete compacted by vibratory rollers”
– Same components —well-graded aggregates, cementitious materials, and water—but different mixture proportions
– Consolidated by paver and vibratory rollers
– After curing, RCC properties are similar to PCC

What is Roller-Compacted Concrete Pavement?

- Typically placed with asphalt-type paver equipped with standard or high-density screed
- Followed by a combination of passes with rollers for compaction

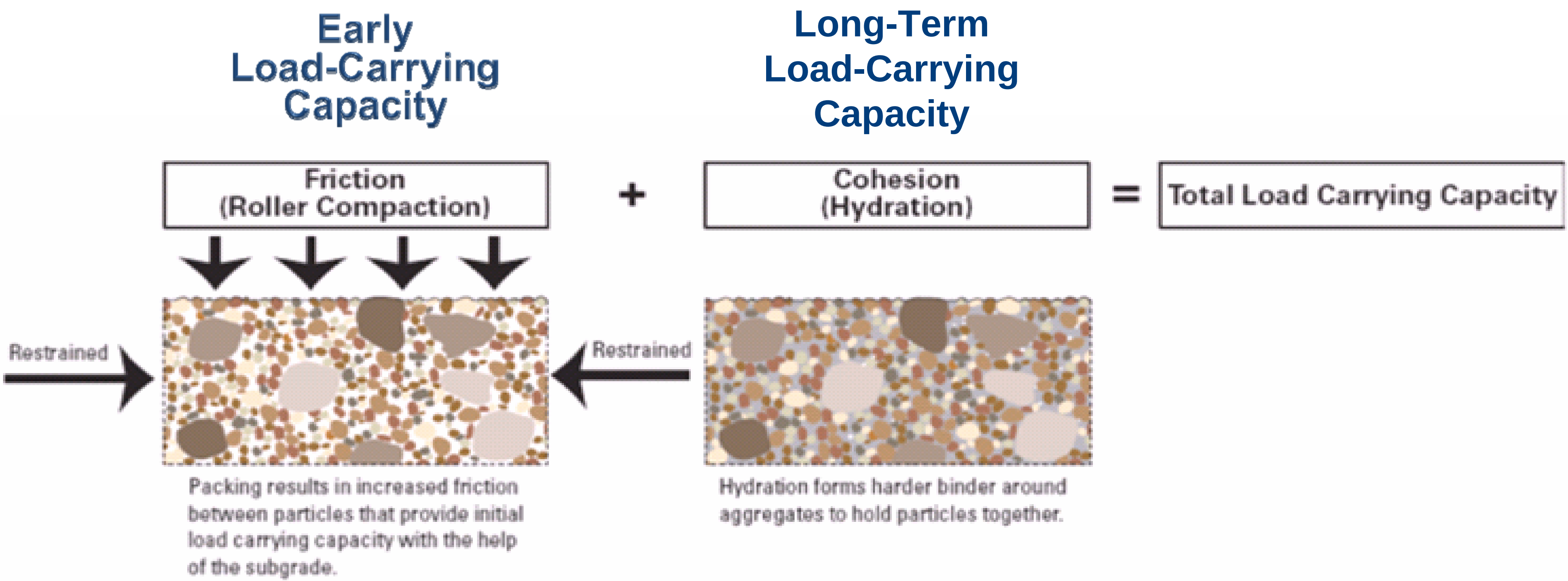
Conventional Asphalt Paver

High-Density Paver

What is Roller-Compacted Concrete Pavement?

- Final compaction is generally achieved within one hour of mixing
- RCC pavements are constructed without forms, dowels, or reinforcing steel
- Joint sawing is not always required, but when sawing is specified, transverse joints are spaced farther apart than with conventional concrete pavements

How Does RCC Work?



Common Uses of RCC Pavements

- Ports/Heavy Industry
- Light Industry
- Airports
- Local Streets
- Arterial Streets
- Shoulders/Widening
- Base for Overlays

Example

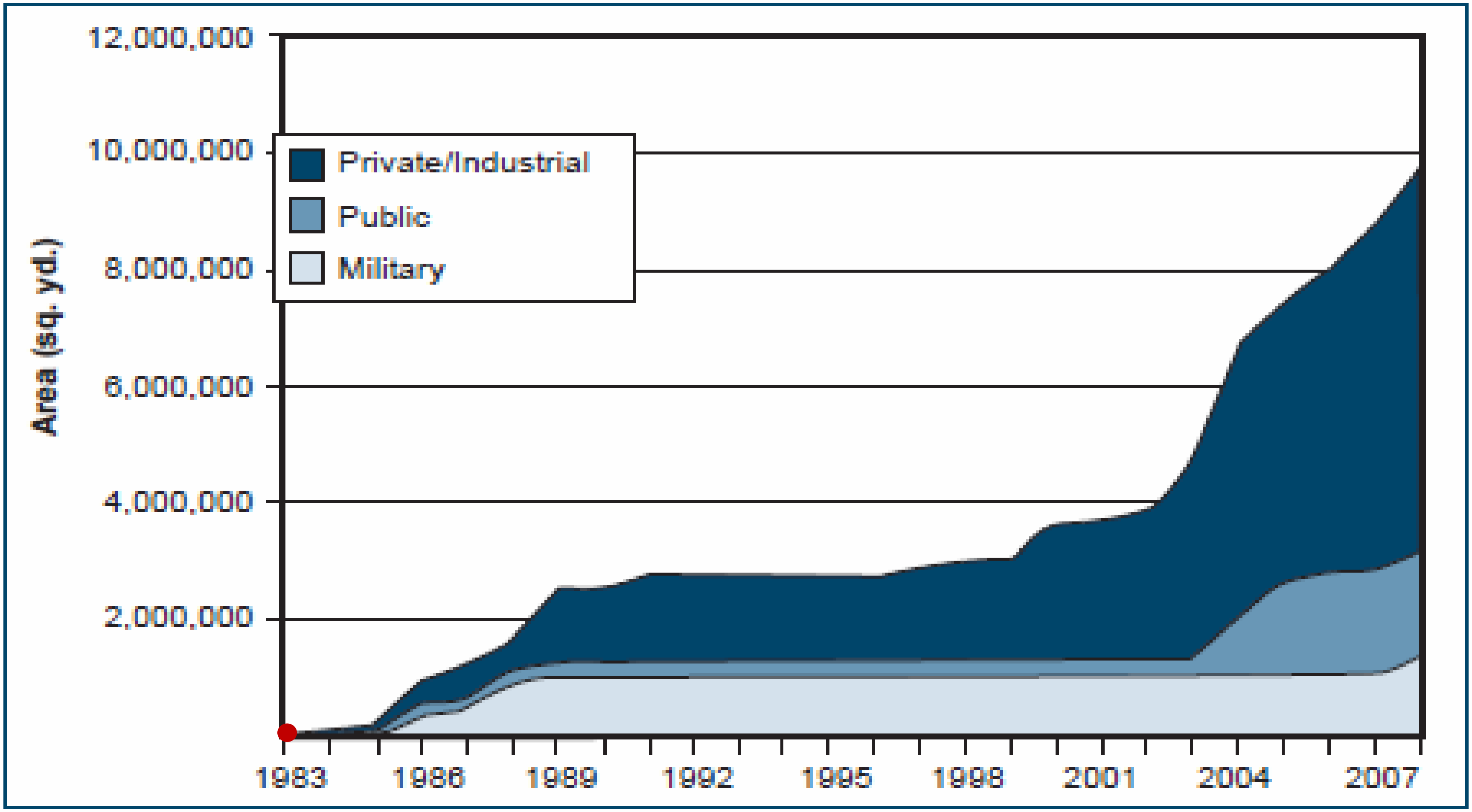
- Reconstruction of Lane Avenue pavement in Columbus, Ohio
- 200mm of RCC base
- 75 mm of asphalt (provide smoothness for higher speed traffic)
- RCC constructed under traffic

Example

- Reconstruction of US 78 in South Carolina
- 250mm RCC pavement replaced full-depth asphalt pavement
- RCC surface diamond ground to improve smoothness and provide surface texture at affordable cost

RCC provides enough structure capacity to allow early opening to light traffic (<4 hours)

Increased Use of RCC in U.S.



Concrete Pavement Texture

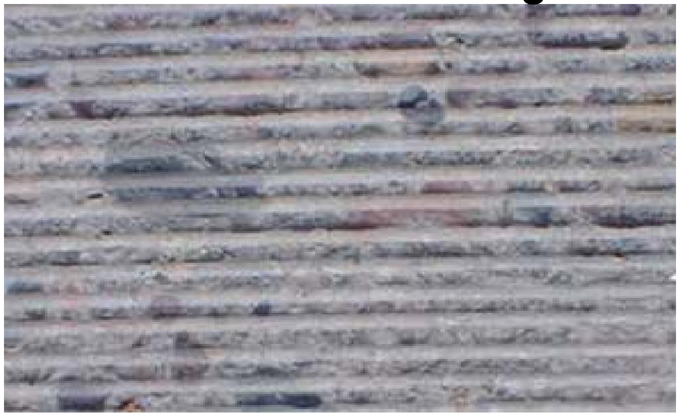
Goals: Safe, Smooth and Quiet

…

Conventional Concrete Pavement Texture Types

Transverse Tine

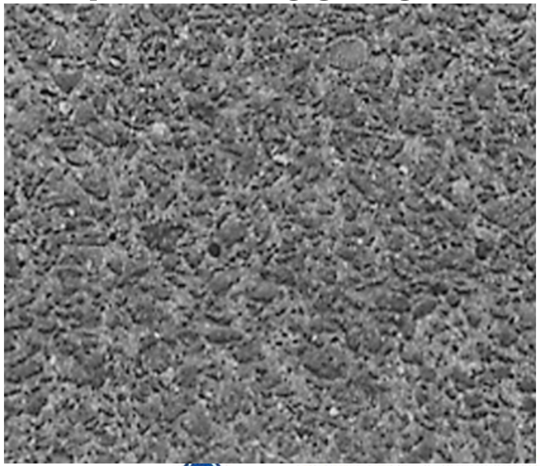
Conventional Diamond Grinding



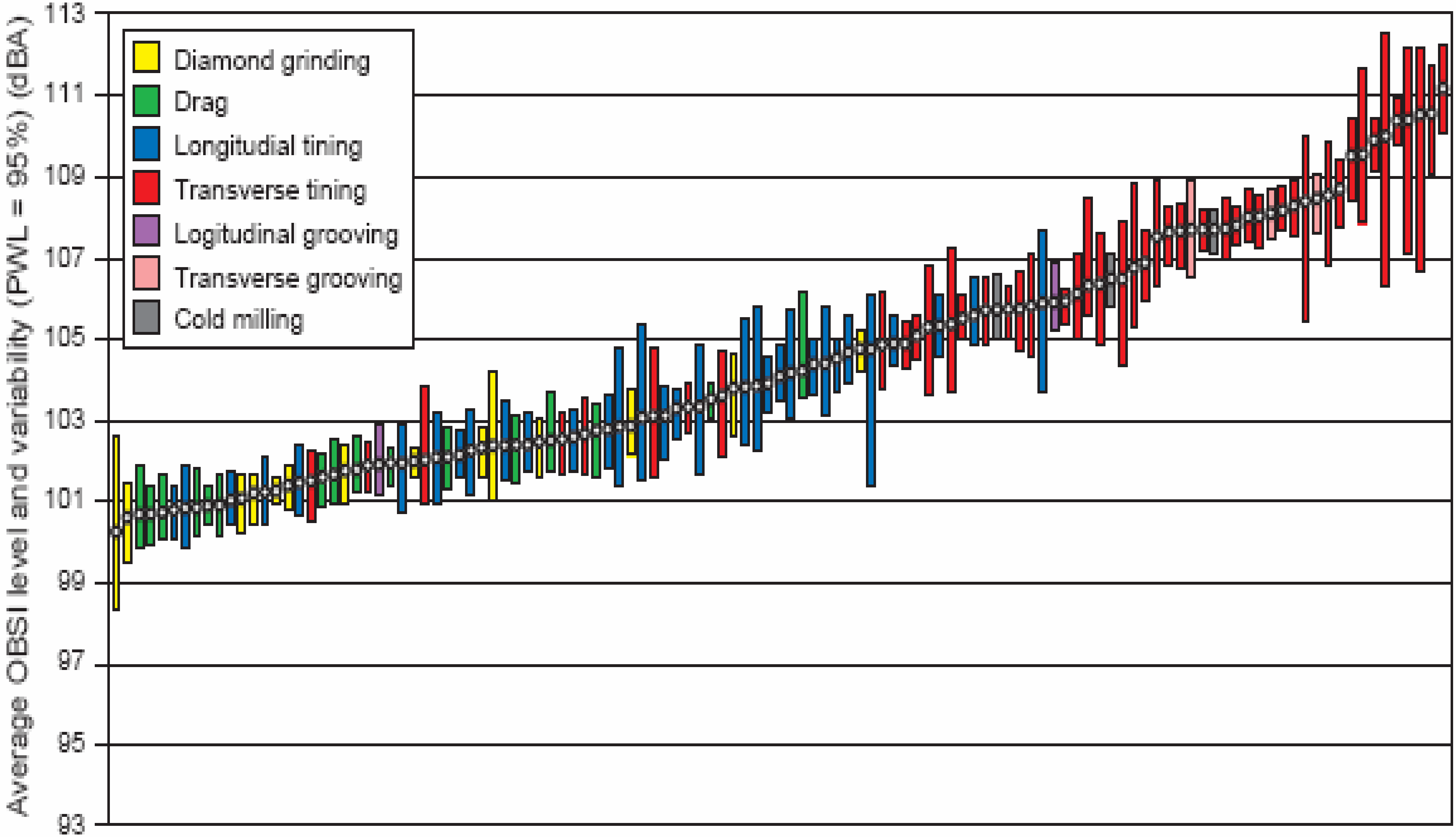
Traffic →

Longitudinal Tining

Exposed Aggregate




IMCP Manual



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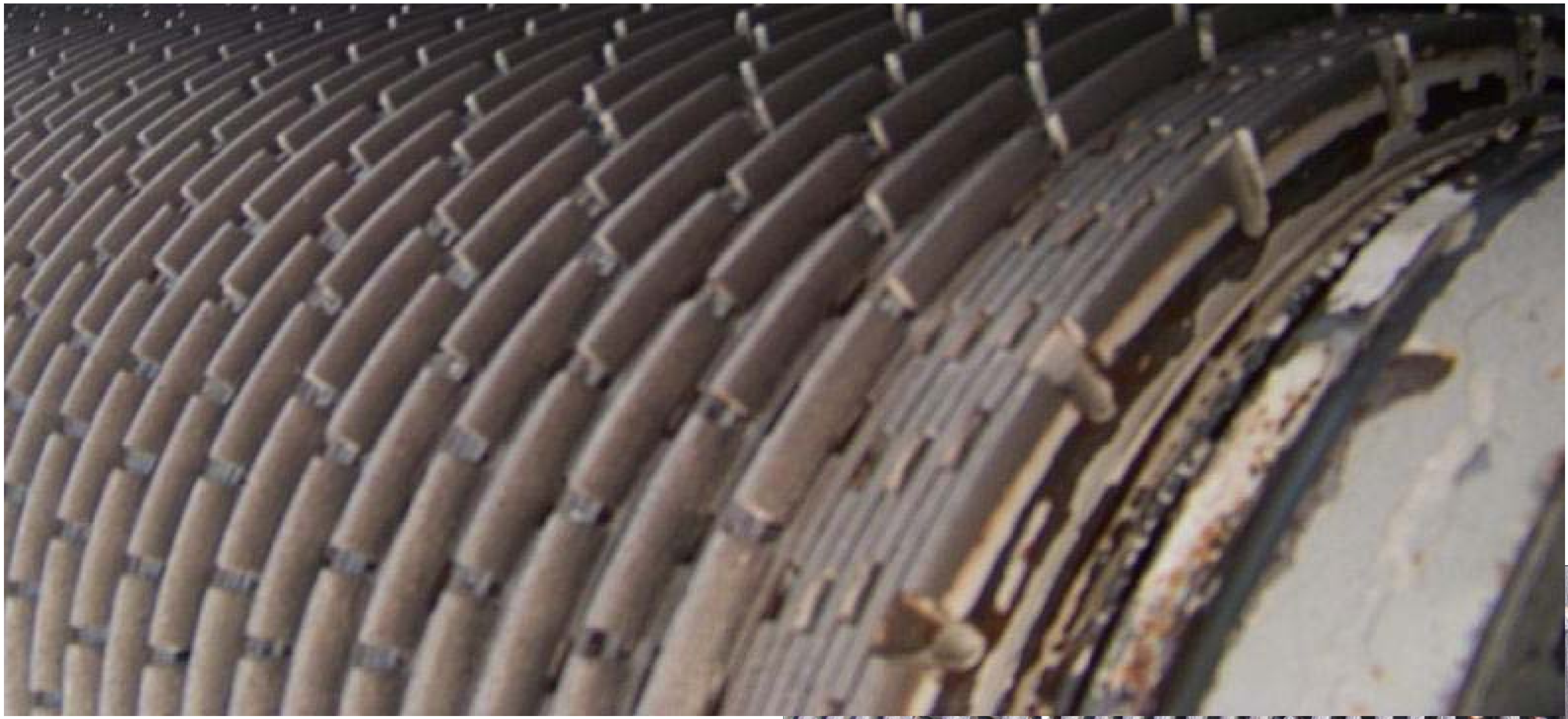
DE PAVIMENTOS DE HORMIGÓN

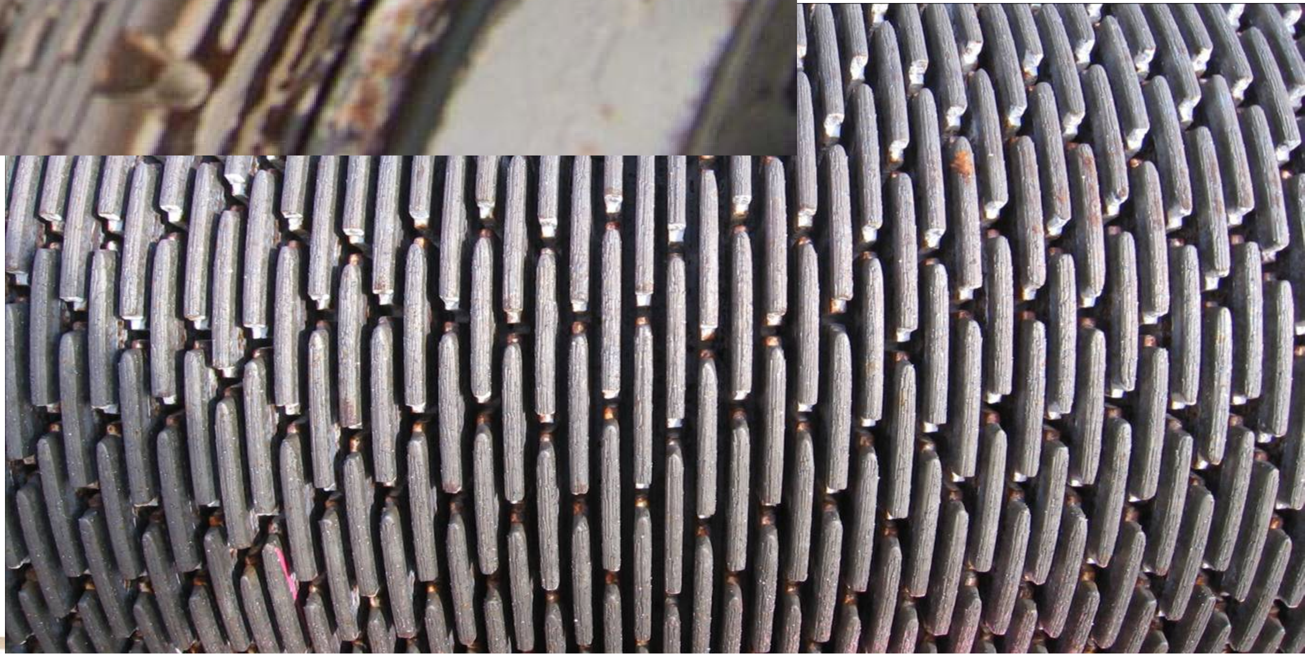
Source: Iowa State University, 2006

Next Generation Concrete Surface (NGCS) vs. Conventional Diamond Grinding (CDG)

Equipment Head Differences

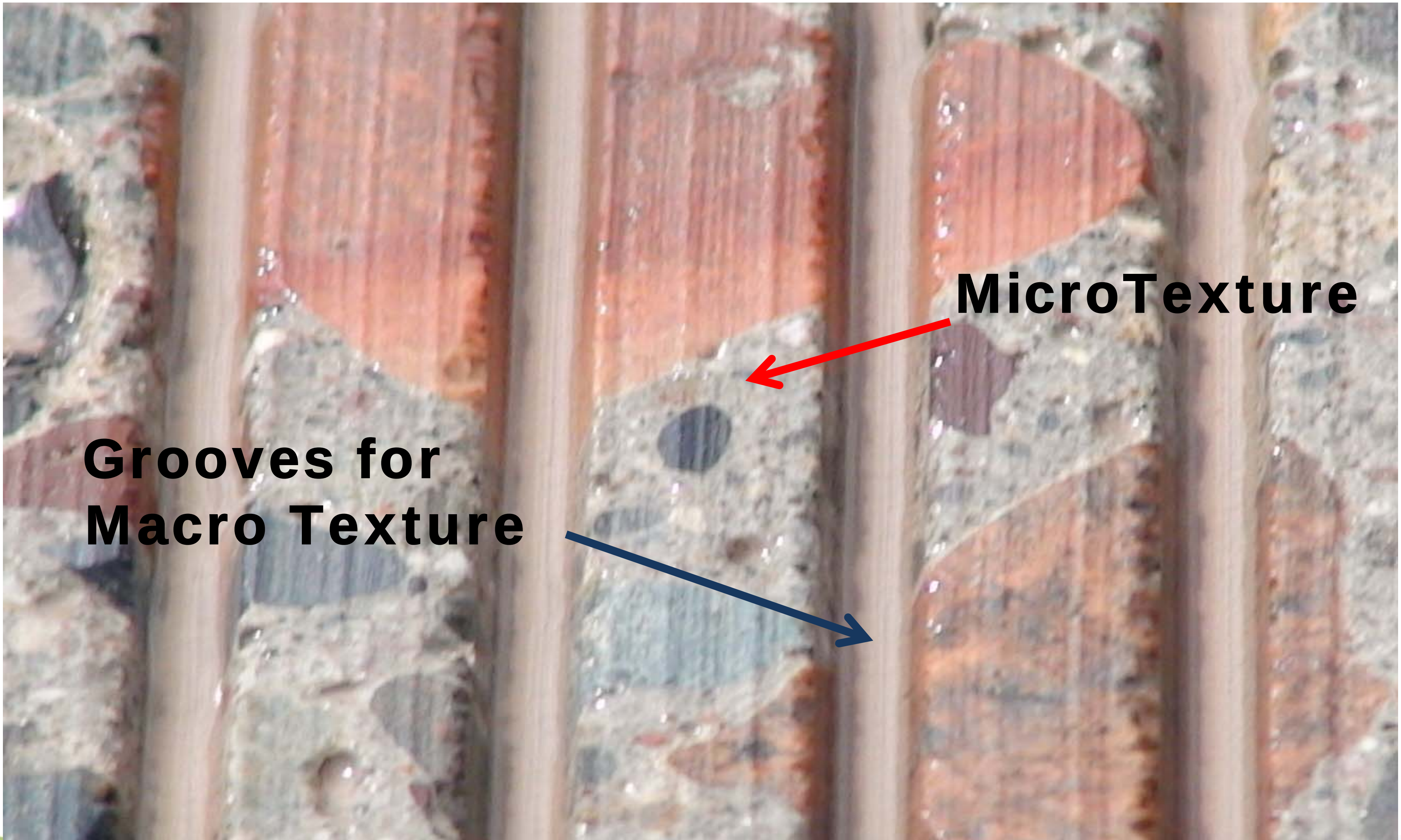


NGCS Head



Conventional Diamond Grinding Head

NGCS Texture



Summary

Many recent innovations in concrete pavement materials, design and construction, including:

- Improved mixture designs (aggregate blending, blended cements, admixtures, etc.)
- Dowel materials and designs
- Precast pavement systems
- Software – design, analysis and construction tools
- Paving equipment, Concrete Overlays, Roller-Compacted Concrete
- Innovative Surface Textures

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- U.S. Federal Highway Administration
- U.S. National Highway Institute

SEMINARIO INTERNACIONAL
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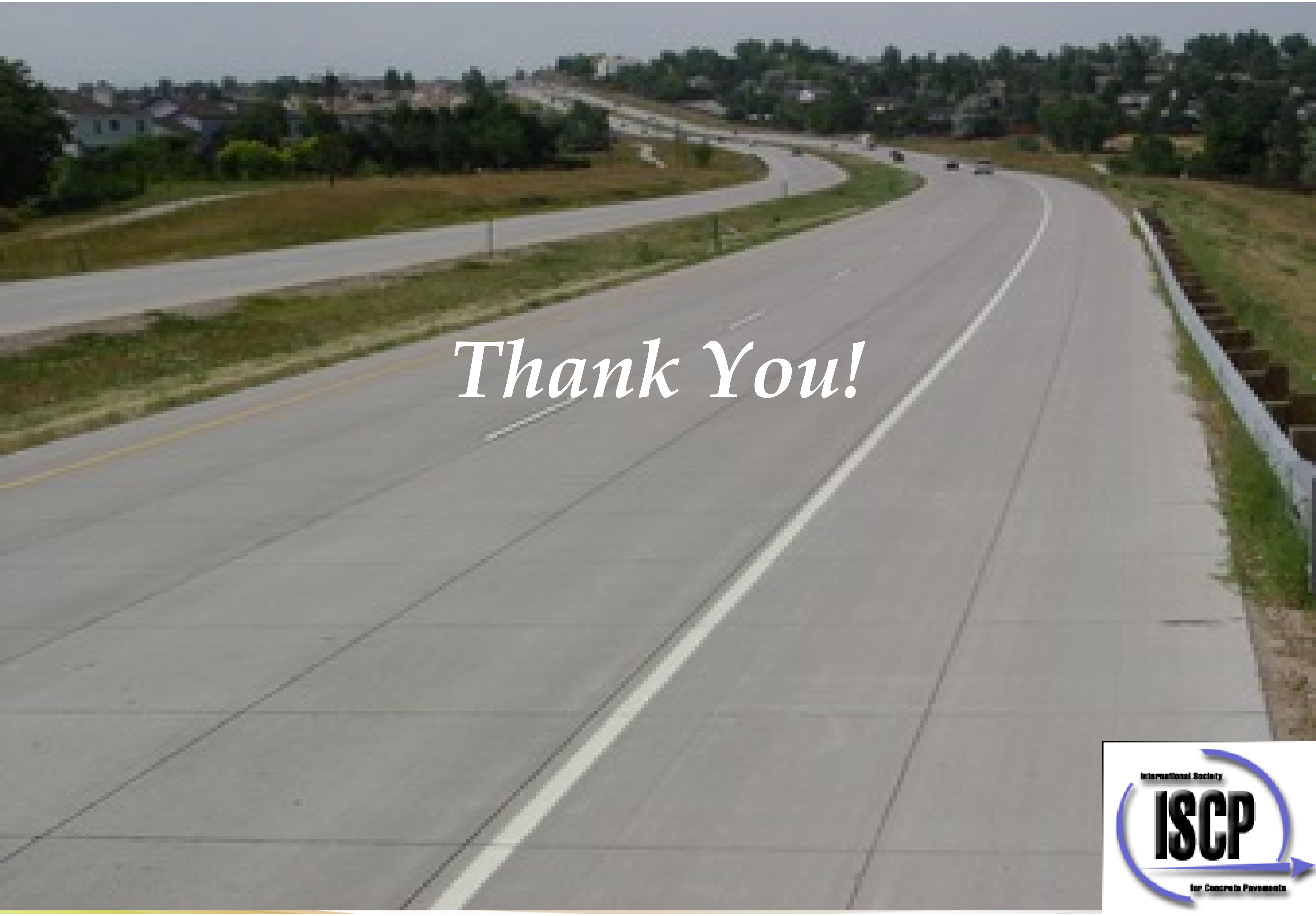
Thank You!
International Society
ISCP
for Concrete Pavements

International Society

ISCP

for Concrete Pavements

ISCP's Mission

- Facilitate the advancement of knowledge and technology related to concrete pavements through education, technology transfer and research at an international level.
  - Gather and disseminate information for the concrete pavement community.
  - Promote technological advancements and competence of its members leading to improved concrete pavement performance.

Recurring ISCP Activities:

- Organize International Conference every 4 years.
- Electronic Newsletter (bi-monthly).
  - Society news, Calendar
  - Thesis and research report abstracts
  - Industry news and developments, more
- ISCP Website
  - Online event and membership registration
  - Meeting minutes, Society documents
  - Member Forum
  - PCC Pavement Information Clearinghouse (under development)
- Annual Membership Business Meeting in Washington DC (in conjunction with TRB)

Summary of ISCP International Conferences

- 7th Int'l Conference (2001, Orlando, Florida, USA)
  - Approx. 365 attendees representing > 20 countries
- 8th Int'l Conference (2005, Colorado Springs, USA)
  - Approx. 450 attendees representing ~30 countries
- 9th Int'l Conference (2008, San Francisco, USA)
  - Approx. 325 attendees representing 30 countries
- 10th Int'l Conference (2012, Québec, QC, Canada)
  - Approx. 300 attendees representing 28 countries
- *Summary to date: More than 800 different attendees representing more than 40 different countries.*

Recent Conference and Workshop Sponsorship and Collaboration

– August 2007 – South Africa with C&CI
– September 2007 – Xi'an, China with Chang'An University
– October 2007 – IBRACON Conference, Brazil
– November 2009 – Chile Concrete Pavement Design Workshop with Catholic University
– March 2010 – Lima, Peru, with Peru ACI
– FHWA/CPTP Int'l Conference on Concrete Sustainability (September 2010 - Sacramento, CA, USA)
– EUPAVE Int'l Symposium on Concrete Pavements (October 2010 - Seville, Spain)
– April 2011 – Xi'an, China with Chang'An University
– August 2011 – Sydney, Australia with Australian Society for Concrete Pavements
– November 2011 – Florianopolis, Brazil with University of São Paulo and IBRACON

Other Current ISCP Activities

- Technology Transfer Center
  - Online clearinghouse for all international publications concerning PCC pavement technology
  - Website “Hot Topic” Links
  - Speaker’s Bureau
- Develop Network of Local Technical Coordinators
  - Encourage broader international activity
  - Organize local ISCP events

Active ISCP Membership

- Individual Members
  - Approaching 200 Members (including 14 honorary)
    - Increased from ~30 in 1999
  - ~25 Countries Represented
  - Membership represents contractors, consultants, academia, government, students, suppliers, association members, etc.

Membership Benefits

- Registration Discounts at ISCP-sponsored events
- Complete and free access to ISCP website information and features
  - LinkedIN technical forum online
- Monthly ISCP E-newsletter
- Reciprocal benefits with affiliated organizations

- *Opportunity to develop contacts with pavement engineering professionals from around the world!*

Active ISCP Organizational Members (Sponsors)

- American Concrete Pavement Association
- Canadian Airfield Pavement Technical Group
- Cement Association of Canada
- CEMEX
- CIMA
- Concrete Reinforcing Steel Institute (CRSI)
- U.S. Federal Aviation Administration
- Fugro Consultants, Inc.
- GENIVAR
- Holcim
- Instituto del Cemento y del Hormigón de Chile
- Manitoba Infrastructure and Transportation
- National Concrete Pavement Technology Center (US)
- National Precast Concrete Association (US)
- Ontario Ministry of Transportation
- Precast/Prestressed Concrete Institute
- Stantec Consulting Ltd.
- Transports Québec
- University of California Pavement Research Center
- Wirtgen

Organizational Sponsors: Current Benefits

- Complimentary membership for key contact
- Discounted membership fee for employees
- Access to members-only online forum
- Link to corporate website from ISCP website
- Logo placement on ISCP website and newsletter
- More …

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