National Concrete Pavement Technology Center

Tech Center

IOWA STATE UNIVERSITY

Institute for Transportation

Integrated Materials and Construction Practices for Concrete Pavement

May 13, 2025

A State-of-the-Practice Manual
2nd Edition

Iowa State University
Institute for Transportation

massDOT
Massachusetts Department of Transportation

National Concrete Pavement Technology Center
CP Tech Center

National Concrete Pavement Technology Center (CP Tech Center)

Missions:

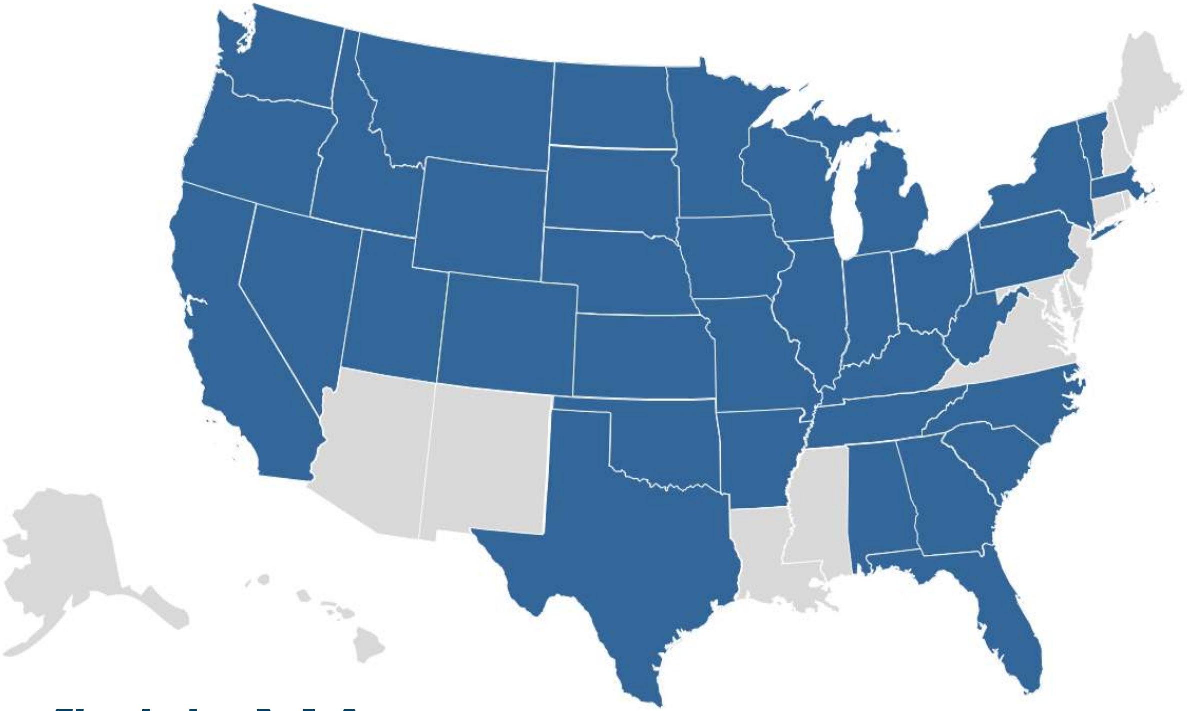
- Advance innovative concrete pavement technologies
- Lead implementation of best practices
- Educate the concrete pavement community
- Find solutions to strategic problems
- Provide independent technical expertise

www.cptechcenter.org

INDUSTRY
AGENCIES
ACADEMIA

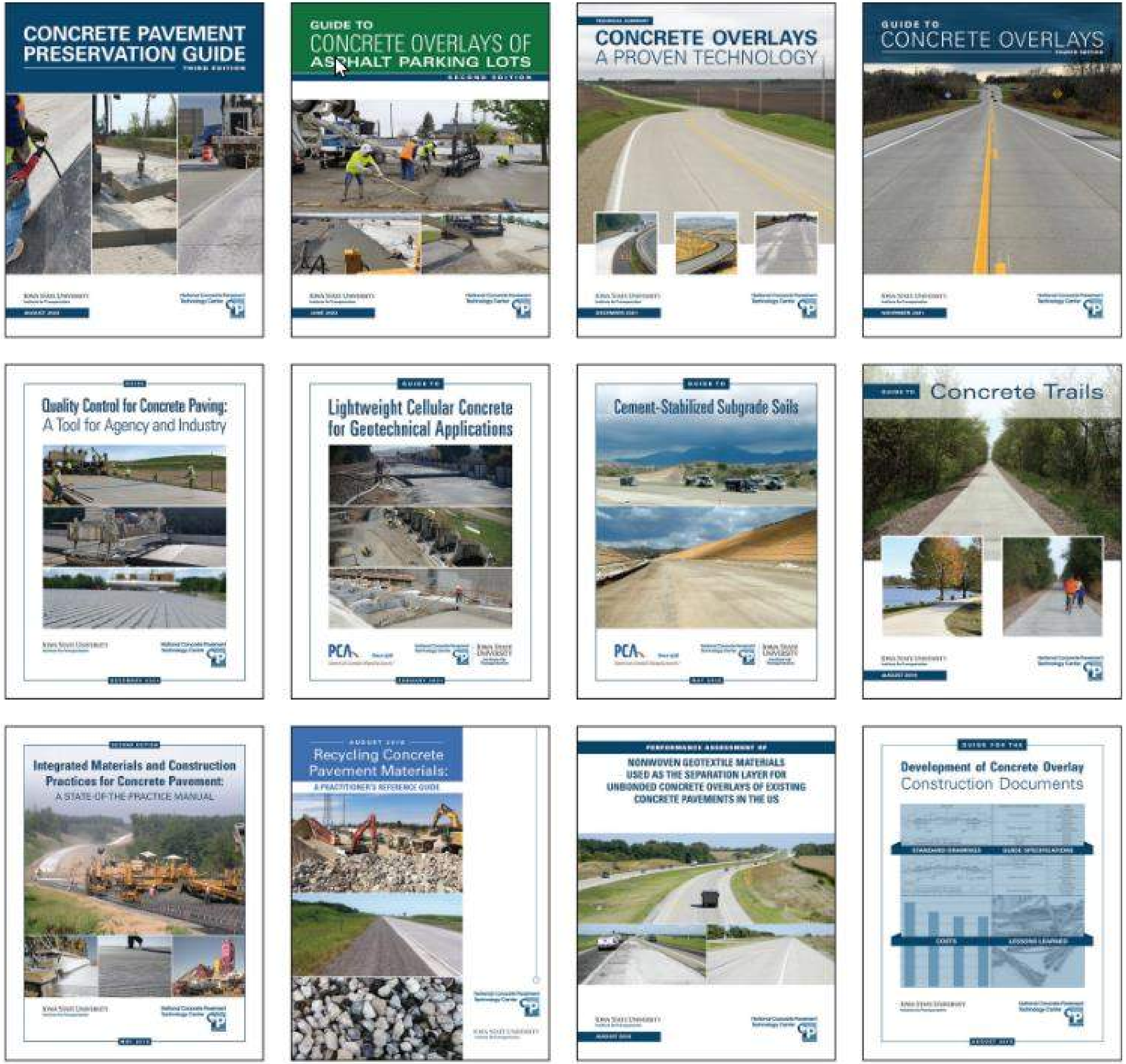
National Concrete Consortium - NC^2

- **TPF-5(544) Commitments**
  - 36 states + IL Tollway
- **Other information available:**
  - E-News
  - MAP Briefs
  - Research Resources



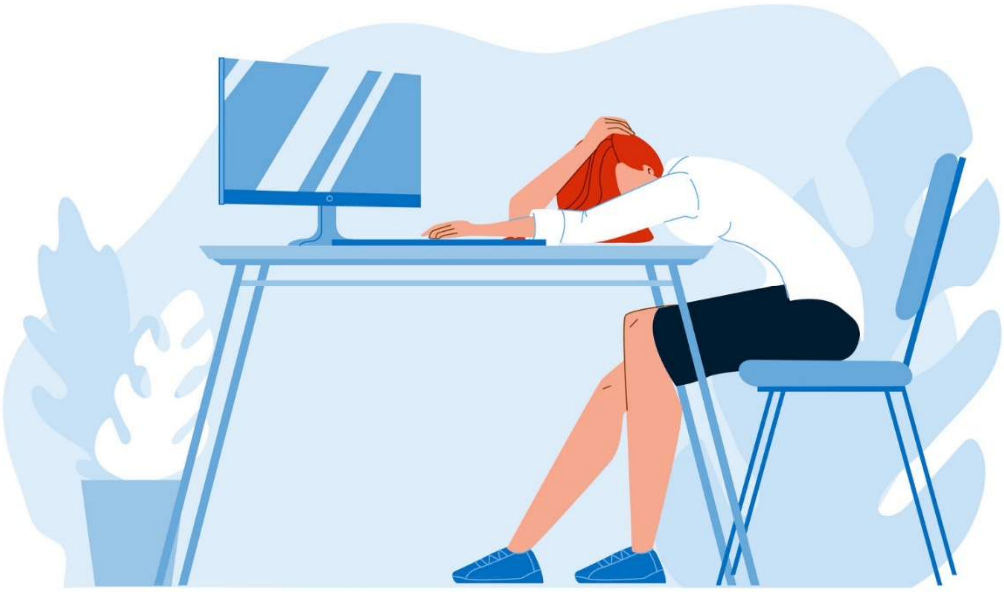
- **NCC Fall Meeting**
  - September 9-11, 2025: Springfield, MA

CP Tech Publications



Why Are We Here?

- Because the boss insisted
- Collect PDHs
- To learn about concrete!



IMCP Workshop

Please ask questions – that is how we all learn

Presenters today:

Peter Taylor PhD, PE
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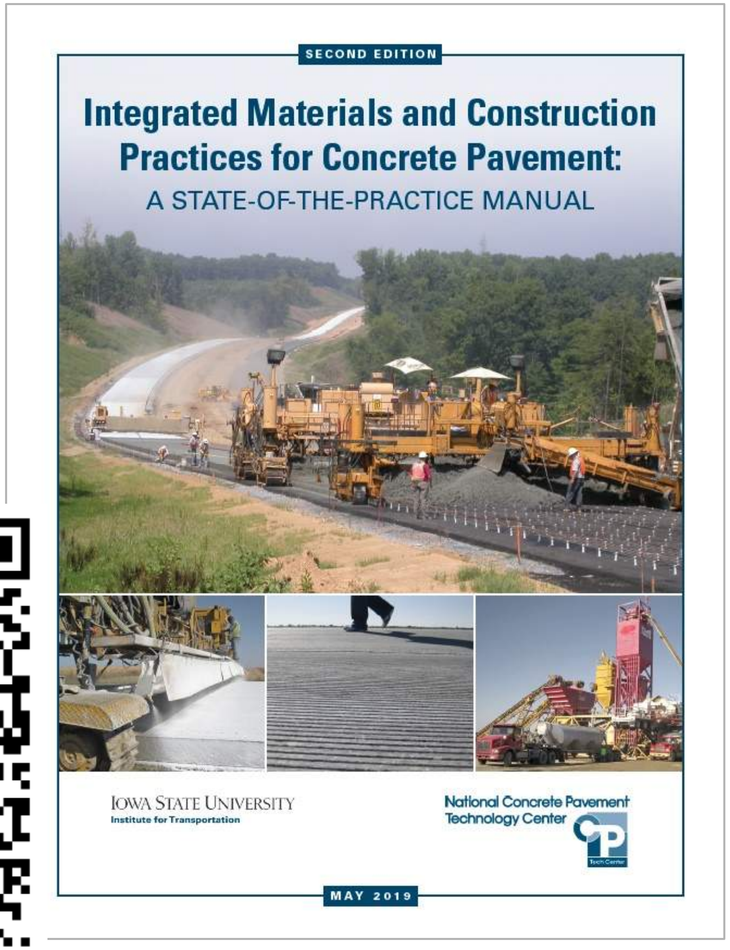
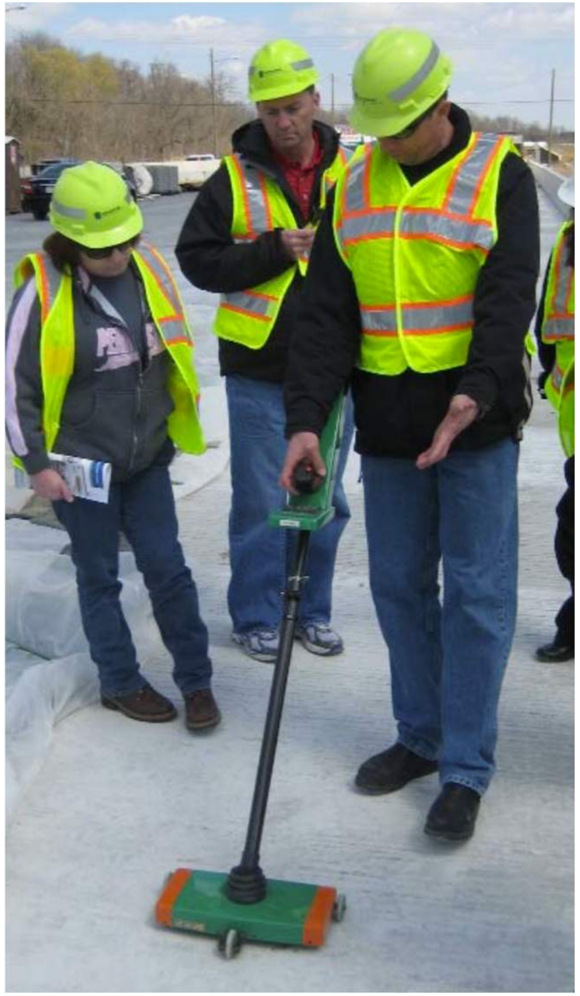
Jerod Gross, PE, LEED AP
jgross@snyder-associates.com



Today's Participants?

Organizations

- State DOTs
- FHWA
- Local agencies
- Contractors
- Materials suppliers
- Consultants
- Universities
- Other?



Why Was the Manual Developed?

Help practitioners

- Understand how their decisions will affect other processes
- Make wise decisions
- Be smart inspectors

Provide a ready reference and/or troubleshooting guide

Today's Agenda

8:00	Welcome & Introduction
8:15	Overview of Concrete Pavements
8:45	Breakout Discussion
9:15	Design
9:45	BREAK
10:15	Materials & Hydration
10:45	ACMs
11:15	Mixture Proportions
11:45	LUNCH
12:30	Breakout Discussion
1:00	Construction
2:00	BREAK
2:30	Tests & Specifications
3:00	Quality & Inspections
3:45	Application to Mass
4:15	Adjourn

Overview

Questions before we dig in?

Overview of Concrete Pavements

National Concrete Pavement Technology Center

Tech Center

Outline

Sustainability

Durability

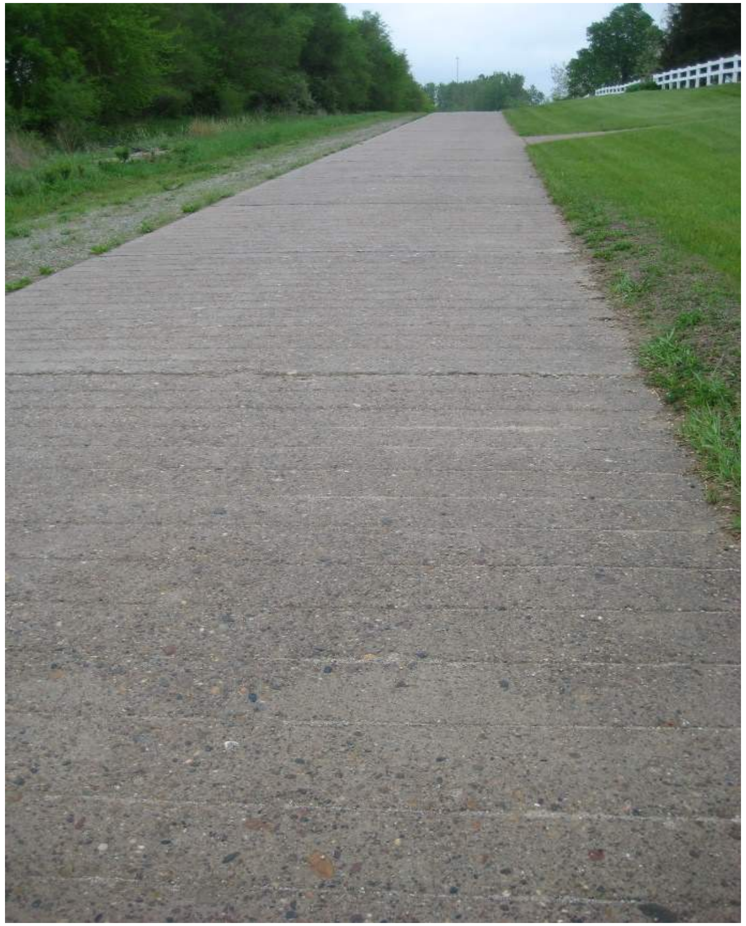
PEM

Concrete History

Concrete pavements can and should last a long time

Concrete History

LeMars, Iowa (1904 construction) - 1950 photo

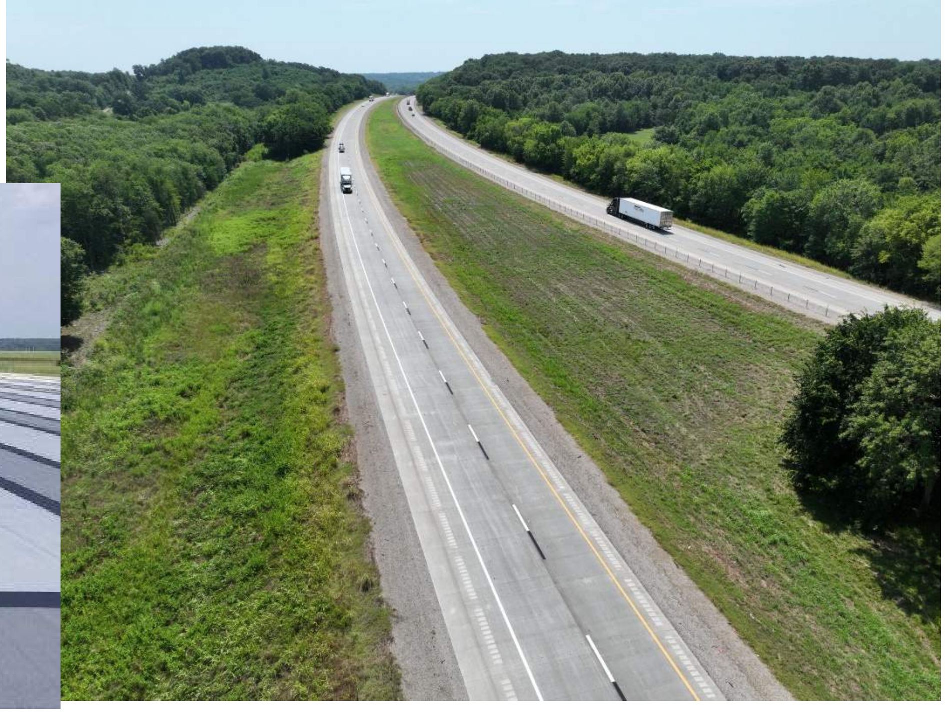


Eddyville, Iowa (1909 construction)

Why Build More Concrete?

Our society is built on the ability to move people, goods and energy

- Food
- Expertise
- Education
- Healthcare



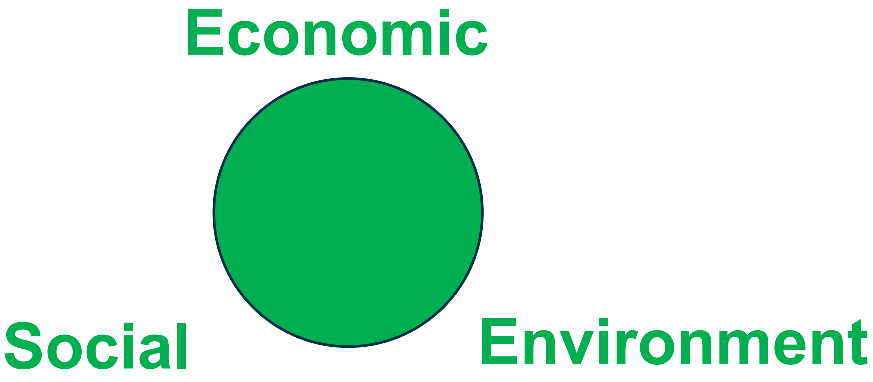
Pavement should last a long time

Which is more Economical?

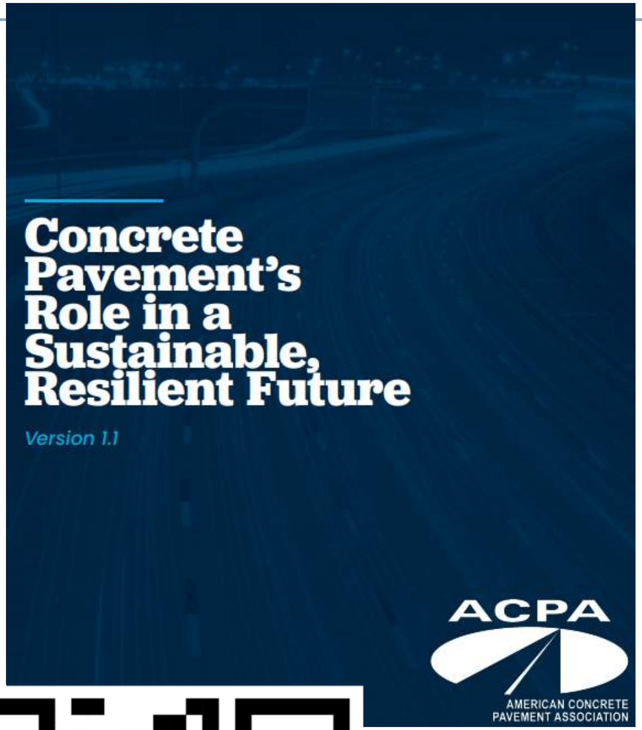
What is Sustainability?

A sustainable pavement is one that achieves its specific engineering goals, while:

- It meets basic human needs
- Uses resources effectively
- Preserves/ restores surrounding ecosystems



Begins with Sustainable Value



How to Improve Concrete Sustainability

Target the Cementitious Binder

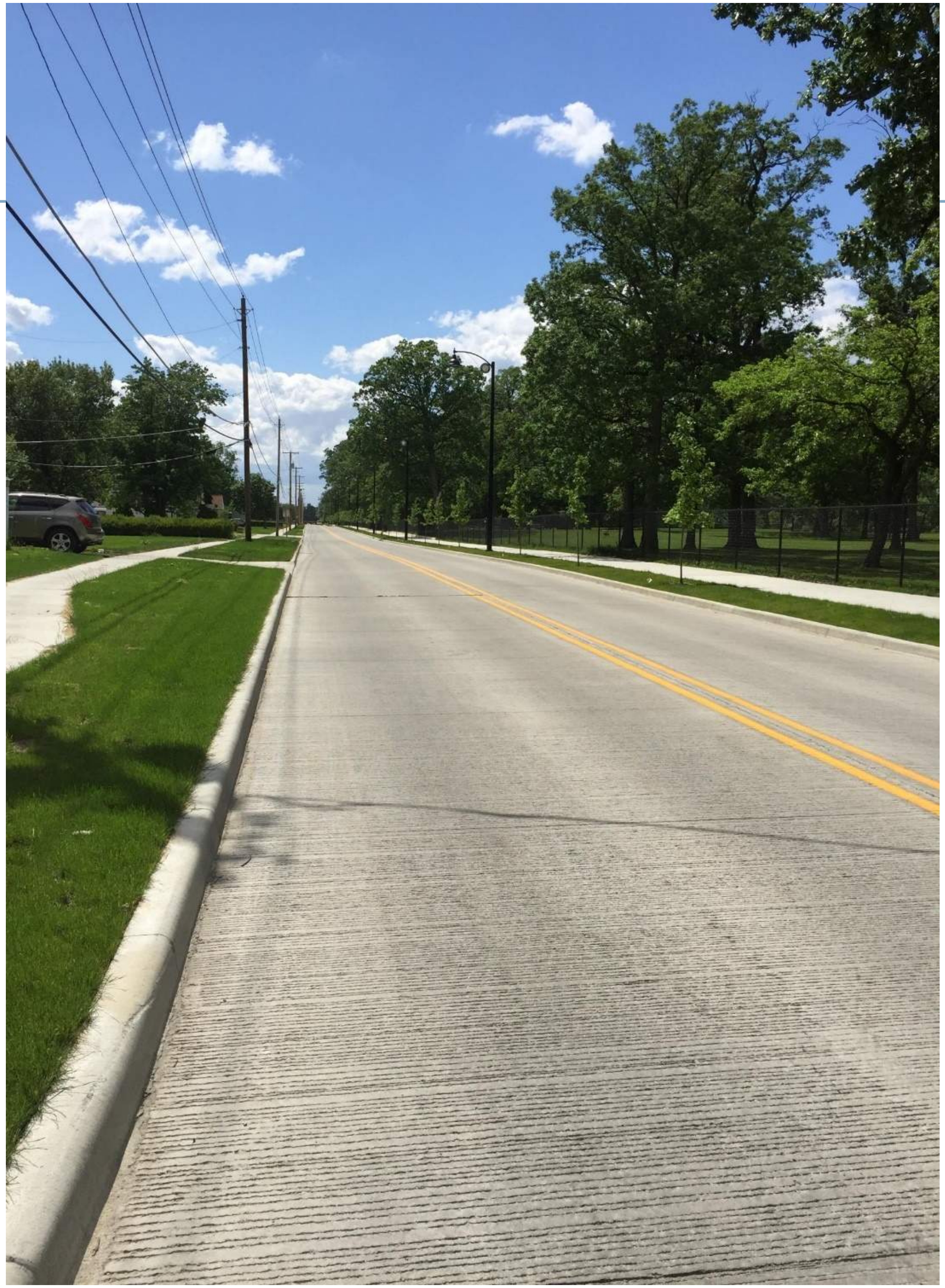
- Use Type IL & SCMs
- SCMs improve workability, durability & long term strength (watch setting & strength rate)

Target the Concrete Mixture

- Optimized aggregate gradations
- Paste Volume $\leq$ 25%

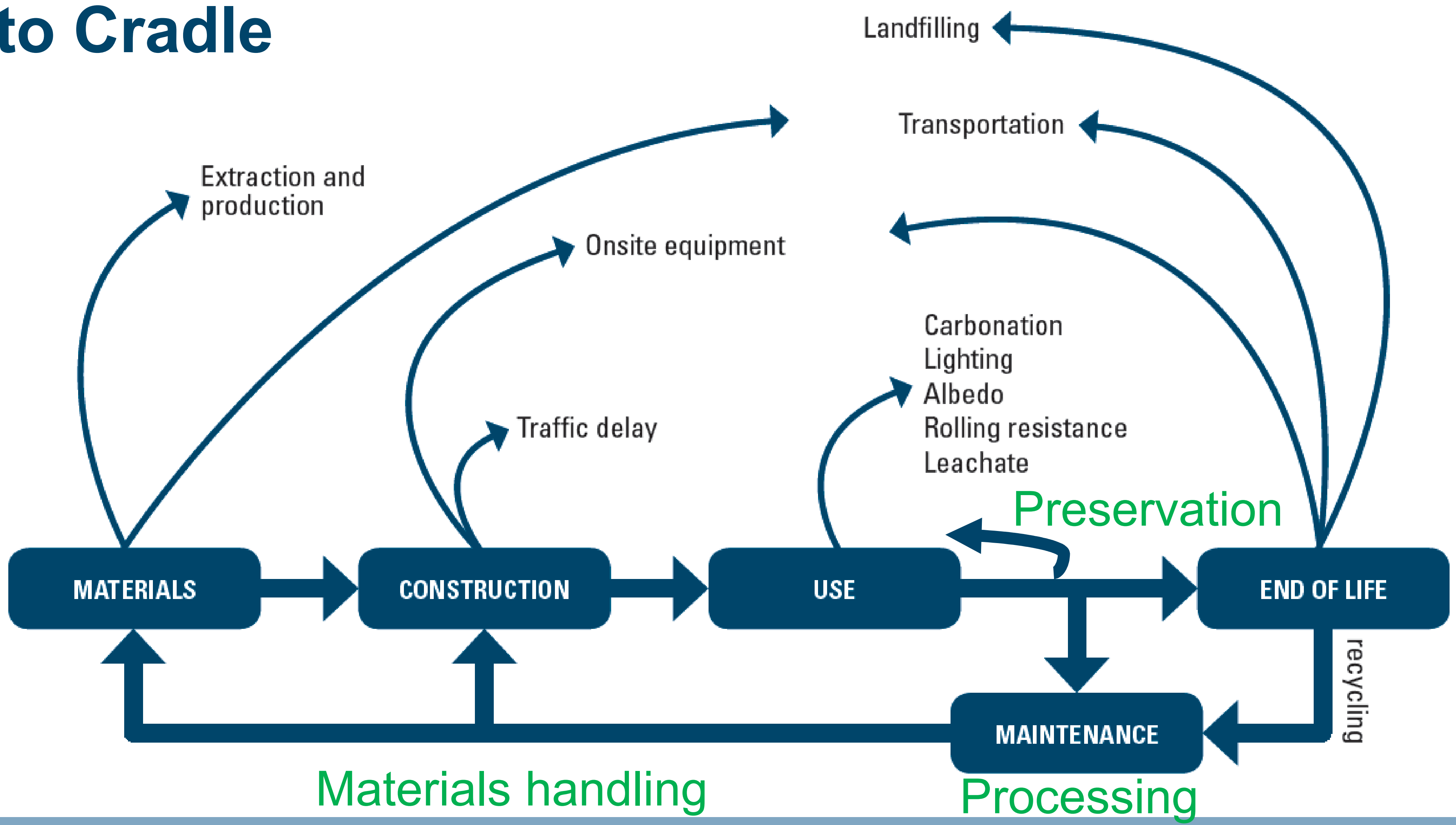
Target Mixture Performance Requirements

- Implementing performance-based specifications
- AASHTO R101



Durability - Pavement Life Cycle

Cradle to Cradle



Sustainability Through 'Use' Phase

- 80% of the energy and emissions associated with pavements is incurred during use phase
  - Fuel efficiency / Rolling resistance
  - Albedo / Reflectance
    - Heat island
    - Lighting costs
  - Grinding
    - Smoothness
    - Less noise

MIT Fuel/Carbon Savings Calculator

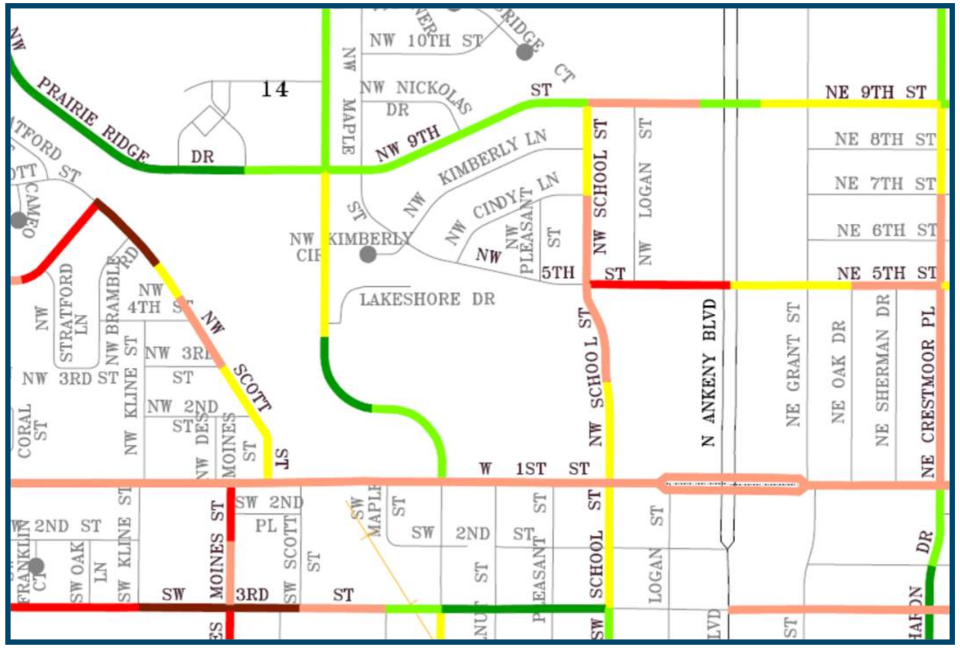
Assessing Durability

How do we assess durability?

What can we measure?

Performance assessment

- Condition ratings (Distresses)
- Structural capacity (PCI)
- Ride quality (IRI)
- Friction characteristics for safety
- Noise



Durability based on LCCA

Life-cycle cost analysis (LCCA)

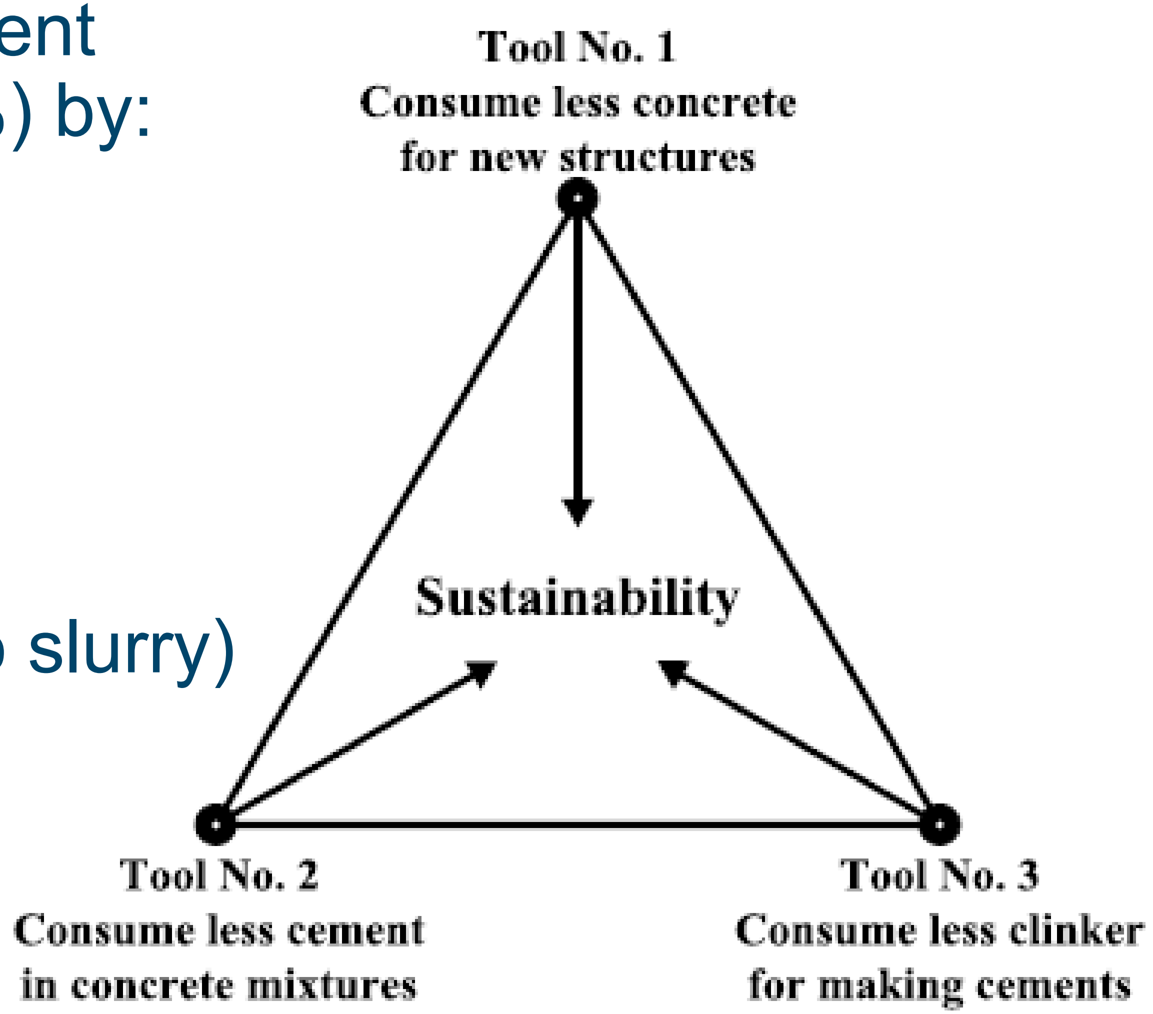
- ACPA Life Cycle Cost Analysis (2020)
- FHWA's RealCost 3.0 (FHWA 2011)
- CPAM – LCCA spreadsheet
- MIT Concrete Sustainability Hub

Leslie Ashauer, Wisconsin Concrete Pavement Association

What about Cement?

Costs can be reduced by reducing cement (and cutting carbon by as much as 50%) by:

- efficient thickness design
- 30% SCM's
- Optimized aggregate gradation
- Introduce ground limestone
- Dry processing cement production (no slurry)



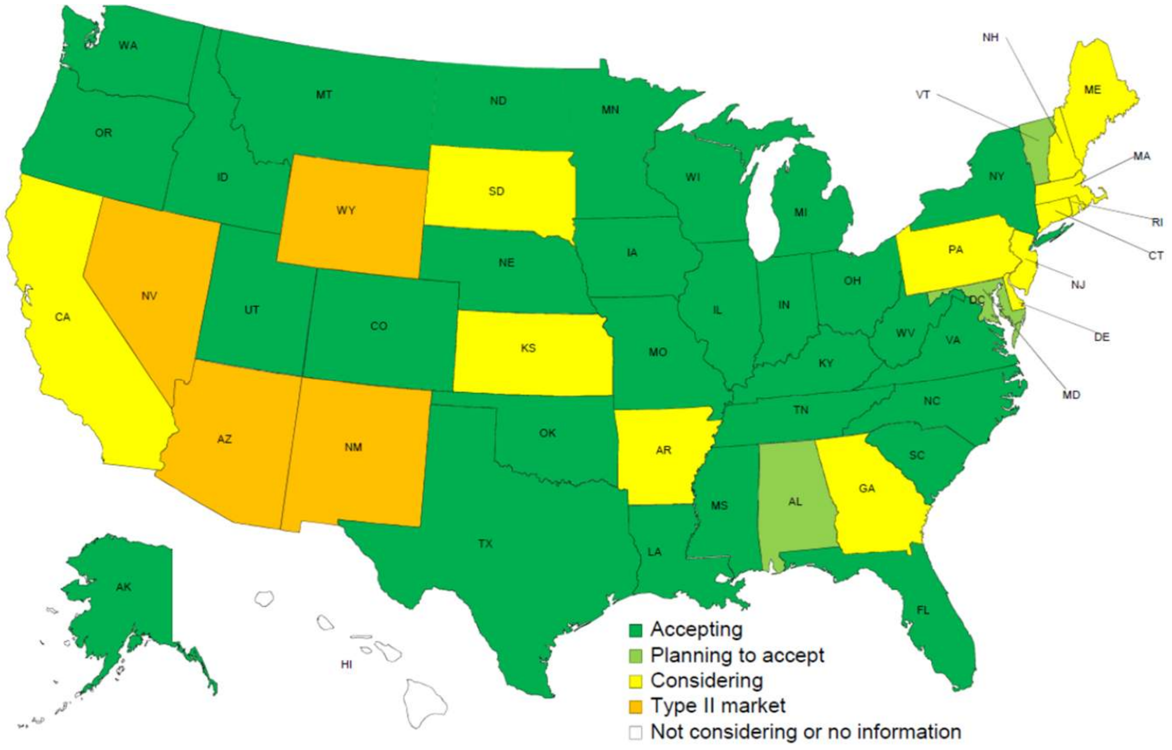
Mehta, CI Feb. 2009

Portland Limestone Cements – Type IL

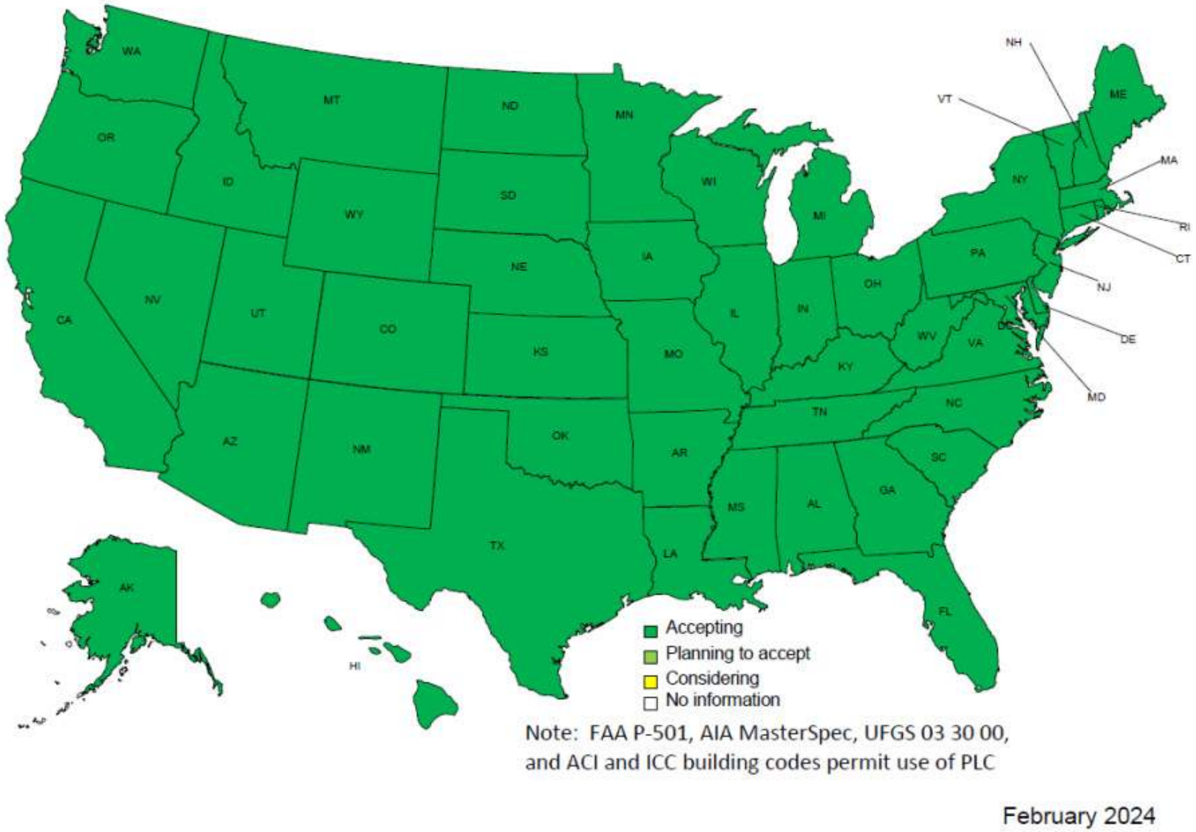
- 5% - 15% finely ground limestone interground with clinker
- Can reduce carbon footprint by 10%
- Equivalent performance with ordinary portland cement
- 2022 was changeover year
- All domestic producers switched to PLC
- ASTM C595 referenced in specifications

PLC Specified 2020 to 2024

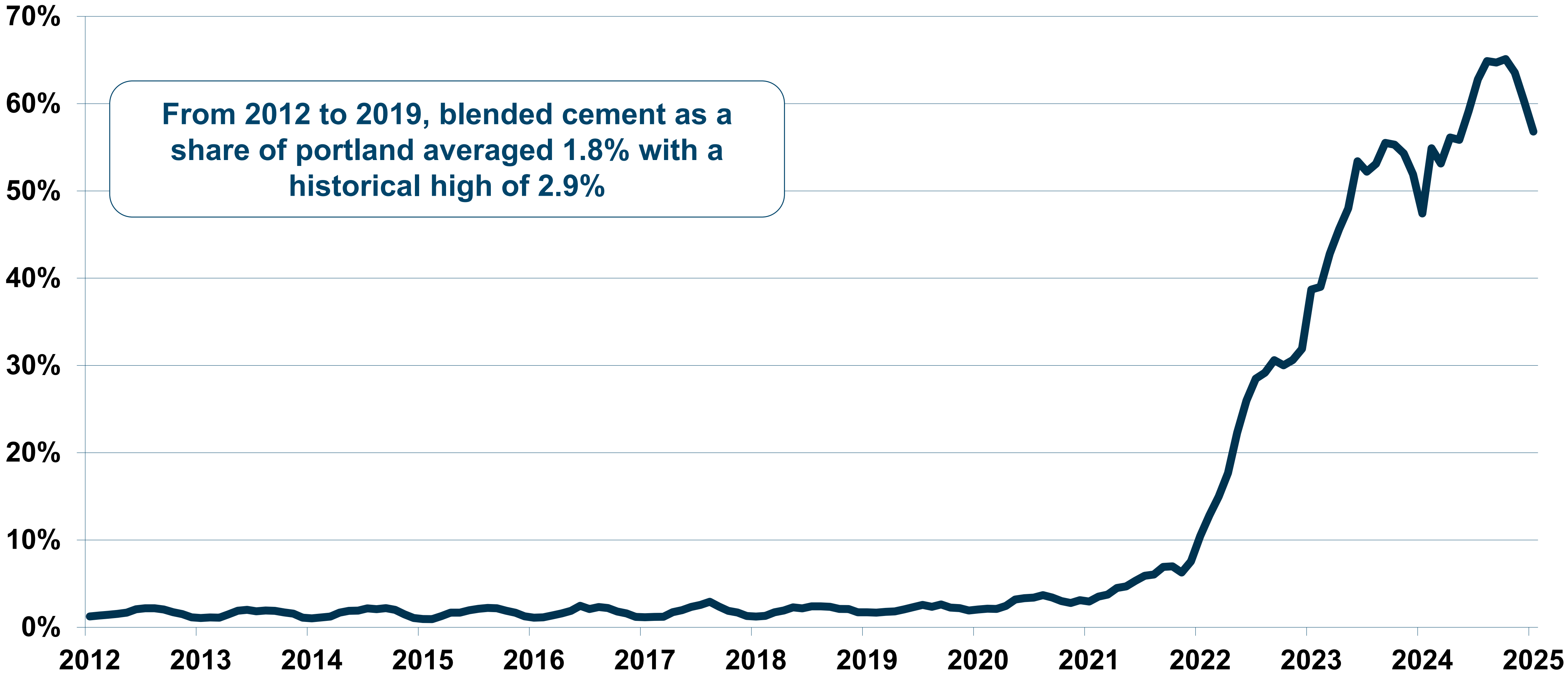
- 2018



- 2024



Blended Cement as a Share of Total Cement - US



Source: USGS & PCA

Ternary Paving Mixtures

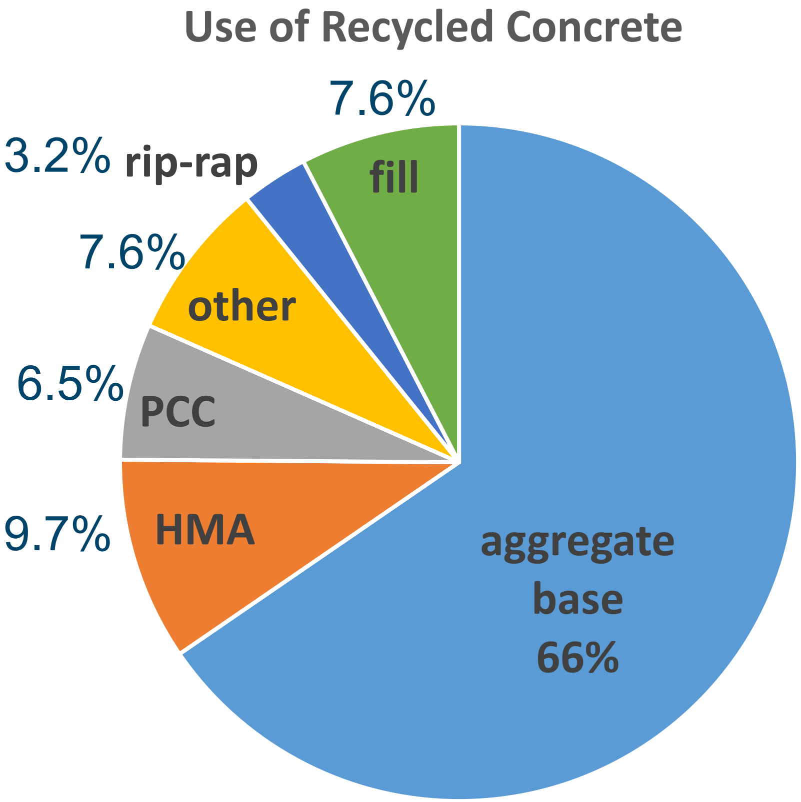
- Supplementary Cementitious Materials (SCMs)
  - Fly ash
  - Slag
  - Silica fume
  - Natural pozzolans
- Can enhance engineering properties and performance of pavements
- Can improve sustainability ($$ & CO_2)

Strategies for Design

Local and Recycled Materials

- Use less fuel to haul it in
- Avoid throwing away the old pavement
  - Recycling

'Cradle to Cradle'



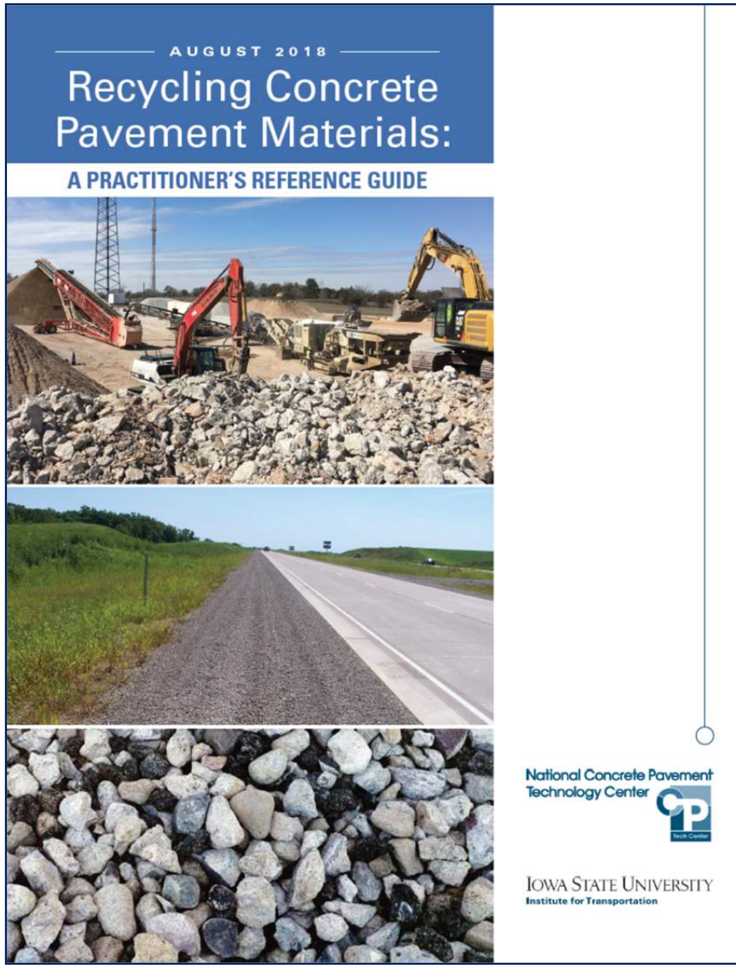
Recycled Concrete Aggregate

Technical products developed:

- How to engineer RCA applications
- Use RCA in most advantageous way

Products:

- RCA Materials: Practitioner's Reference Guide
- Webinar series
- Tech Briefs
- 2016 Benchmarking Survey
- Technical Resources

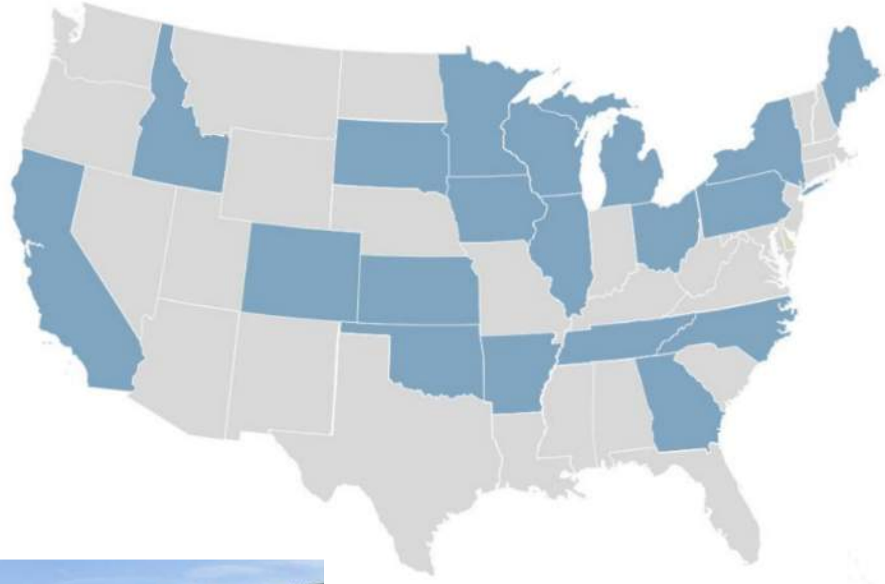


cptechcenter.org/concrete-recycling/

What is Performance Engineered Mixtures (PEM)?

- Performance-Engineered Mixtures TPF-5(368) 2017-2022
- Performance Centered Concrete Construction TPF-5(517) **2024-2029**
- Assist states in adoption of test methods that will help deliver concrete durability
- Focus on the things that matter

cptechcenter.org/pem



How can we achieve durable concrete?

Six Critical Properties

1. Transport properties
2. Aggregate stability
3. Freeze-thaw durability
4. Shrinkage
5. Workability
6. Strength

These are the properties of PEM

PEM Shadow Projects

- State DOT & MCTC coordination
- Test Training
- Data collection and evaluation

Durability through PEM

Optimized Aggregate Gradation
- Lower cement (30 + pcy)
- Lower paste
- Lower shrinkage
    - Reduced cracking
- Cost savings
- Increased workability
- Increased durability

Use of SCMs
- Lower cement
- Cost savings
- Increased workability
- Increased resistivity
- Increased durability
- Reduce CO2

PEM Accomplishments

AASHTO R101

DOT specification improvements

Training

PEM exposure

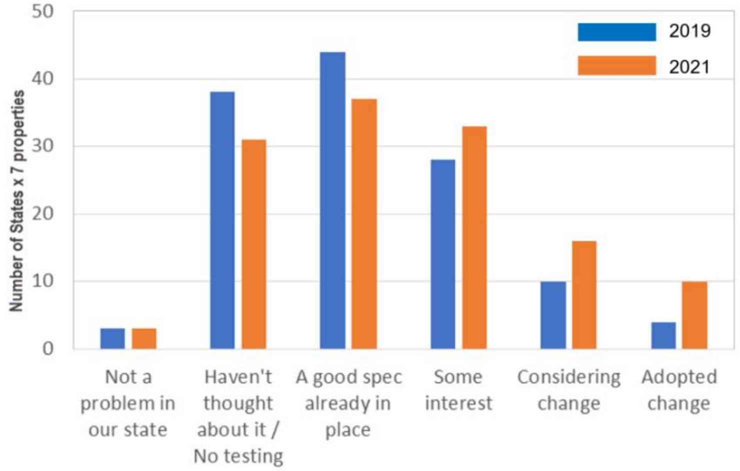
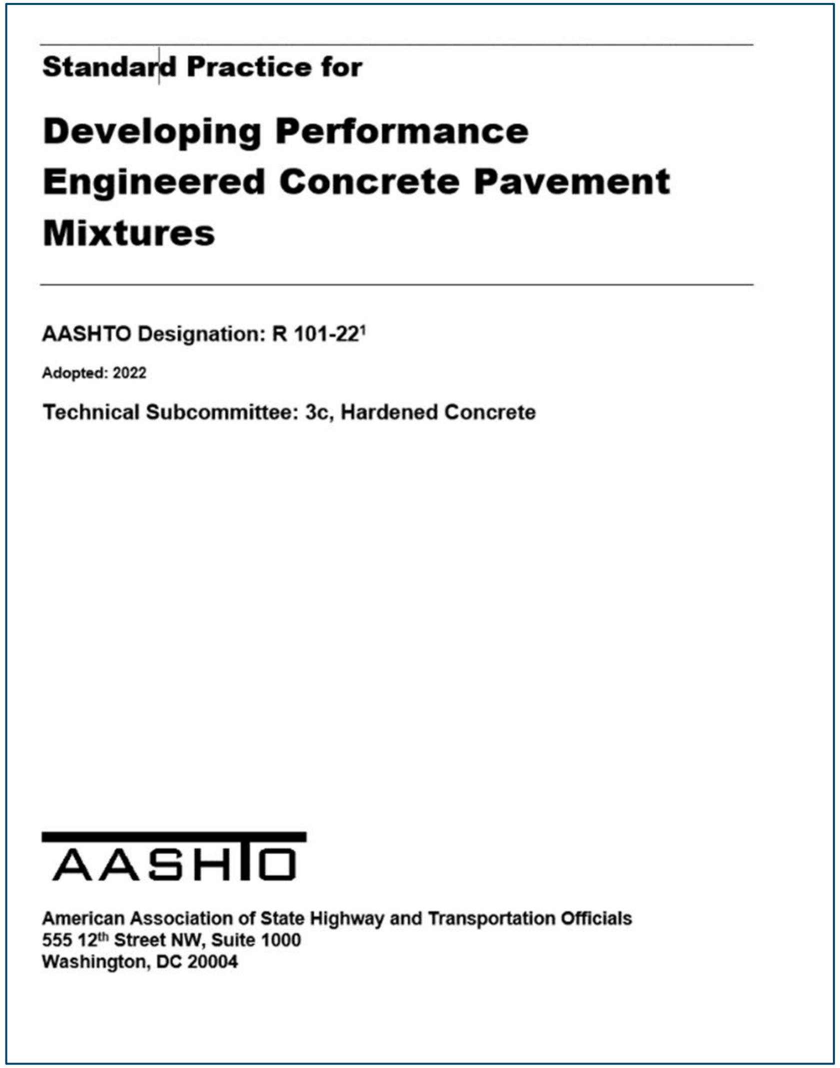


Figure 31. PEM advancement in state specifications



Standard Practice for

Developing Performance Engineered Concrete Pavement Mixtures

AASHTO Designation: R 101-22[1]

Adopted: 2022

Technical Subcommittee: 3c, Hardened Concrete

AASHTO

American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, DC 20004

AASHTO R 101 Philosophy and Goals

- Allows an agency to specify performance characteristics rather than prescriptive
- Respects agency traditions and knowledge
  - Keep existing requirements that make sense based on local knowledge and experience
- Not a Specification
  - A tool to help agencies develop a specification that fits their needs

AASHTO R101 - Table 2

Table 2—Specification Worksheet for Mixture Proportioning

Section	Property	Specified Test	Specified Value		Mixture Qualification	Acceptance	Selection Details	Special Notes
			6.3 Concrete Strength					
6.3.1	Flexural Strength	T 97	4.1 MPa	600 psi	Yes	Yes	Choose either or both	—
6.3.2	Compressive Strength	T 22M/T 22	27.5 MPa	4000 psi	Yes	Yes		—
			6.4 Reducing Unwanted Slab Warping and Cracking Due to Shrinkage (if cracking is a concern)					
6.4.1.1	Volume of Paste	—	≤25%		Yes	No	Choose only one	—
6.4.1.2	Unrestrained Volume Change	T 160	420 με	At 28 days	Yes	No		—
6.4.2.2	Unrestrained Volume Change	T 160	360, 420, 480 με	At 91 days	Yes	No		—
6.4.2.1.1	Unrestrained Volume Change	T 334	No cracking	At 180 days	Yes	No		
6.4.2.1.2	Restrained Volume Change	T 363	<60% f'r	At 7 days	Yes	No		
			6.5 Durability of Hydrated Cement Paste for Freeze–Thaw Durability					
6.5.1.1	Water to Cementitious Ratio	—	0.45	—	Yes	Yes	[a]	—
6.5.1.2	Fresh Air Content	T 152, T 196, TP 118	5 to 8%	—	Yes	Yes	Choose only one	—
6.5.1.3	Fresh Air Content/SAM	T 152, T 196, TP 118	≥4%; ≤0.20	—	Yes	Yes		—
6.5.2.1	Time of Critical Saturation	ASTM C1585	30	yr	Yes	No	[a, b]	Variation controlled with mixture proportion observation or *F* factor and porosity measures
6.5.3.1	Deicing Salt Damage	—	30%	SCM	Yes	Yes	Choose only one if concrete will be exposed to deicing salts	Are calcium or magnesium chloride used
6.5.3.2	Deicing Salt Damage	M 224	—	Topical treatment	Yes	Yes		Are calcium or magnesium chloride used; use specified sealers
6.5.4.1	Calcium Oxychloride Limit	T 365	<0.15 g CaOXY/100 g paste		Yes	No		Are calcium or magnesium chloride used

Expansion (mortar bar)

Single Ring Test

Dual Ring Test

AASHTO R101 - Table 2

				6.6 Transport Properties				
6.6.1.1	Water to Cementitious Ratio	—	≤ 0.45 or ≤ 0.50	91 days[c]	Yes	Yes	Choose only one	The required maximum water to cementitious ratio is selected based on freeze–thaw conditions
6.6.1.2	Formation Factor	Table 1	≥ 500 or ≥ 1000	91 days[c]	Yes	Yes		Based on freeze–thaw conditions; other criteria could be selected
6.6.2.1	Ionic Penetration, *F* Factor		25 mm at 30 yr	91 days[c]	Yes, F	Through ρ		
				6.7 Aggregate Stability				
6.7.1	D Cracking	ASTM C1646, T 161	—	—	Yes	No		Procedure A
6.7.2	Alkali Aggregate Reactivity	R 80	—	—	Yes	No		—
				6.8 Workability				
6.8.1	Box Test	TP 137	<6.25 mm, $<30\%$ surface void			No		—
6.8.2	Modified VKelly Test	TP 129	15–30 mm/root s			No		—

Notes:

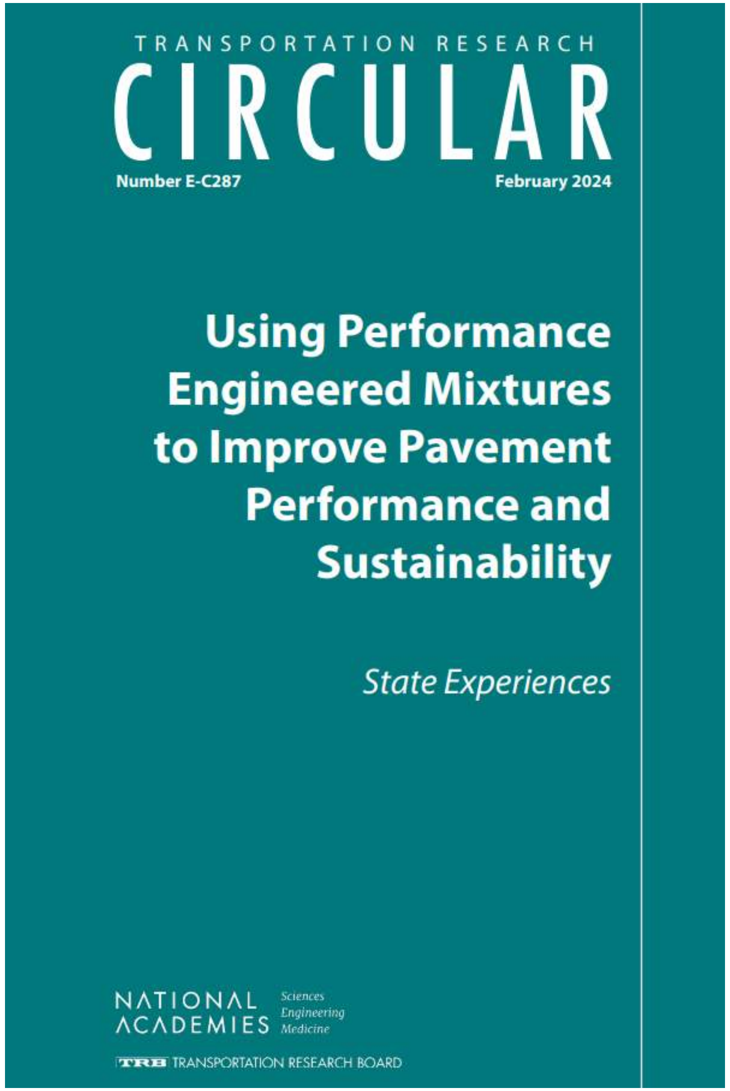
[a] Choose either Section 6.5.1.1 or 6.5.2.1.

[b] Choose either Section 6.5.1.2, 6.5.1.3, or 6.5.2.1.

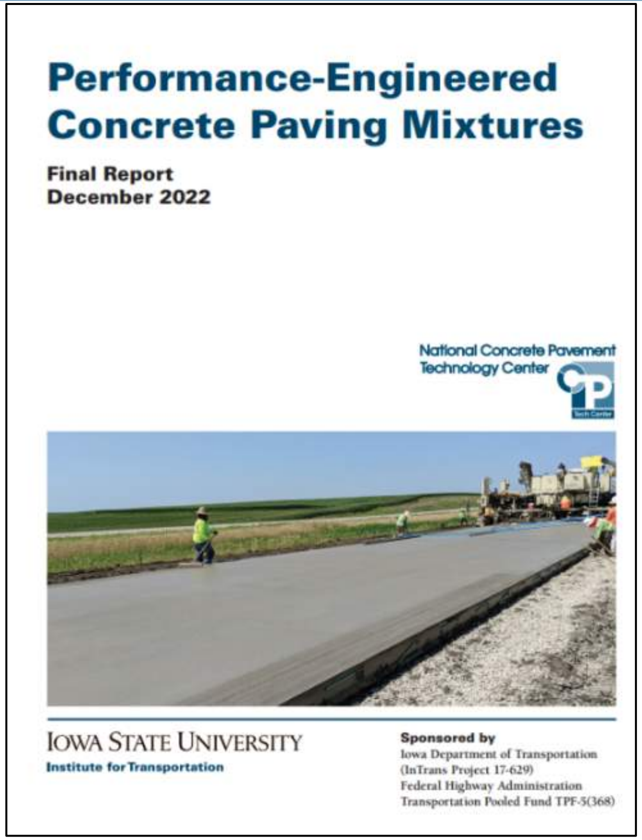
[c] Other ages can be used if desired however for SCM sufficient time should be allowed for the pozzolanic reaction.

TRB Circular – PEM State Experiences

- Iowa
- Minnesota
- Wisconsin
- Michigan
- New York
- North Carolina



PEM Resources



Performance-Engineered Concrete Paving Mixtures

Final Report
December 2022

National Concrete Pavement Technology Center

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Department of Transportation
(InTrans Project 17-629)
Federal Highway Administration
Transportation Pooled Fund TPF-5(368)

NATIONAL CONCRETE CONSORTIUM

"Moving Advancements into Practice"

MAP Brief Fall 2023

Best practices and promising technologies that can be used now to enhance concrete paving

PEM Evolution: Then and Now

FALL 2023

PROJECT TITLE
PEM Evolution: Then and Now

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Introduction

Performance-Engineered Mixtures (PEM) is an initiative that began several years ago with discussions between the Federal Highway Administration (FHWA), American Concrete Pavement Association (ACPA), and the National Concrete Pavement Technology Center (CP Tech Center). The goal was to advance concrete pavement mixtures toward performance-based specifications with the main challenge of defining effective methods of measuring the performance characteristics of concrete that directly relate to pavement durability and structural longevity. Concluding in 2022, TPF-5(368) focused on materials and mixtures, while, currently, TPF-5(517) focuses on what happens to the mixture after it is delivered to the site. A copy of the final report *Performance-Engineered Concrete Paving Mixtures* can be accessed here: intrans.iastate.edu/app/uploads/2023/04/performance-engineered_concrete_paving_mixtures_w_cvr.pdf.

This document provides the background of PEM; outlines the accomplishments, key findings, and implementation of TPF-5(368); and provides a look at what is current with PEM regarding construction practices (Figure 1).

Problem Statement and Project Justification

State transportation agencies and concrete pavement professionals have traditionally accepted concrete based on measurements like strength, slump, and air content. These measurements have had very limited correlation to future performance. However, recent developments in concrete testing technologies have yielded methods that are better predictors of long-term performance.

Todd Hanson, Iowa DOT, used with permission

Figure 1. Paving on US 20 using PEM test procedures

U.S. Department of Transportation
Federal Highway Administration

National Concrete Pavement Technology Center

Oregon State University

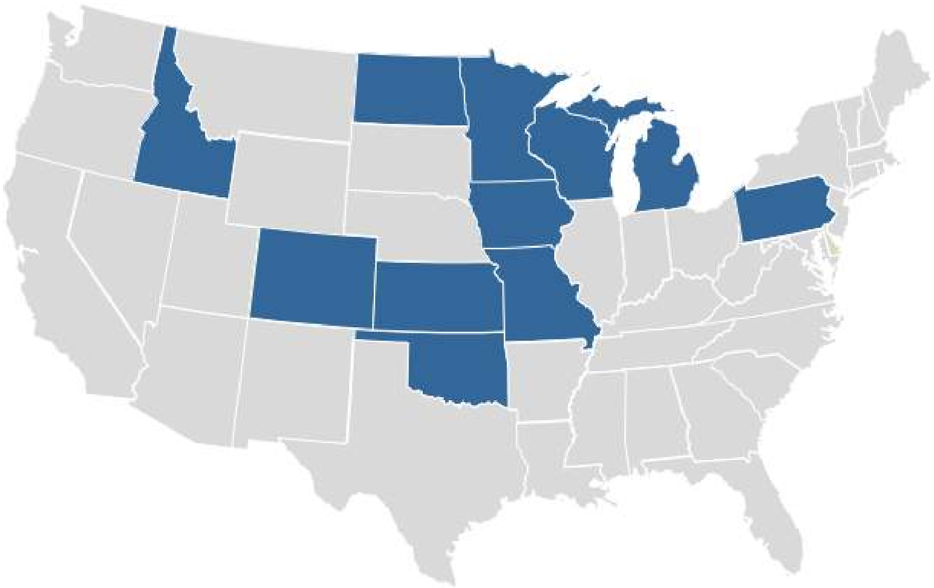
NCE

Diversified
Engineering
Services, Inc

SNYDER & ASSOCIATES

What is Next? P3C

- Performance Centered Concrete Construction (P3C) TPF-5(517)
- What happens during:
  - Hauling
  - Placement
  - Finishing
  - Curing
  - Sawing



Discussion

Basics of Concrete Pavement Design

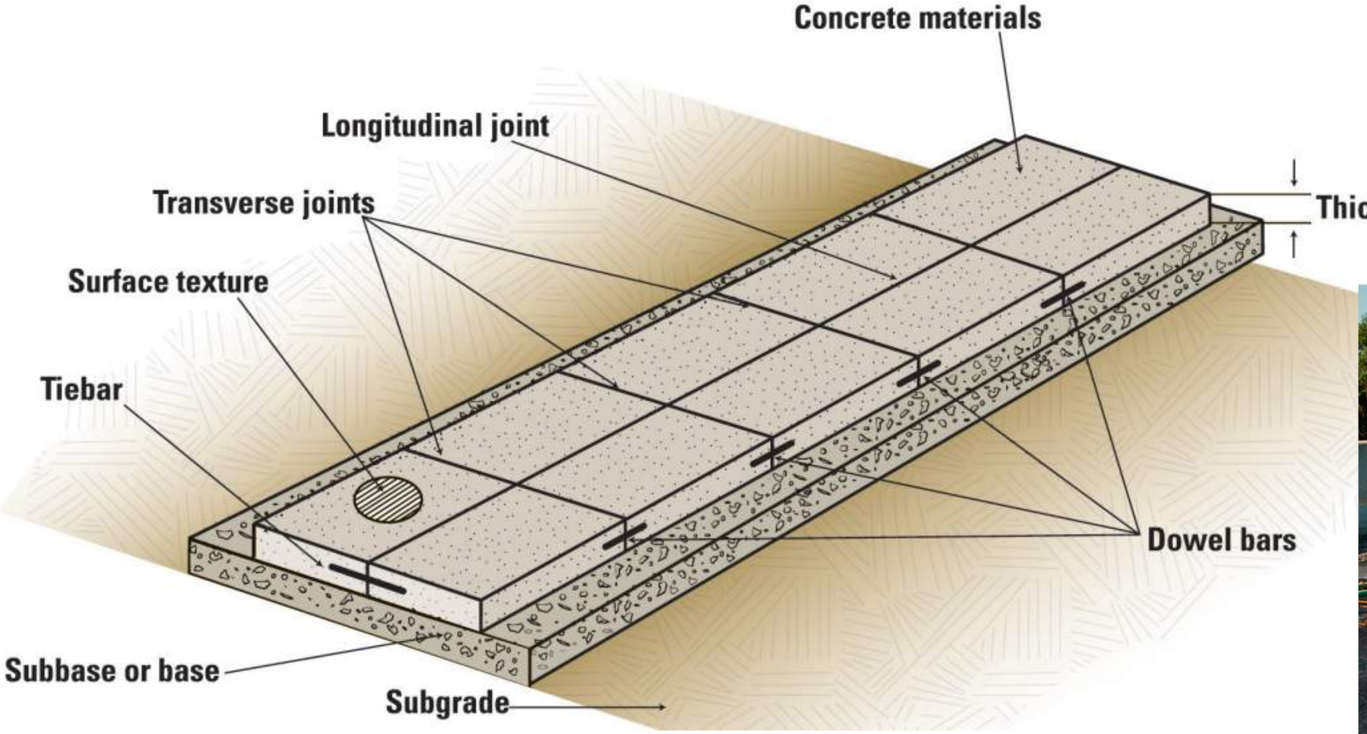
National Concrete Pavement Technology Center

Tech Center

Goal of Pavement Design

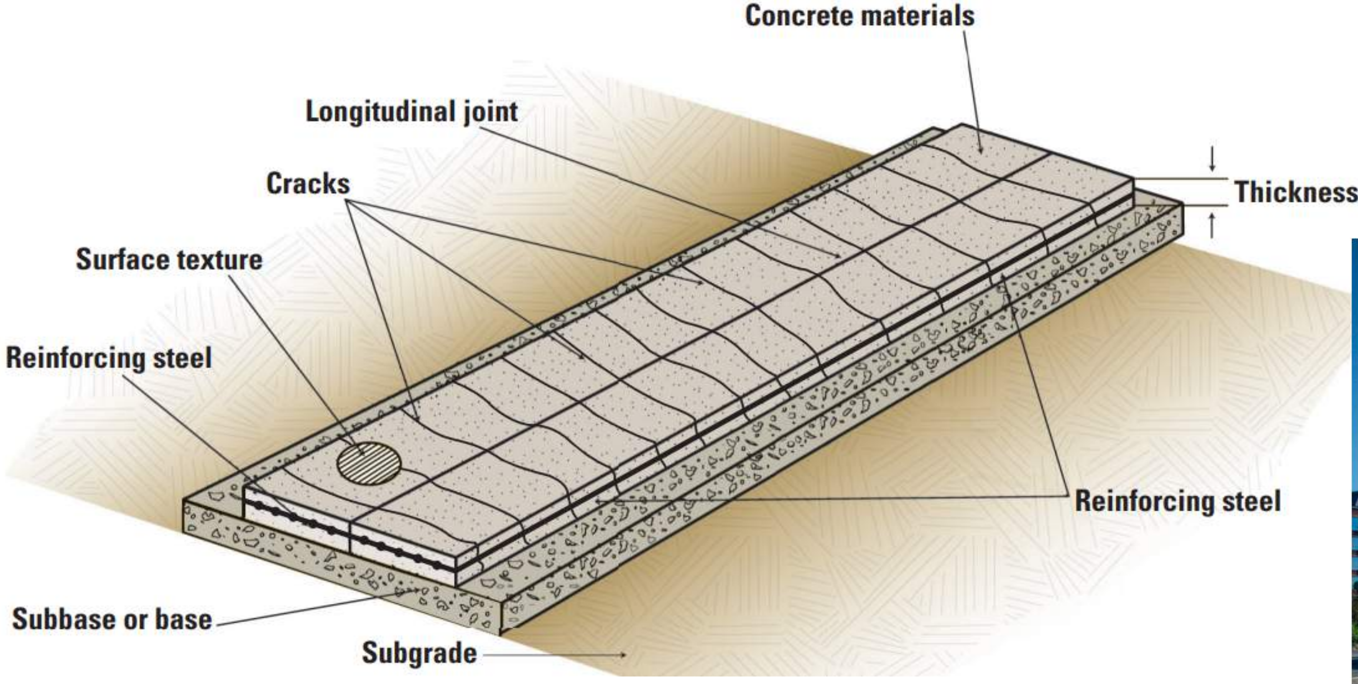
- Long lasting
- Cost effective
- Constructible
- Safe
- Low maintenance
- Serviceable

It’s Not Just Thickness

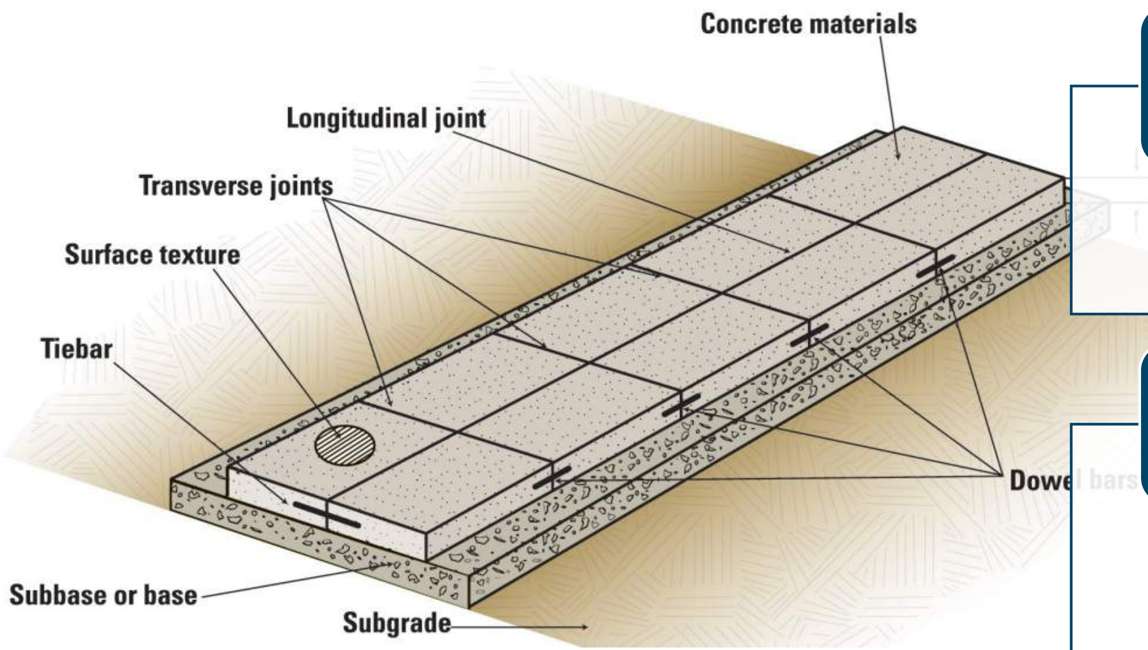


Jointed Plain

It’s Not Just Thickness



Continuously reinforced



Transverse Joints

Contraction Joints (Sawed Joints)

- Control formation of cracks

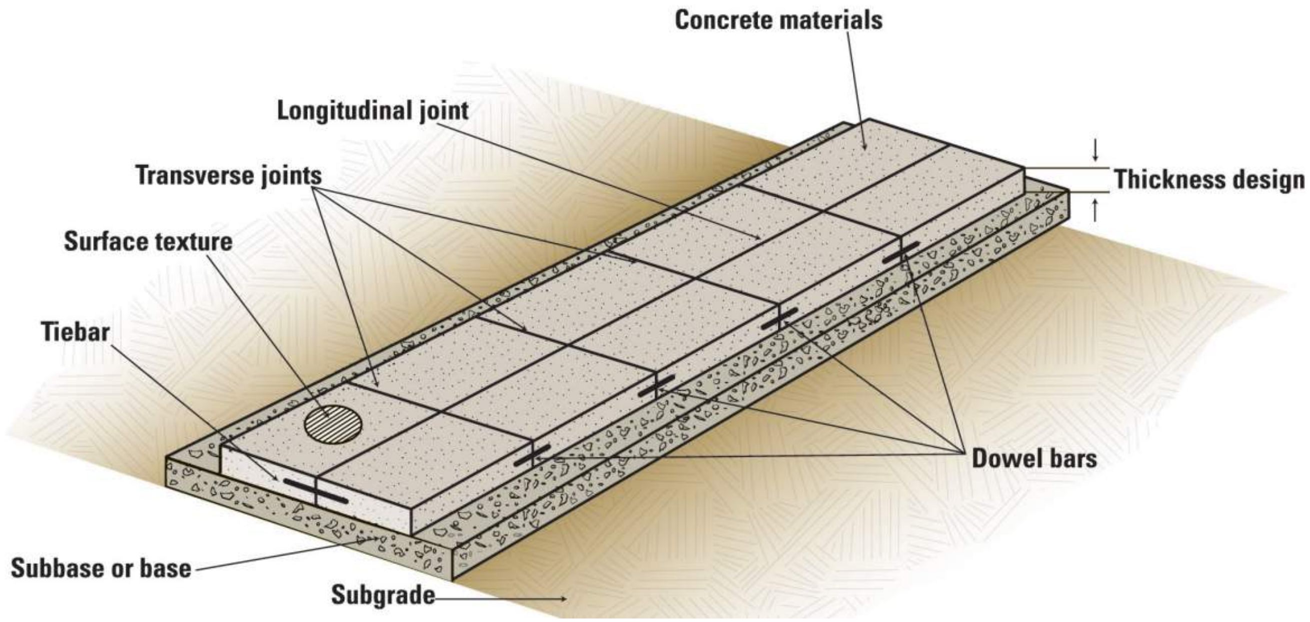
Construction Joints ("Headers")

- At the end of a paving run or at an interruption

Expansion Joints

- For structures within the pavement
- At Intersections
- Small in-pavement objects

Longitudinal Joints



30” deformed tie bars

Depth - middle 1/3 of the slab

Spacing - 36” not within 12” of transverse joint

What Do We Want?

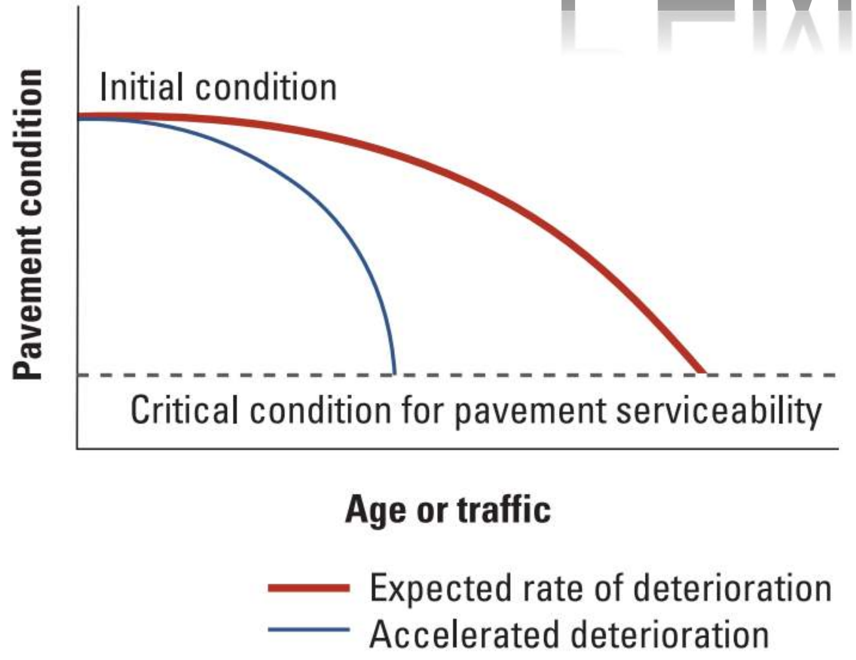
Service life

- Structural models assume that materials will not fail
- How long need it last?

PEM

Performance:

- Structural
- Functional



What Do We Want?

Structural – is it broken?

What Do We Want?

Functional – do I want to drive on it?

What Do We Want?

Resistance to the environment

- The slab
- The support system
- “Resilience”

Dimensionally stable

- Thermal
- Moisture
- Chemical reactions

Eddyville, Iowa – 1909 Const.

What Do We Want?

Surface Texture: Balancing Friction and Noise

Conventional

- Tining
- Dragging
- Brooming

Innovative

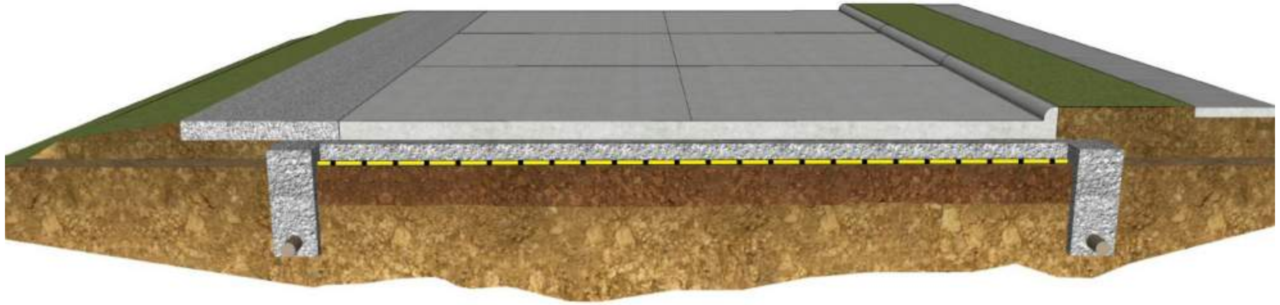
- Grinding (for ride)
- Grooving (for friction/safety)
- Next Generation Concrete Surface

What Do We Have to Think About?

Support system
- As is
- Modified

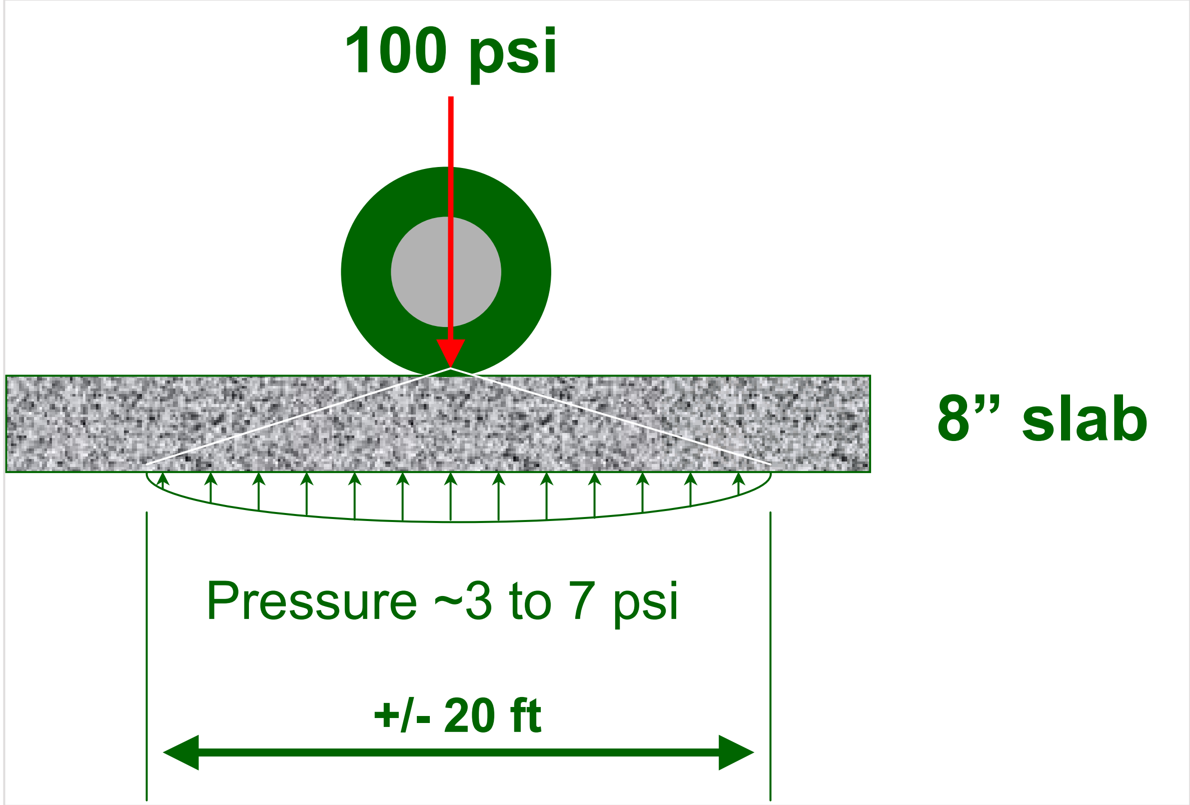
Environment
- Hot - wet - cold - dry
- Water table

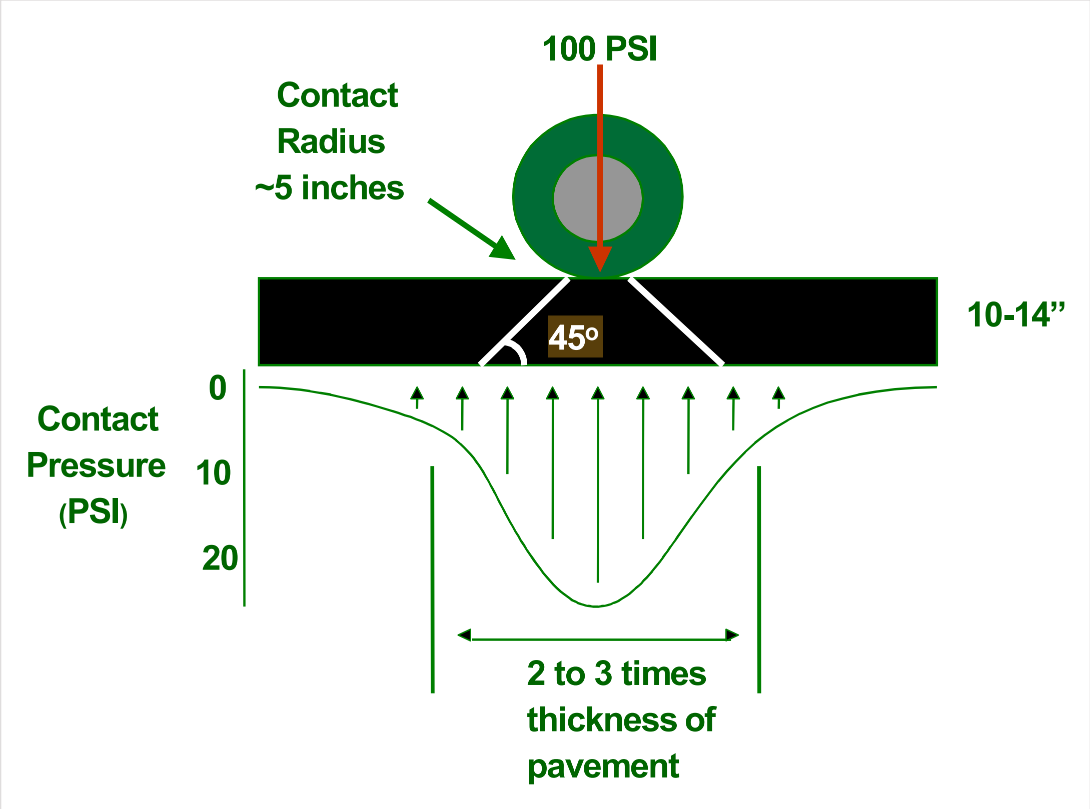
Traffic
- Trucks do the damage
- Fatigue



Pavement Support

Uniformity!





Pavement Design Methods

AASHTO 1993 Pavement Design Guide

Construction/materials inputs include:

- Slab thickness
- Concrete strength
- Support (subgrade and base)
- Smoothness

$$\log_{10}(W_{18}) = Z_R \times S_o + 7.35 \times \log_{10}(D+1) - 0.06 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.5-1.5}\right)}{1 + \frac{1.624 \times 10^7}{(D+1)^{8.46}}} + (4.22 - 0.32 p_t) \times \log_{10}\left[\frac{(S'_c)(C_d)(D^{0.75} - 1.132)}{215.63(J)\left(D^{0.75} - \frac{18.42}{\left(\frac{E_c}{k}\right)^{0.25}}\right)}\right]$$

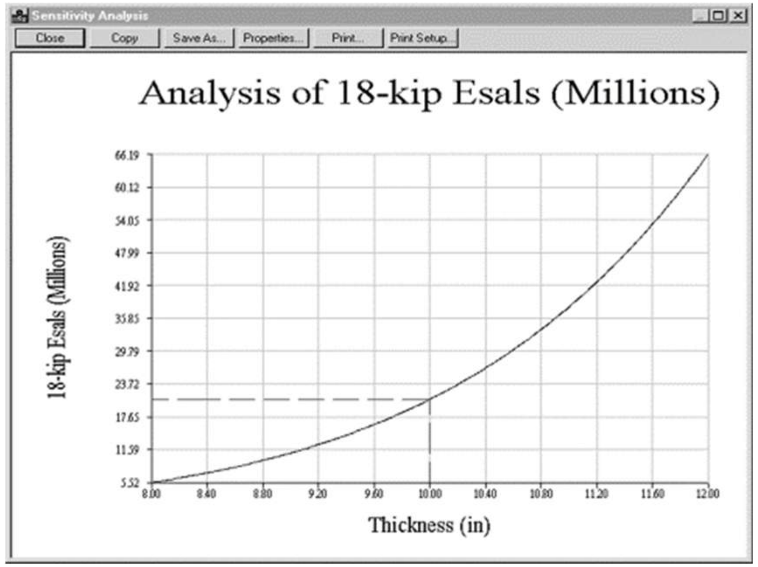
Pavement Design Methods

- **Mechanistic Empirical**
  - AASHTOWare ME Design software
    - Based on modelling damage growth
    - Should be locally calibrated
    - Includes BCOA-ME for overlays

AASHTOWare™
AASHTO

Pavement Design Methods

- Mechanical Empirical
  - AASHTOWare ME Design software
    - Inputs: truck traffic, climate, soils, water table, CTE, and many more!
    - Adjustments: thickness, mixture, support system, joint spacing



Continuous Improvement

Format, Transfer Functions, and Calibration Coefficients	MEPDG version 1.1	AASHTOWare Pavement ME Design version 2.3.1	AASHTOWare Pavement ME Design version 2.5.3	AASHTOWare Pavement ME Design version 2.6	AASHTOWare Pavement ME Design version 3.0
Application Type	Desk Top Version	Desk Top Version	Desk Top Version	Desk Top Version	Web-Application (Cloud) Version
Output Format	Excel-based	PDF- and Excel-based	PDF- and Excel-based	PDF- and Excel-based	PDF- and Excel-based
Climatic Input Data and Included in Output Summary	Data from Ground-Based Weather Stations; output summary NOT included.	Data from NARR database for rigid and flexible pavements; output summary included.	Data from NARR database for rigid pavements, and MERRA2 database for flexible and semi-rigid pavements; output summary included.	Data from NARR database for rigid pavements, and MERRA2 database for flexible and semi-rigid pavements; output summary included.	Data from MERRA2 database for all pavement design strategies; output summary included.
Axle Configuration Data in Output Summary	Excluded	Included	Included	Included	Included
Special Axle Load Configuration	Included	Excluded	Excluded	Included, but only for Asphalt and Semi-Rigid pavement design.	Included, but only for Asphalt and Semi-Rigid pavement design.
Recalibration of PCC Pavements because of issue with CTE Values in the LTPP Database	Original CTE values in LTPP database	Updated with revised CTE values in LTPP database	Updated with revised CTE values in LTPP database	Updated with revised CTE values in LTPP database	Updated with revised CTE values in LTPP database
Interface Friction between the PCC Slab and Underlying Layer	Constant to a specific age & then no interface friction.	Constant to a specific age & then no interface friction.	Constant to a specific age & then no interface friction.	Constant to a specific age & then no interface friction.	Added NCHRP 1-51; Interface friction varies through design life.

File Location:

Design Inputs

Design Life: 20 years
Design Type: JPCP

Existing Construction: -
Pavement construction: June 2026
Traffic Opening: September 2026

Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

Layer Type	Material Type	Thickness (in)
PCC	Default JPCP 1	10
NonStabilized	Crushed gravel (A-1-a)	6
Subgrade	A-1-b (A-1-b)	Semi-infinite

Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

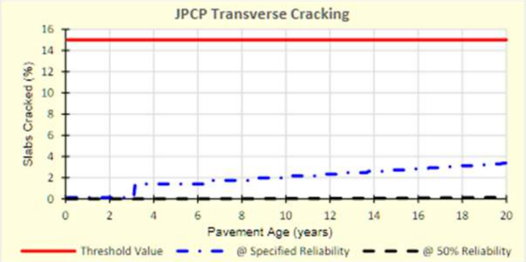
Age (year)	Heavy Trucks (cumulative)
2026 (initial)	2,656
2036 (10 years)	5,230,070
2046 (20 years)	11,842,500

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	79.46	90.00	100.00	Pass
Mean joint faulting (in)	0.12	0.05	90.00	99.99	Pass
JPCP transverse cracking (% slabs)	15.00	3.38	90.00	100.00	Pass

Distress Charts



File Location:

Design Inputs

Design Life: 20 years
Design Type: JPCP

Existing Construction: -
Pavement construction: June 2026
Traffic Opening: September 2026

Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

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Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	-
Slab width (ft)	12.0

Traffic

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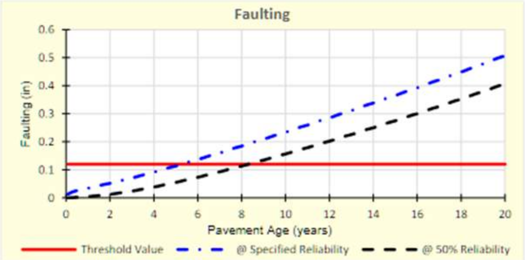
2026 (initial)	2,656
2036 (10 years)	5,230,070
2046 (20 years)	11,842,500

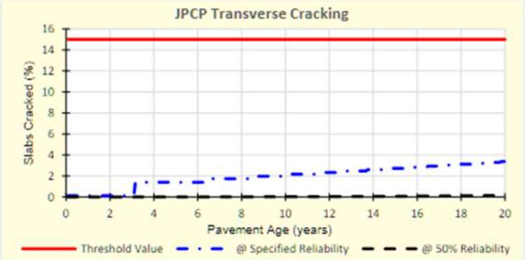
Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	239.49	90.00	10.71	Fail
Mean joint faulting (in)	0.12	0.51	90.00	0.01	Fail
JPCP transverse cracking (% slabs)	15.00	3.38	90.00	100.00	Pass

Distress Charts





Distress Prediction Summary

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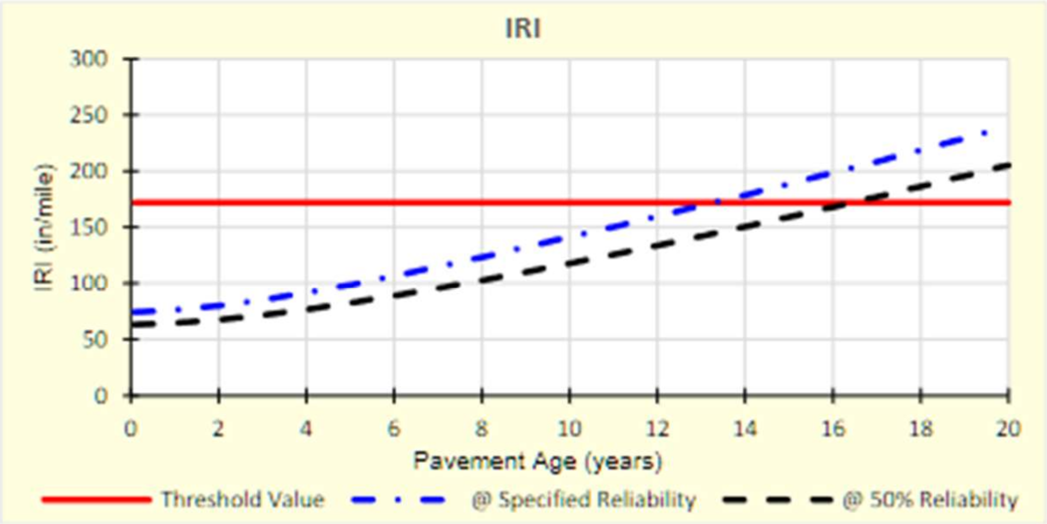
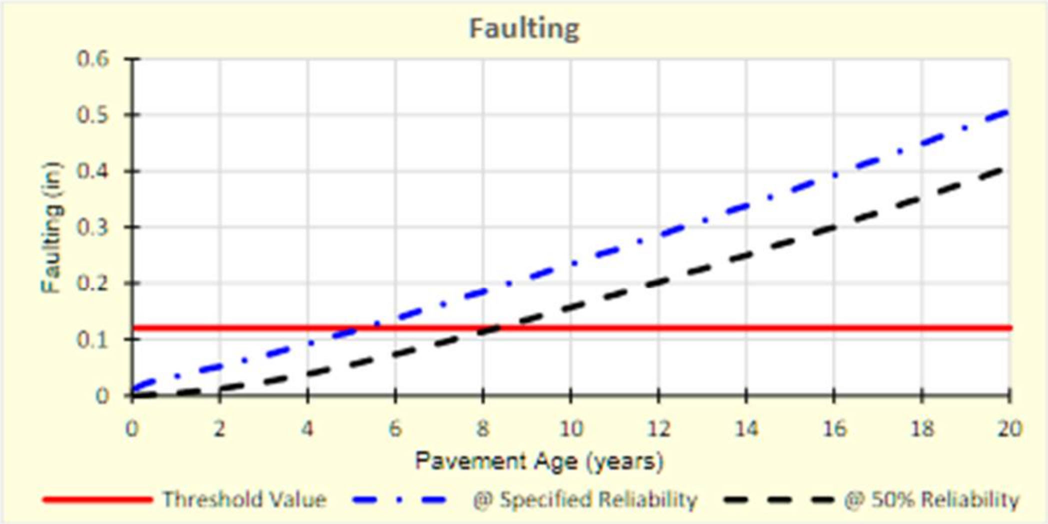
Distress Charts





Pavement Design Methods

PavementDesigner.org

- Combines StreetPave, AirPave, WinPas, PCAPave
- Online tool
- For local agencies

1 PROJECT LEVEL | 2 PAVEMENT STRUCTURE | 3 SUMMARY

Home | New Design | Log In Signup | Resources | Support

Units US METRIC

Help

Project Type: Street ➜ Concrete

TRAFFIC

Collector

Design Life: 40 (Years)

User Defined Traffic Info

Trucks/Day: 100

Traffic Growth Rate: 2 (% per year)

Directional Distribution: 50 (%)

Design Lane Distribution: 100 (%)

GLOBAL

Reliability: 90 (%)

% of Slabs Cracked at End of Design Life: 15 (%)

CALCULATED TRAFFIC RESULTS

Avg Trucks/Day in Design Lane over the Design Life: 76

Total Trucks in Design Lane over the Design Life: 1,103,091

TRAFFIC SUMMARY DETAILS

Single AXLE LOAD (kips)	Single AXLES/ 1000 TRUCKS	Tandem AXLE LOAD (kips)	Tandem AXLES/ 1000 TRUCKS	Tridem AXLE LOAD (kips)	Tridem AXLES/ 1000 TRUCKS
26	0.07	44	1.16	62	0
24	1.6	36	7.76	56	0
22	2.6	40	38.79	50	0
20	6.63	32	54.76	44	0
18	16.61	28	44.43	38	0
16	23.88	24	30.74	32	0
14	47.76	20	45	26	0
12	116.76	16	59.25	20	0
10	142.7	12	91.15	14	0
8	233.6	8	47.01	8	0

Help (Select Spectrum Type)

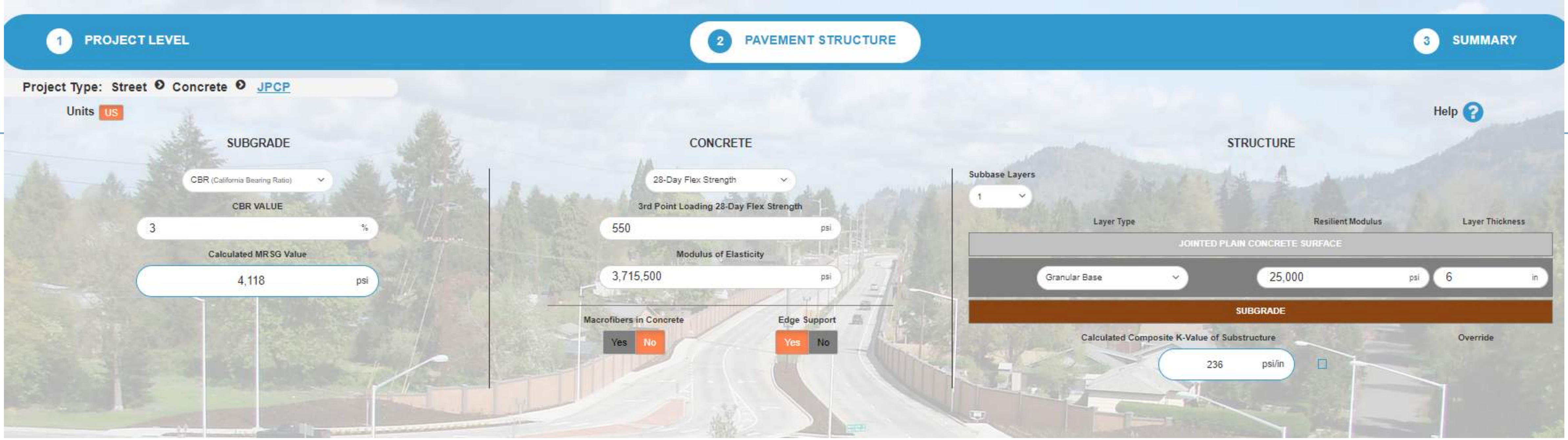
The four default traffic categories in the left column are each a composite of data averaged from loadometer tables representative of the facility type listed and the five default traffic categories in the right column are from the forthcoming ACI 330-18 design guide, 'Guide for Design and Construction of Concrete Parking Lots.' ACI 330R-08 describes Category A as passenger cars only, Categories B and C as composites of data averaged from several loadometer tables representing appropriate pavement facilities, and Category D as tractor semitrailer trucks with gross weights of 80 kips (360 kN). The table below gives general details for each default traffic category in the left column.

Traffic Category	Description	Traffic			Maximum Axles Loads (kips)	
		ADT	% Trucks	ADTT**	Single Axles	Tandem Axles
Residential	Residential streets, rural and secondary roads (low to medium*)	50-800	1%-3%	1-20	22	36
Collector	Collector streets, rural and secondary roads (high*), arterial streets and primary roads (low*)	700-5,000	3%-15%	40-1,000	26	44
Minor Arterial	Arterial streets and primary roads (medium*), expressways and urban and rural interstate (low to medium*)	3,000-15,000+	5%-25%	300-5,000+	30	52
Major Arterial	Arterial streets, primary roads, expressways (high*), urban and rural interstate (medium to high*)	4,000-50,000+	10%-30%	700-10,000+	34	60

*The descriptors high, medium, or low refer to the relative weights of axle loads for the type of street or road; that is, "low" for a rural Interstate would represent heavier loads than "low" for a secondary road.

** Trucks -- two-axle, four-tire trucks excluded.

‹ Change Design Type | SAVE | PAVEMENT STRUCTURE



1 PROJECT LEVEL
2 PAVEMENT STRUCTURE
3 SUMMARY
Project Type: Street Concrete JPCP
Units US
Help
SUBGRADE
CBR (California Bearing Ratio)
CBR VALUE
3 %
Calculated MR SG Value
4,118 psi
CONCRETE
28-Day Flex Strength
3rd Point Loading 28-Day Flex Strength
550 psi
Modulus of Elasticity
3,715,500 psi
Macrofibers in Concrete
Yes No
Edge Support
Yes No
STRUCTURE
Subbase Layers
1
Layer Type
Resilient Modulus
Layer Thickness
JOINTED PLAIN CONCRETE SURFACE
Granular Base
25,000 psi
6 in
SUBGRADE
Calculated Composite K-Value of Substructure
236 psi/in
Override


1 PROJECT LEVEL
2 PAVEMENT STRUCTURE
3 SUMMARY
Project Type: Street Concrete JPCP
Calculated Minimum Thickness
Doweled
Undoweled
6.20 in
Recommended Design Thickness
Doweled
6.25 in
Maximum Joint Spacing
Doweled
11 ft
Analysis and Guidance
SENSITIVITY
CRACKING
EROSION
LOAD TRANSFER
JOINT SPACING
DOWELED
UNDOWELED
K-value
CONCRETE STRENGTH
DESIGN LIFE
RELIABILITY
SLABS CRACKED
Effect of k-value on Thickness
Thickness, in.
k-value, psi/in.
Home
New Design
Log In
Signup
Resources
Support
PavementDesigner.org
PAVEMENT STRUCTURE
Privacy Policy
Terms of Service
SAVE
GENERATE REPORT

Constructability Review

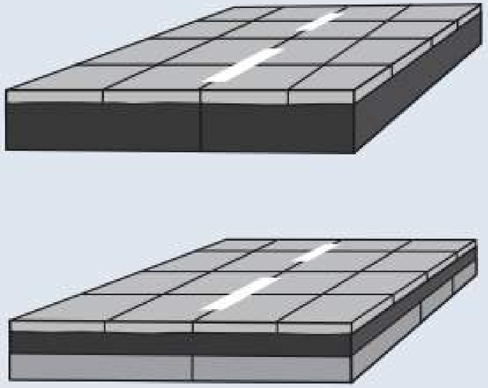
- Conducted by people experienced in the field
- Reduces the need to correct things on the fly
- Reviews:
  - Mixture
  - Pavement design
  - Construction processes
  - Traffic control/staging
  - Opening to traffic

Concrete Overlays

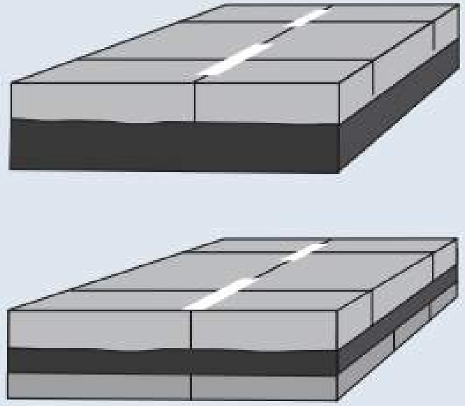
Concrete on Asphalt

Concrete on asphalt (COA) overlays can be designed to address a broad range of existing pavement conditions on both composite and full-depth asphalt pavements. Both bonded (COA–B) and unbonded (COA–U) options enable designs to cost-effectively match the condition of the existing asphalt—from deteriorated to good—as well as geometric parameters.

COA–B (Full Depth and Composite)



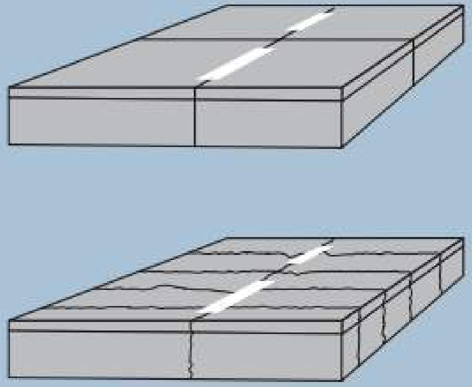
COA–U (Full Depth and Composite)



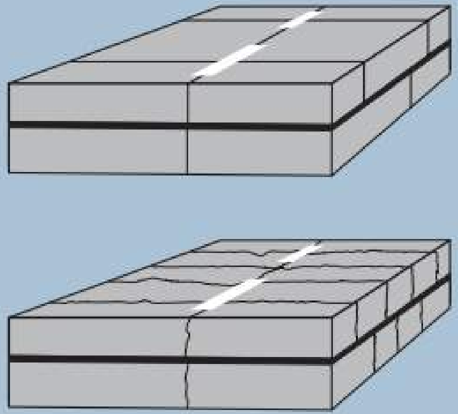
Concrete on Concrete

Concrete on concrete (COC) overlays can be designed for applications on both existing jointed plain concrete pavement (JPCP) and continuously reinforced concrete pavement (CRCP). The predominance of COC overlay designs are unbonded (COC–U) systems; however, bonded (COC–B) applications can be successful, provided the existing pavement is in good condition.

COC–B (JPCP and CRCP)

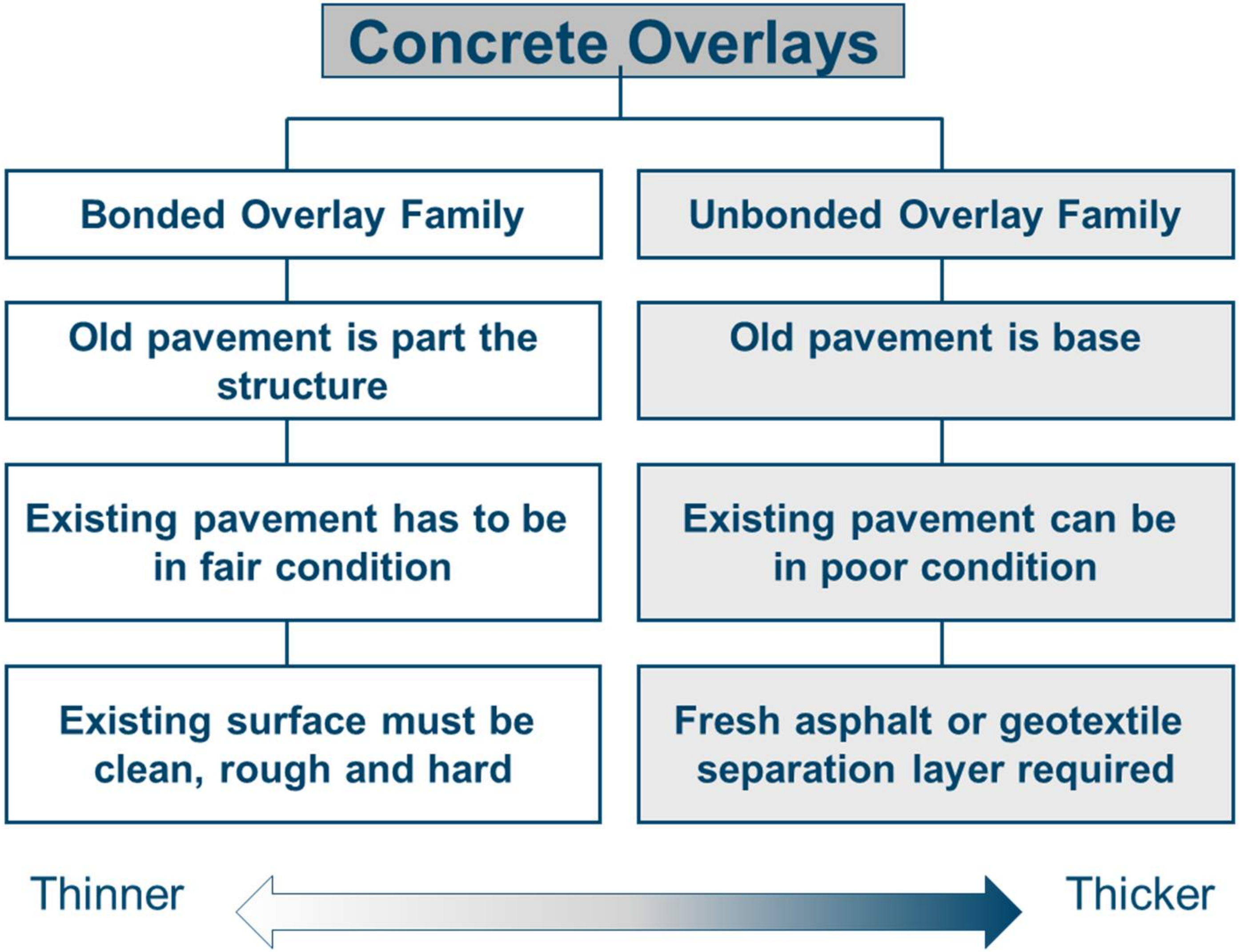


COC–U (JPCP and CRCP)



CP Tech Center

Concrete Overlays



Unbonded Concrete Overlays

2007, Route D-Kansas City

Unbonded Concrete Overlays

Unbonded Concrete Overlays

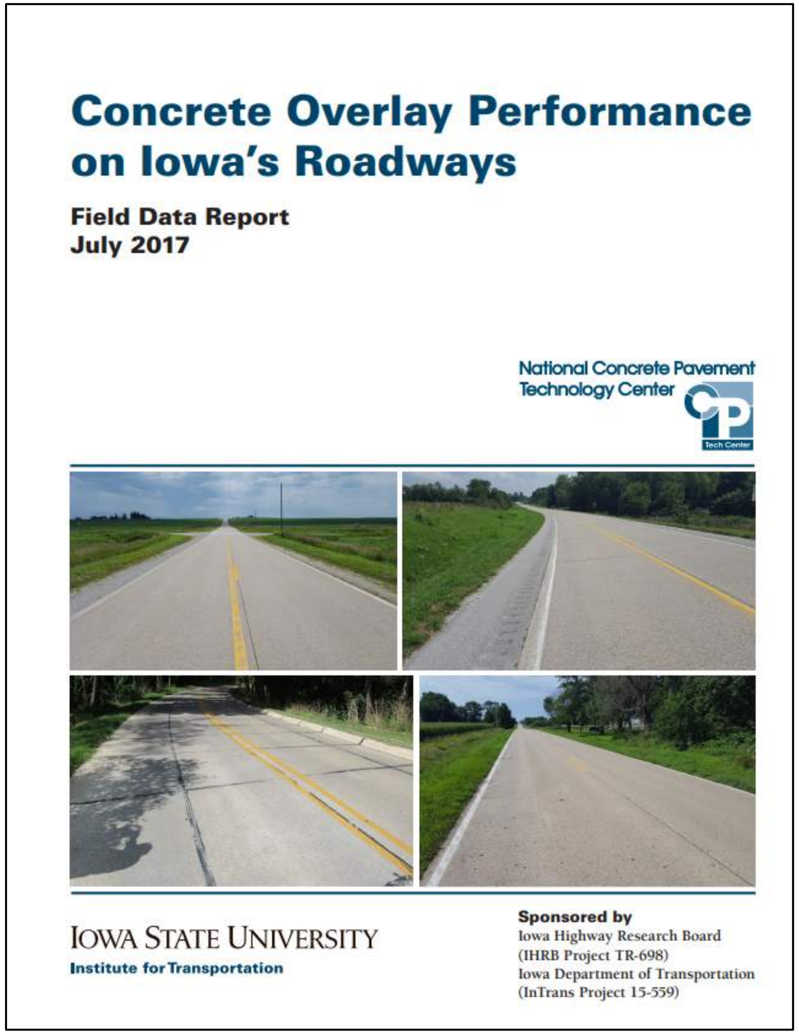
Route D
9,000 ADT
5” Unbonded Overlay
Excellent Condition

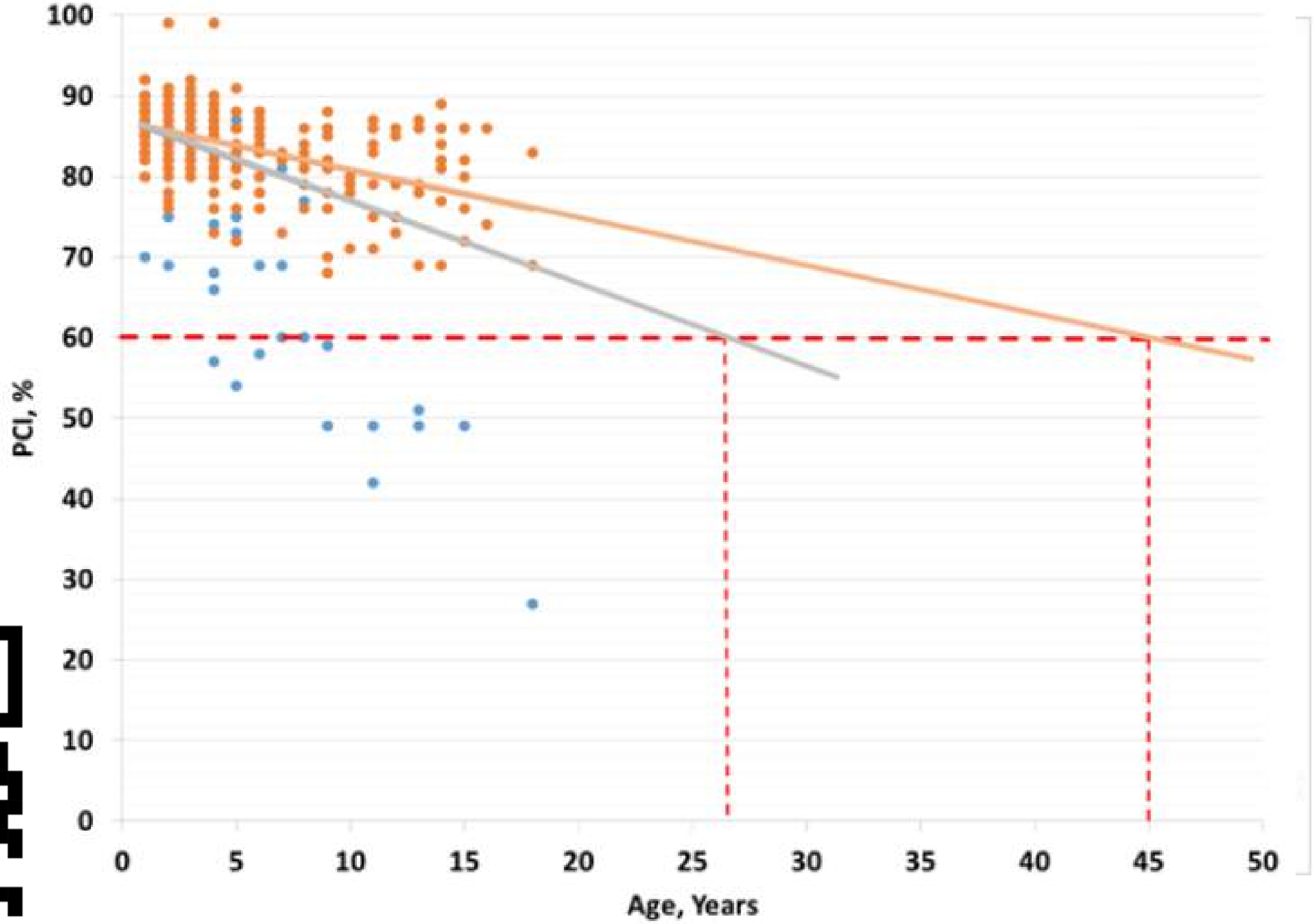
Mitchell County, Iowa

www.cptechcenter.org/concrete-overlays/

Overlay Applications

Concrete Overlay Performance





Overlay Design

Overlay pavement type

- JCP: for bonded overlays (typically 4” to 6”)
- JCP or CRC: for thicker unbonded overlays

Concrete Mixture Design

- Same as conventional concrete paving

Concrete placement

- Same as conventional concrete paving
- Curing & sawing critical for thin overlays

Concrete Overlay Thickness Design

- PavementME
- <6” thickness
- Referred to SJPCP/AC
  (Short JPCP overlay of asphalt concrete pavements)
- Can adjust:
  - Condition of existing pavement
  - Joint spacing of 2’ x 2’, through 15’ x 12’
  - Fibers


National Concrete Pavement Technology Center
Tech Center
Iowa State University
Institute for Transportation

Breakout #1

- 4 Groups
- 15 minutes to discuss the question
- 15 minutes to report back

Breakout #1

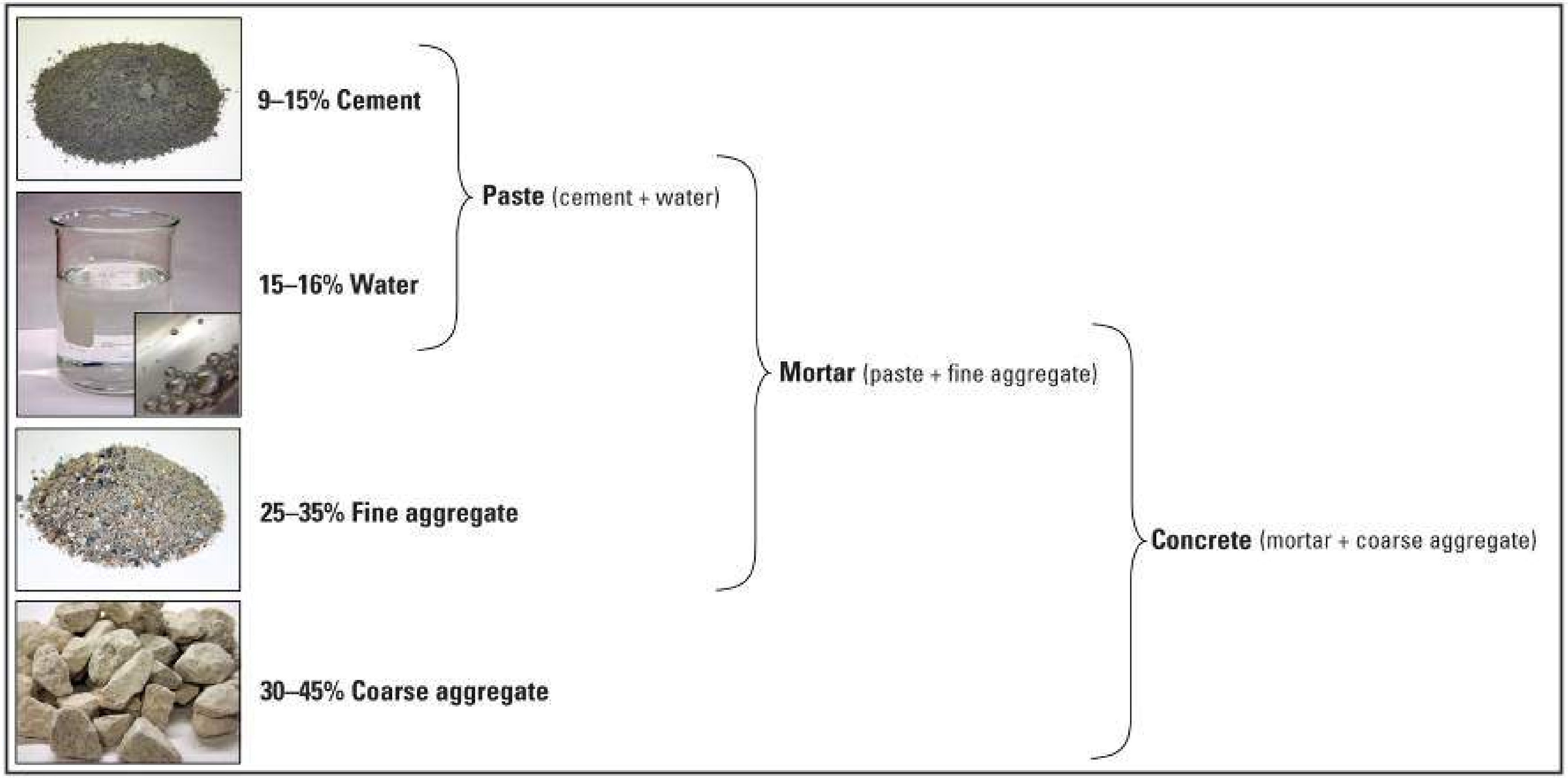
- #1
- What defines the quality of a concrete mixture?

Concrete 101

National Concrete Pavement Technology Center

Tech Center

What do we have to work with



Aggregates

- Aggregates comprise ~70% of the volume of a concrete mix
- Aggregate properties can have an influence on concrete properties:
  - Durability
  - Workability
  - Strength
  - Dimensional changes
  - Polishing

Aggregate Types

Aggregates are generally grouped by their mineralogical classification:

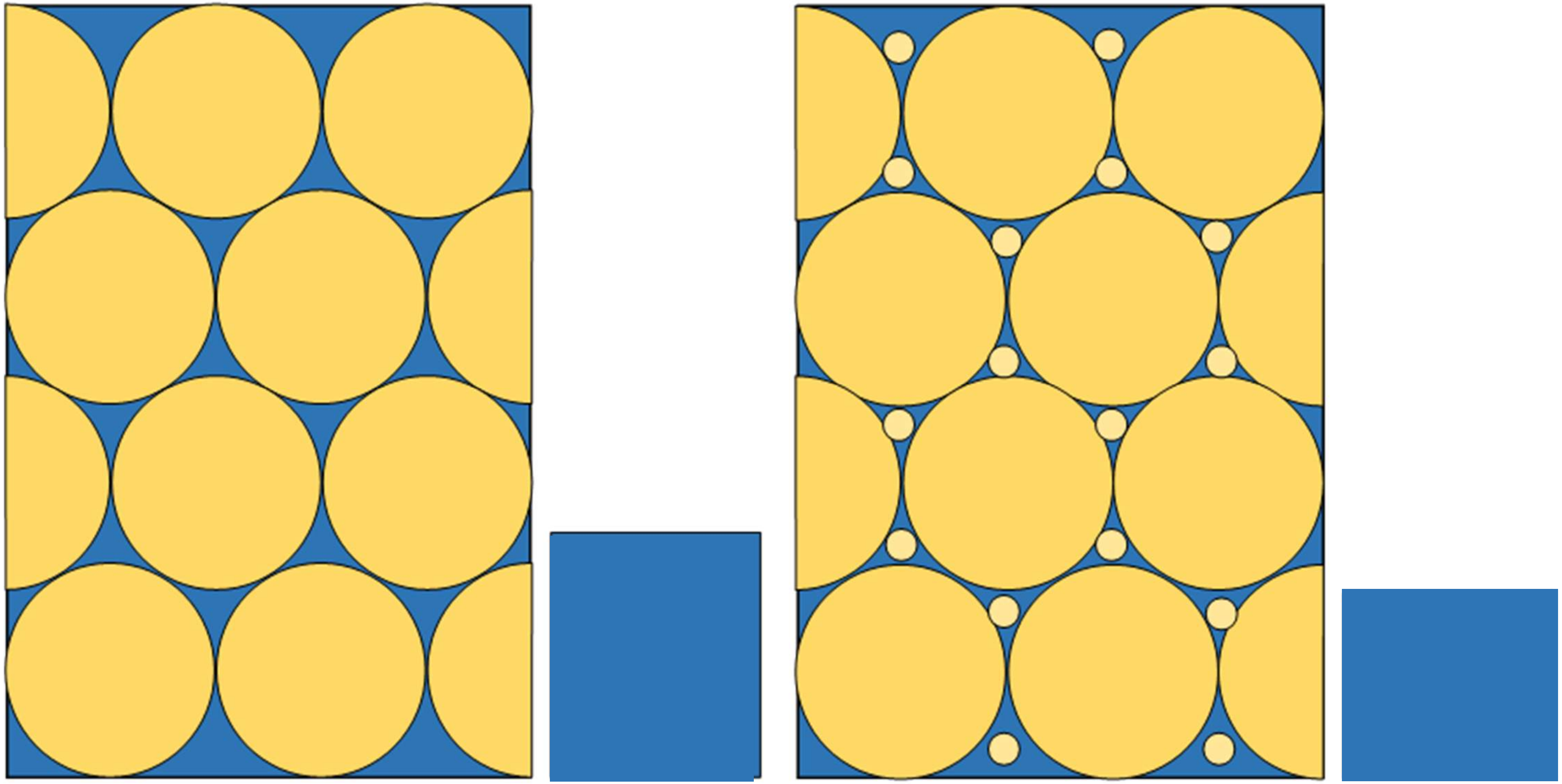
- Siliceous
  - Harder
  - Don’t polish
  - Prone to ASR
- Calcareous
  - D-Cracking

Aggregates in Concrete

- Physical properties to consider:
  - Gradation
    - Workability
  - Absorption
    - Water in the mix

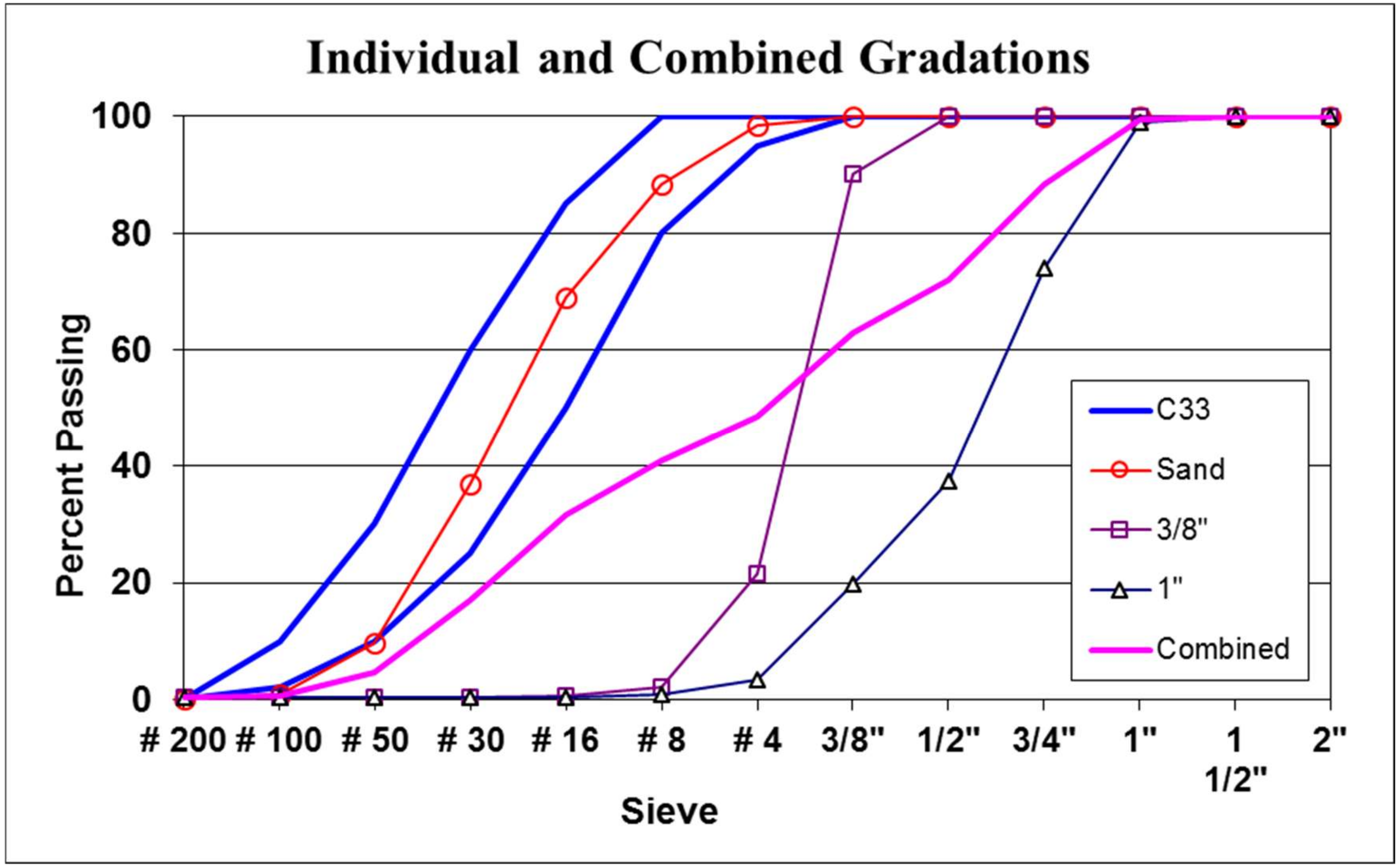
  - Particle shape
    - Workability
    - Flexural strength
  - Surface texture
    - …

Voids



Aggregate Gradation

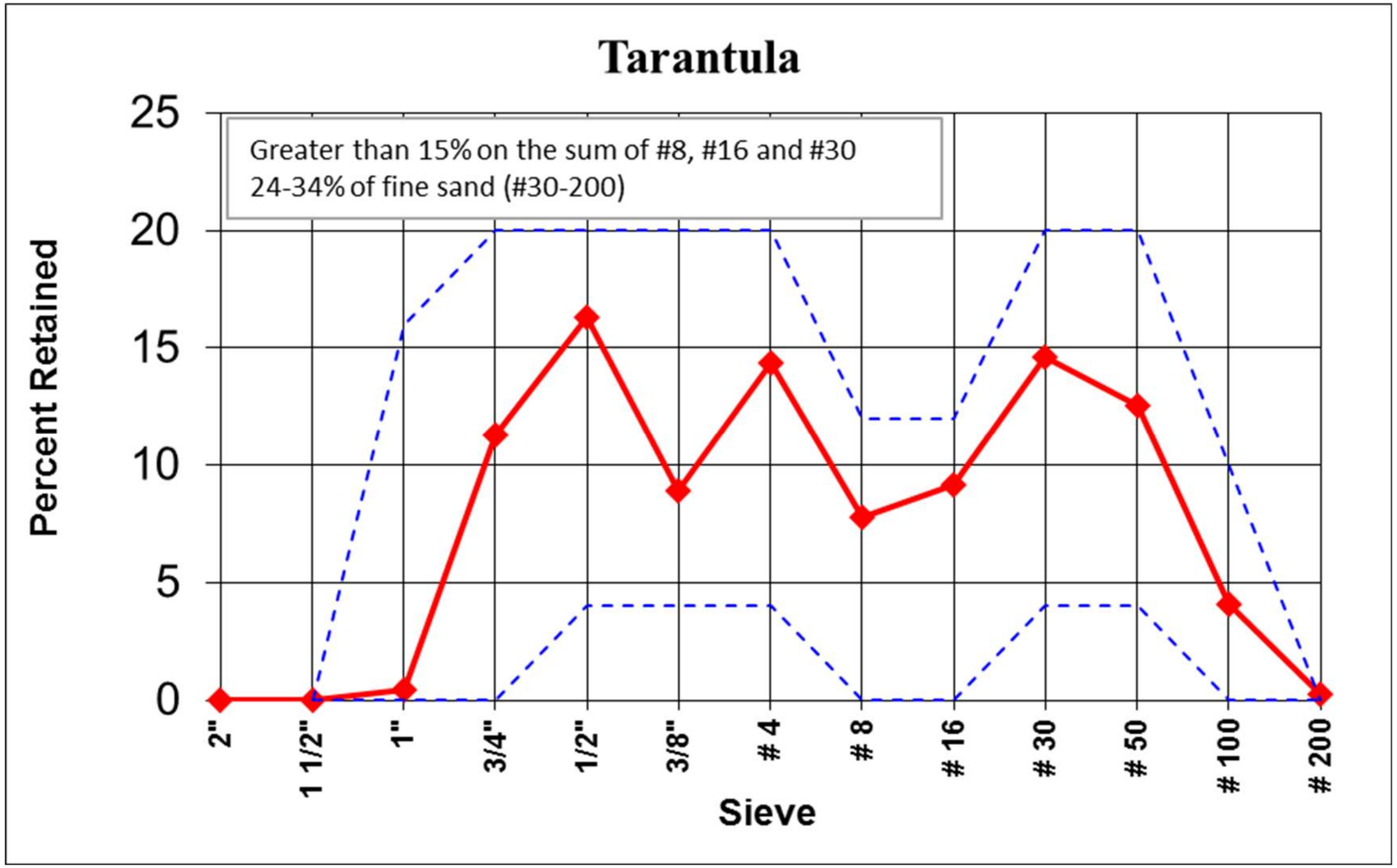
- ASTM C33



Aggregate Gradation

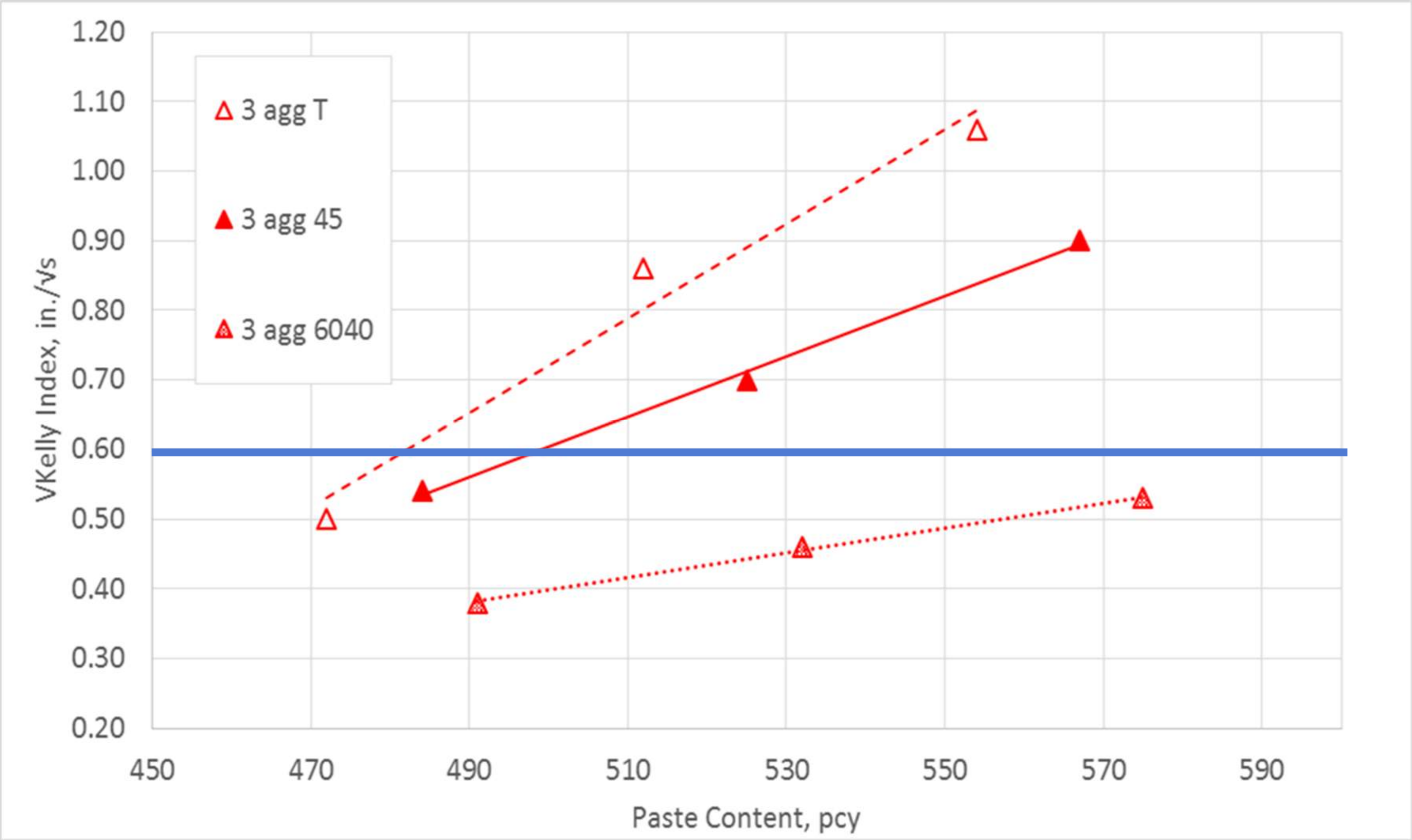
Tarantula Curve

- Most likely to be workable



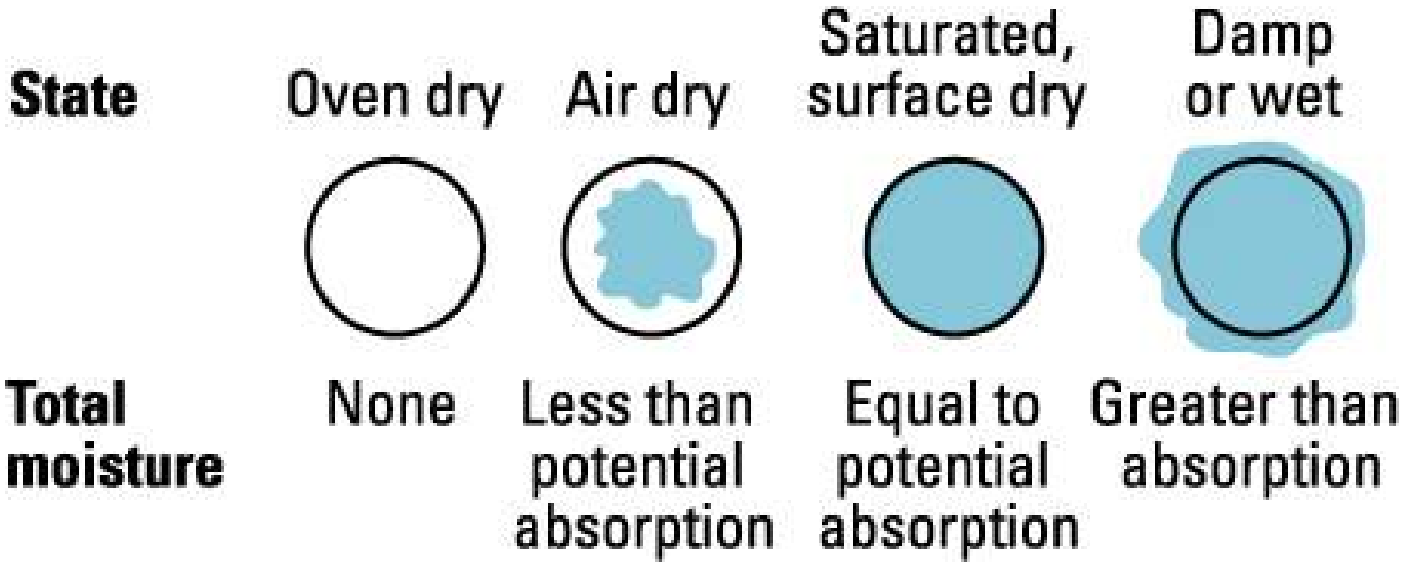
Aggregate Gradation

- Combined gradation matters



Absorption

- A function of the amount and connectivity of void space in the aggregate
- Saturated surface dry (SSD) used in proportioning



Aggregate Durability Issues

Aggregate-related distresses include the following:

- Alkali-aggregate reactivity (ASR / ACR)
- D-cracking
- Surface popouts
- Polishing

Dowel Bars

- Smooth bars to provide load transfer across transverse joints

- Round dowels are typically
  - 1¼ to 1½ inches in diameter
  - 15 to 18 inches in length
  - Spaced 12 to 15 inches apart

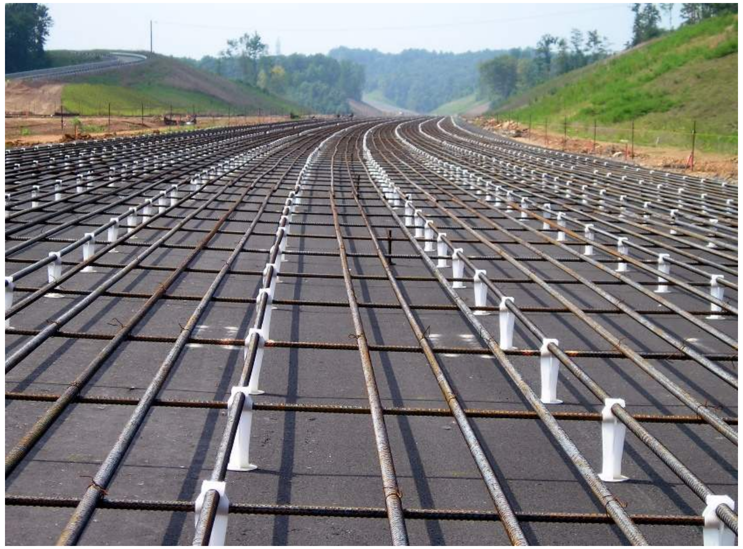
- GFRP are available
- Elliptical, flat and square dowels are available

Tiebars

- Deformed bars to hold lanes together at longitudinal joints
- Tiebars are sized depending on loads

Reinforcement

- To hold random cracks closed
- Continuously reinforced concrete pavement uses ~0.7 percent
- Reinforcement may be
  - Plain steel or epoxy coated
  - Reinforcing bars or welded wire fabric



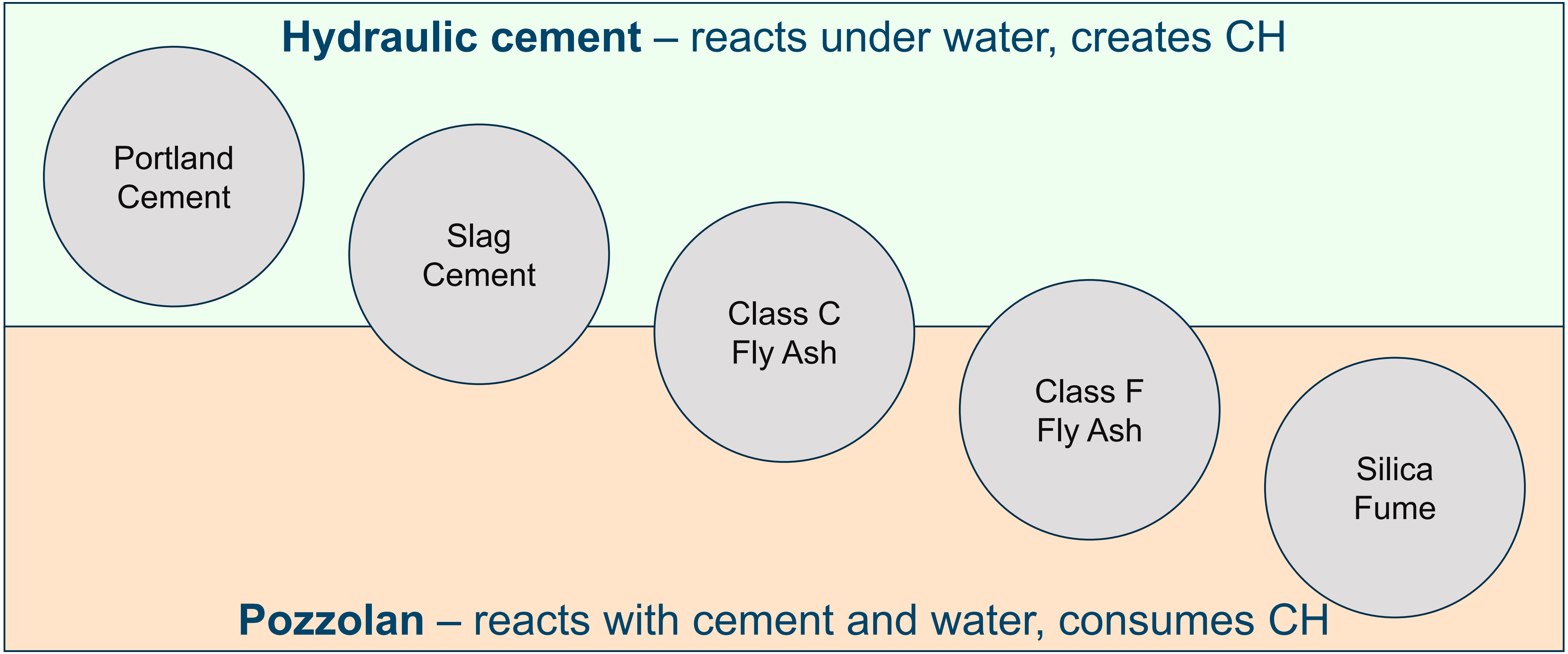
Curing

- Curing compound is applied to all exposed surfaces to retain moisture
- Should be applied as soon as practical after finishing
- Should be white
- Poly-alpha-methylstyrene is effective
- Alternatives are water fogging, plastic sheeting, ponding

Reactive Materials

- Cementitious materials
- Water
- Chemical admixtures

Cementitious Materials



Not to scale

Specifying Cements

- Portland cement (ASTM C 150 / AASHTO M 85)
- Blended cements (ASTM C 595 / AASHTO M 240)
- Performance specification for hydraulic cements (ASTM C 1157)

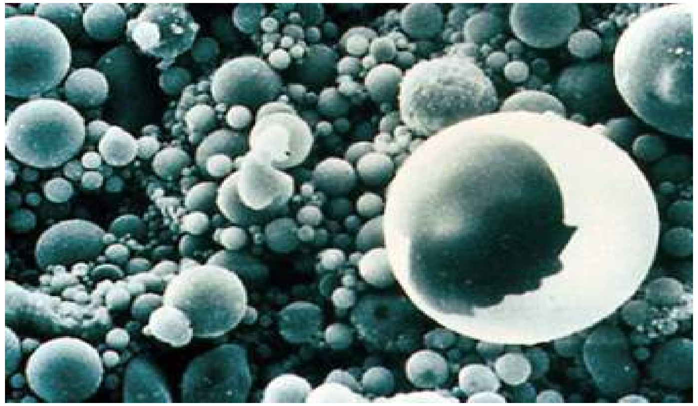
Limits for Constituent Amounts for Blended Cement						
Cement Type	IL	IP	IS	IT	IT(S≥70)	IC
Limestone (L)	>5%, ≤15%	≤15%	≤15%	≤15%	≤15%	≤30%[D]
Pozzolan (P)	0	≤40%	0	≤40%	C	D
Slag (S)	0	0	≤95%[A]	B	A	D
Limestone + Pozzolan + Slag	…	…	…	<70%	≤95%	≤70%
Number of pozzolan or slag constituents	0	1	1	2	2	…

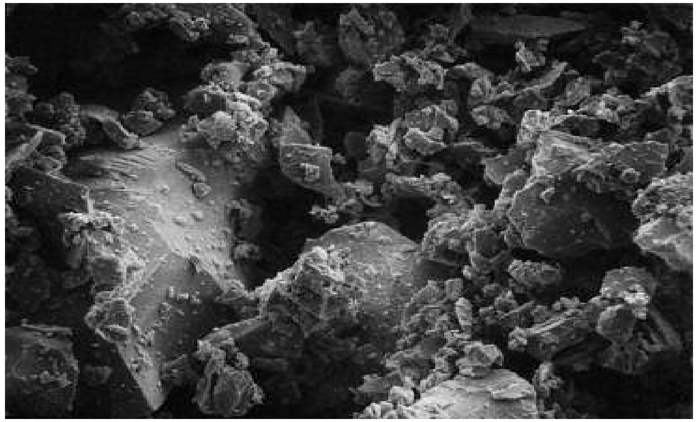
Manufacturing Portland Cement

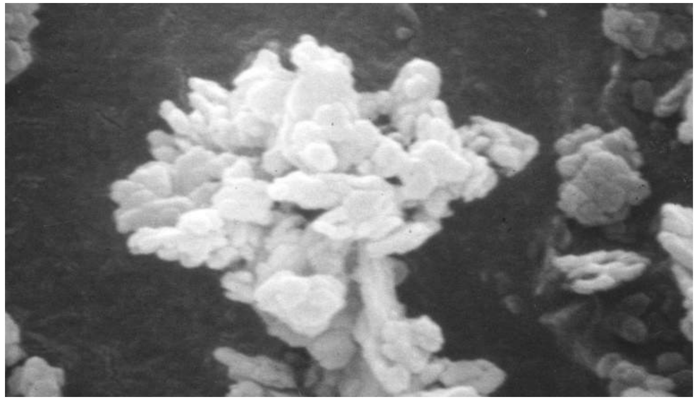
- Grind the raw materials (limestone, clay, iron ore)
- Blend
- Heat
  - Preheater
  - Kiln (2700 ºF)
- Cool (clinker)
- Grind with gypsum, and LS
- Ship

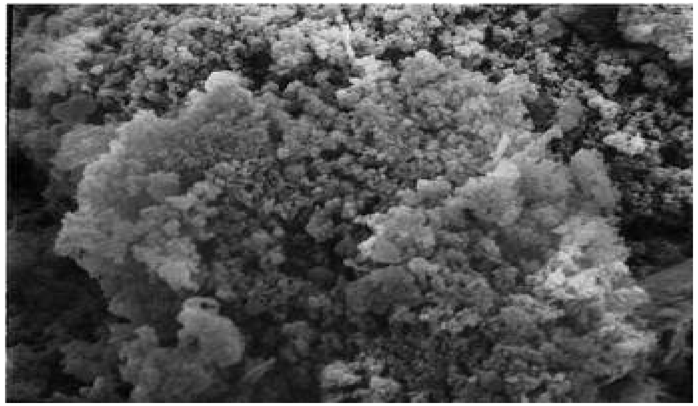
Supplementary Cementitious Materials

- Fly ash
- Slag
- Natural pozzolan
- Silica fume









Specs for Cementitious Materials

- Fly ash and Natural Pozzolans – ASTM C618
- Slag – ASTM C989
- Silica Fume – ASTM C1240

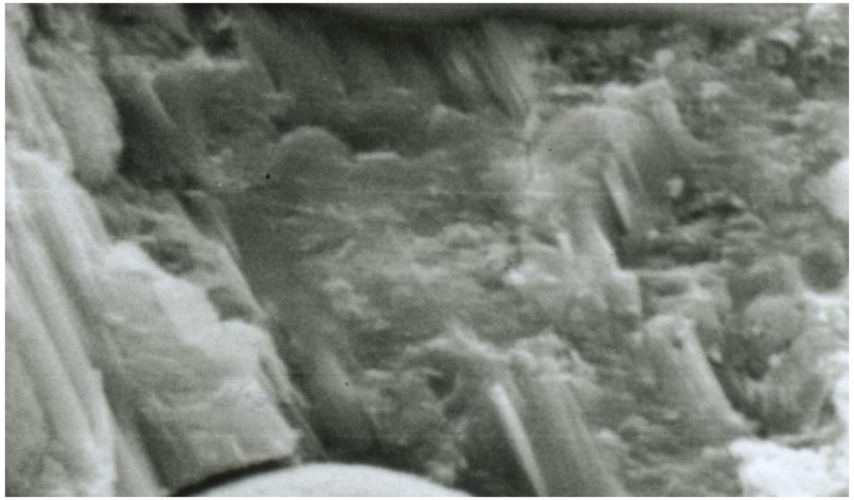
- Specs are changing fast…

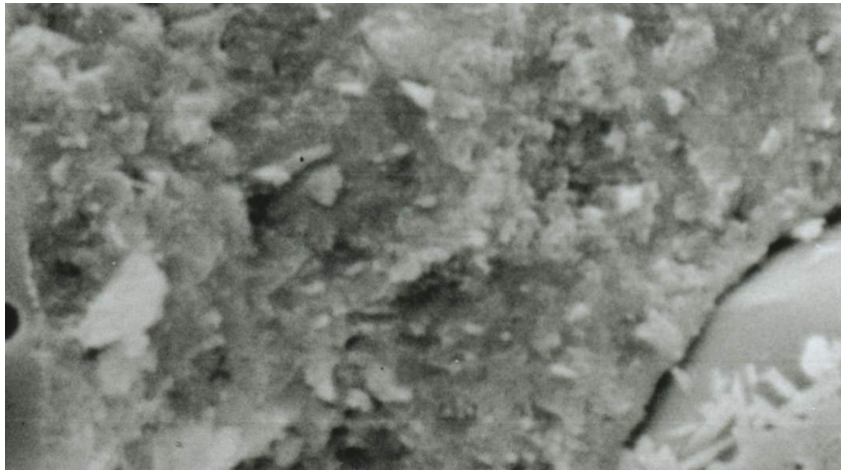
Typical Amounts of Pozzolans and Slag

• Class F fly ash:	15% - 25%
• Class C fly ash:	15% - 40%
• Slag:	25% - 50%
• Silica fume:	6% - 8%

So What Do They Do?

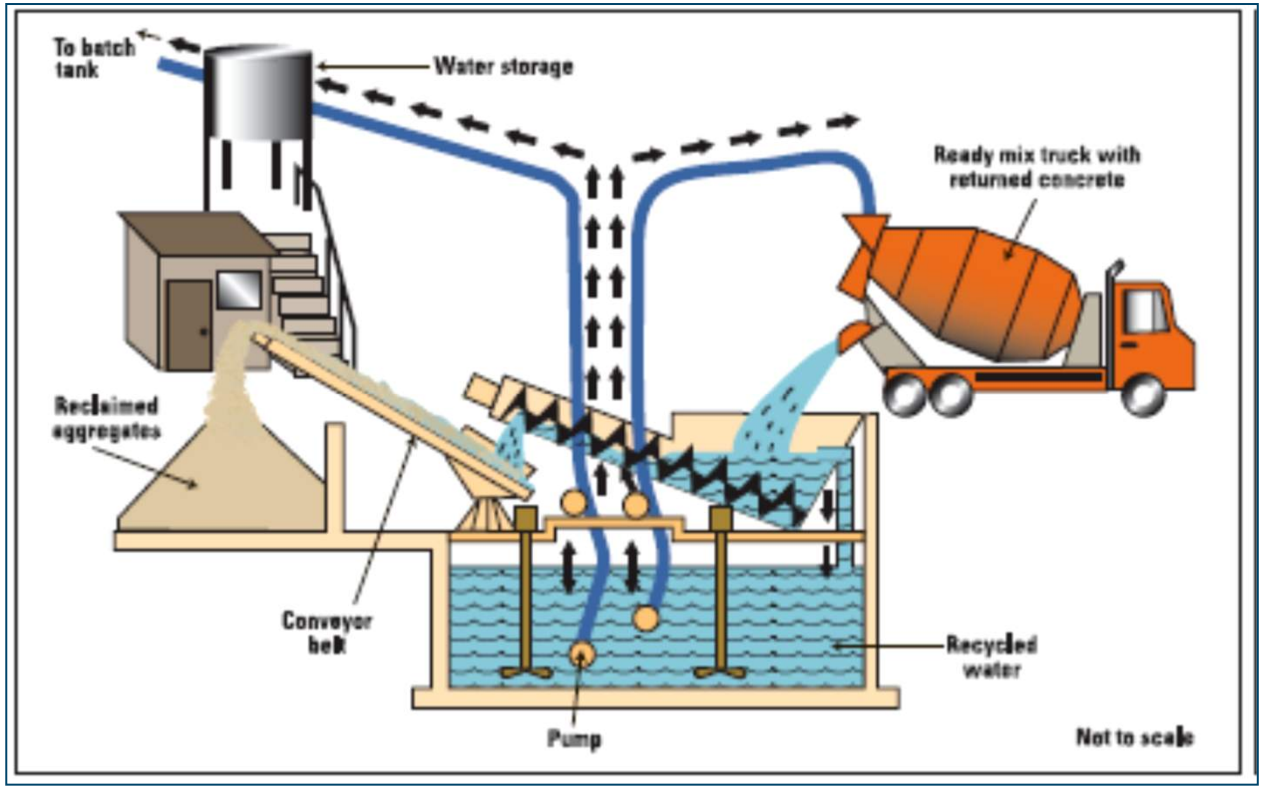
- SCM's change the mix properties
- Finishing and curing needs to adjust
- Strength rate slows
- Permeability decreases (good)





Mixing Water (ASTM C 1602)

- Potable: use
- Non-potable: test and use
  - Strength
  - Time of set
  - Chlorides
  - Sulfates
  - Alkalis
  - Total solids



Water

- Sources
  - Added with batch
  - With aggregates
  - In chemical admixtures
  - Added later

Effects of Extra Water on Concrete

- Increases workability
- Lowers strength
- Increases drying shrinkage
- Increases permeability and reduces durability

- Control w/cm!!!

Chemical Admixtures

- Air entraining admixtures (AEA)
- Water reducers
- Set modifying admixtures
- Rheology modifiers
- Hydration modifiers
- Others

- Make good concrete better
  Not to fix bad concrete

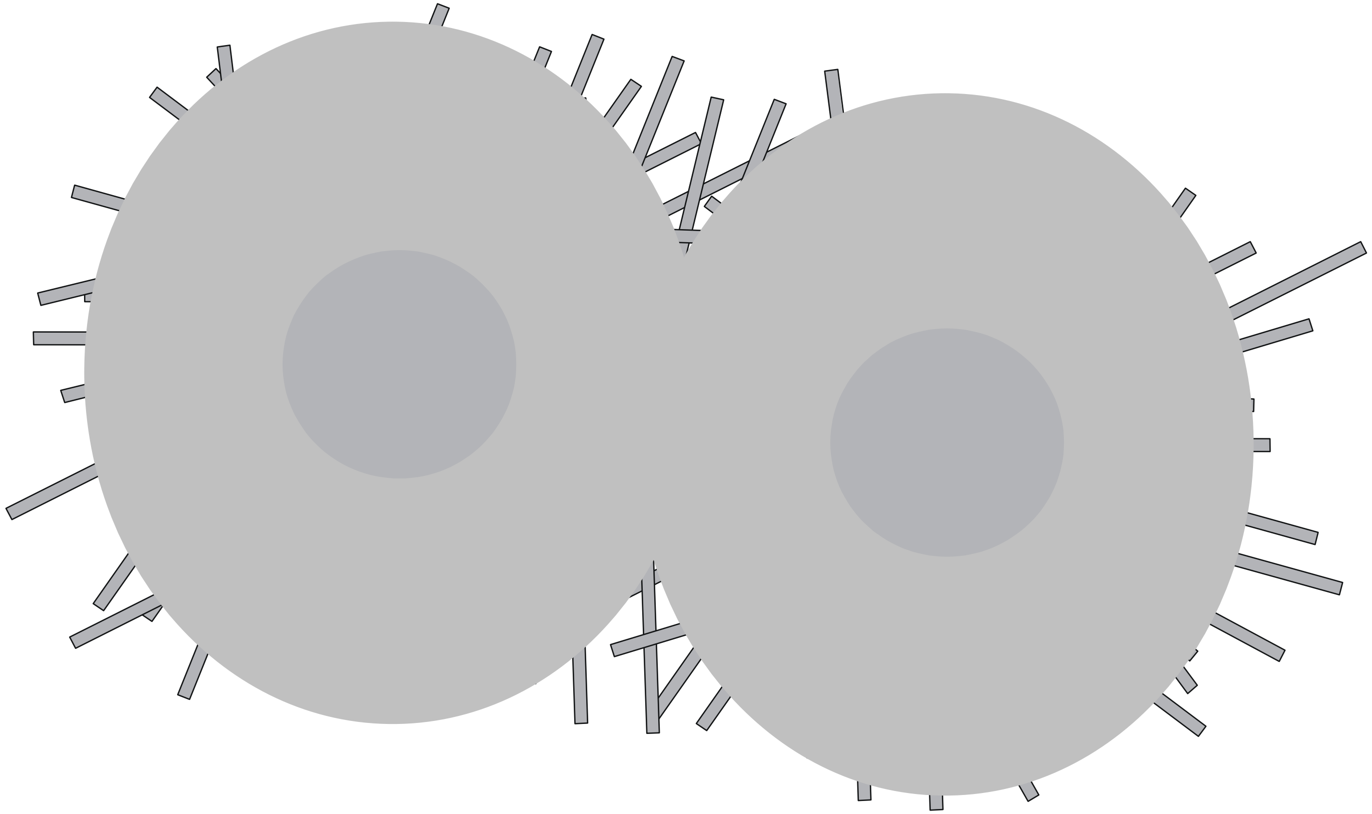
Basics of Cement Hydration

National Concrete Pavement Technology Center

Tech Center

Cement Hydration

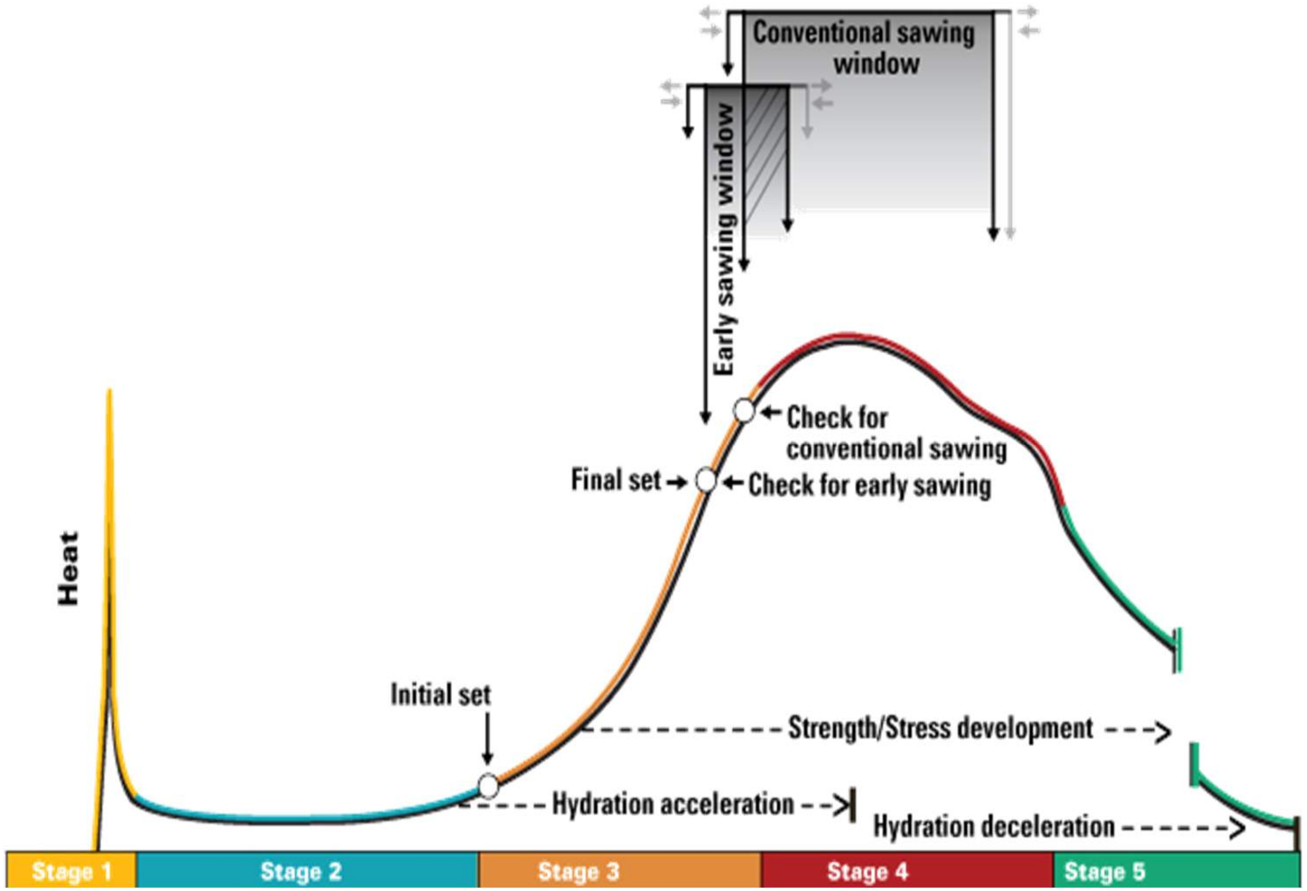
Hydration is a series of irreversible chemical reactions between hydraulic cement and water



Why Should You Care?

- Early reactions affect workability, finishing and sawing
- Later reactions affect long term performance
- Understanding helps wise decisions
- It is complicated…

Five Stages of Hydration



1 Mixing

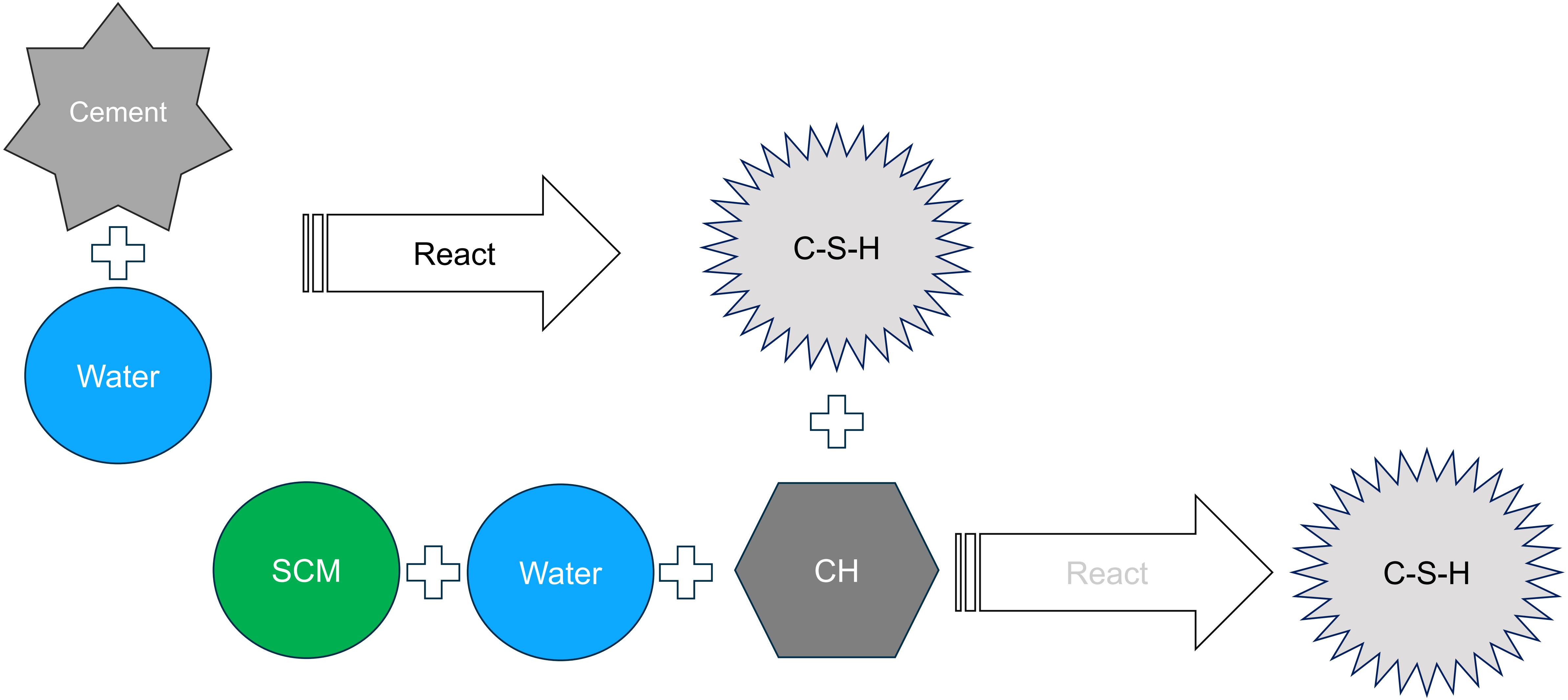
2 Dormancy

3 Hardening

4 Cooling

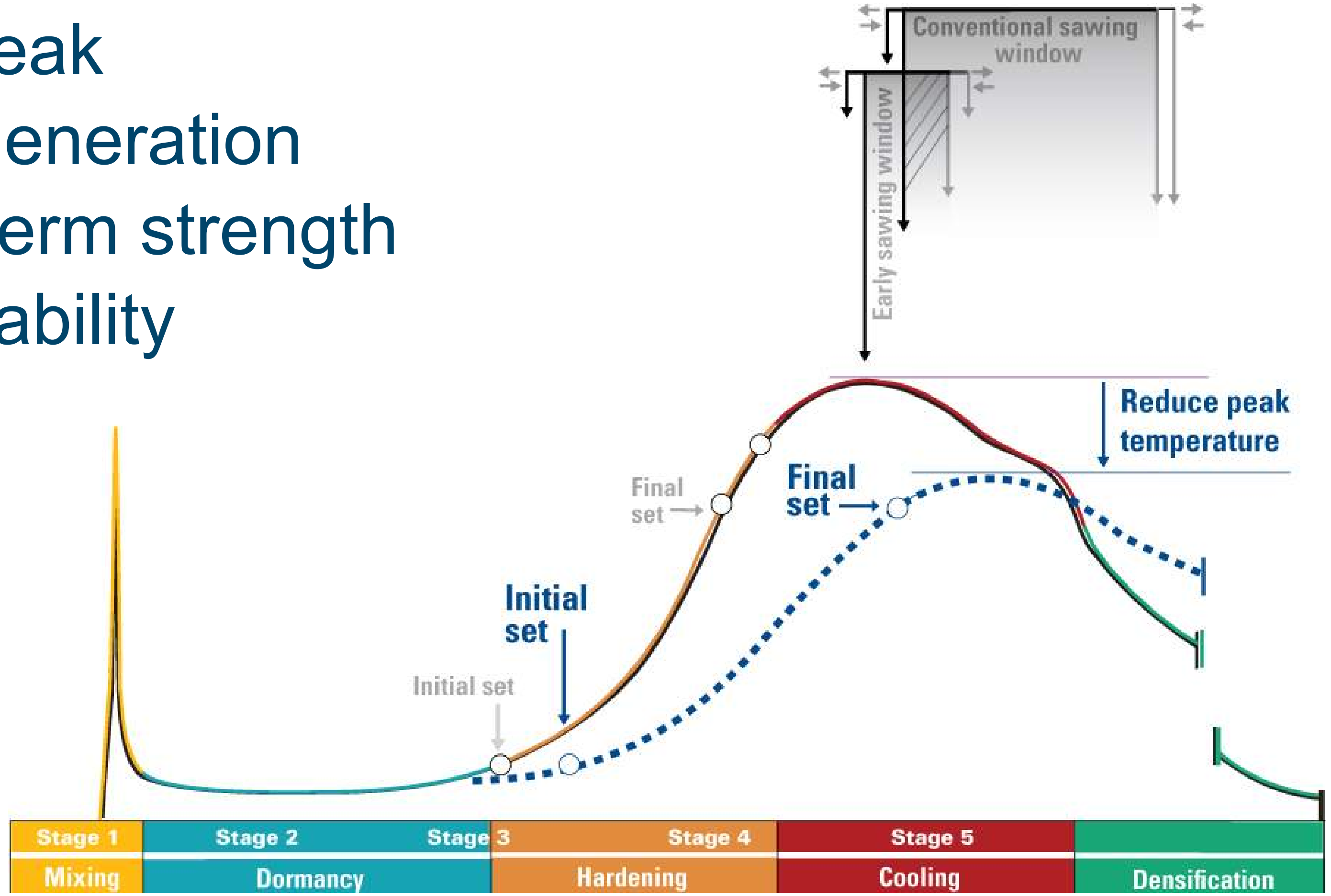
5 Densification

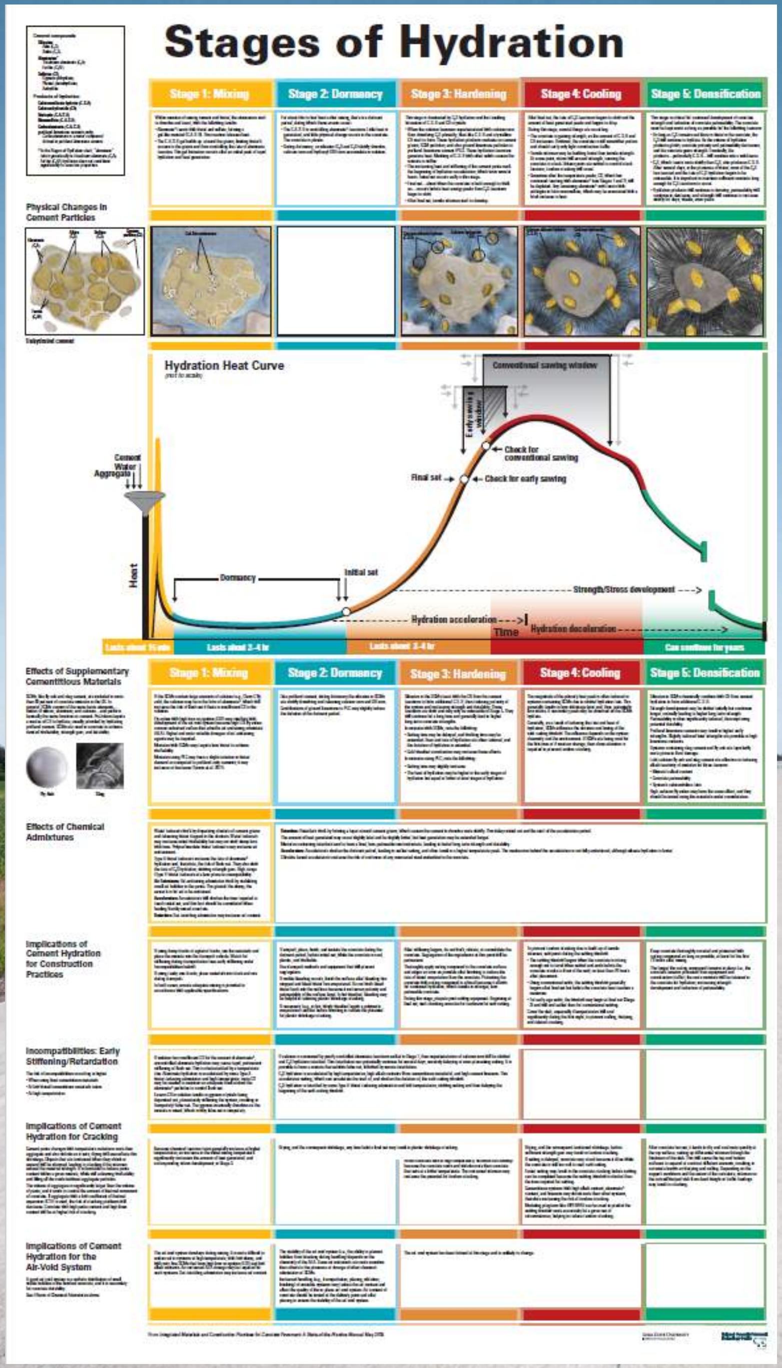
How SCMs Work



Effects of SCMs

- Delayed final set
- Reduced heat peak
- Extended heat generation
- Increased long-term strength
- Reduced permeability





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Mixture Properties

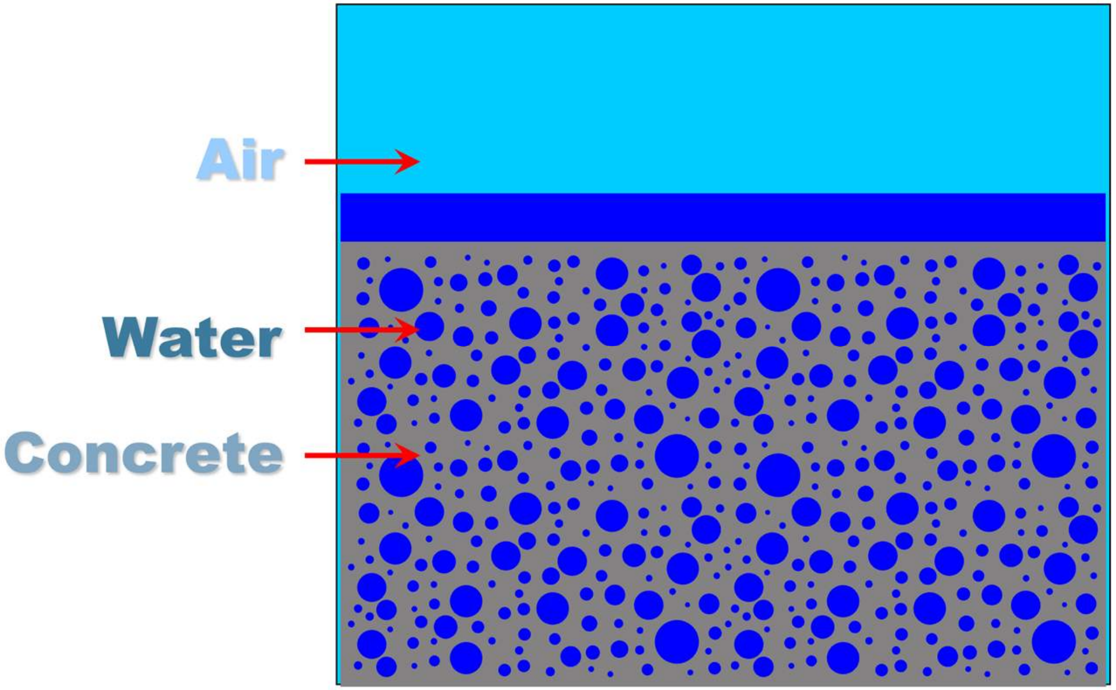
- Fresh
  - Workability*
  - Segregation
  - Bleeding
  - Setting
- Hardened
  - Strength and Stiffness*
  - Shrinkage and Cracking*
  - Air void system*
  - Permeability*

Workability

- Ease of mixing, placing, consolidating, and finishing
- Measure of uniformity
- Affected by mixture, environment, time

Segregation, Bleeding, Setting

- Affects finishing
- Affected by
  - Aggregate gradation
  - Weather

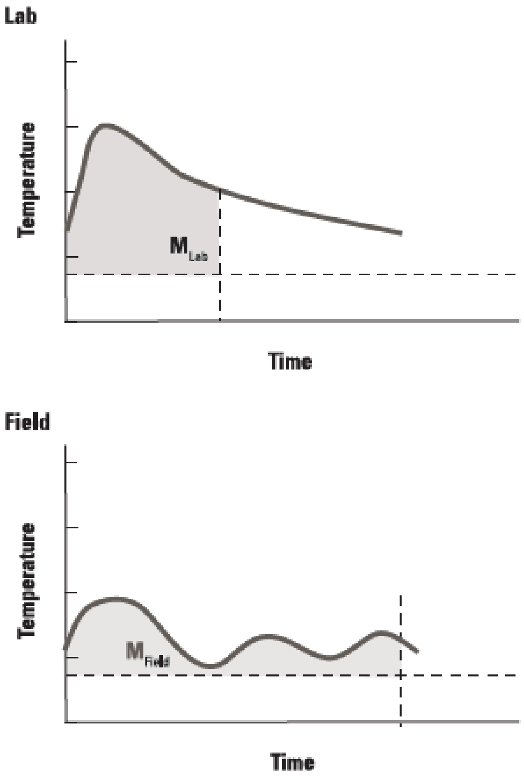


Strength and Stiffness

Significance
- To carry loads…
- No longer a good correlation with “quality”
- Strong in compression, less so in tension

- Higher stiffness increases cracking risk

Factors
- w/cm
- Degree of hydration
- System chemistry
- Interfacial zone
- Air



Shrinkage

Change in volume due to moisture loss

- Significance
  - Cracking
  - Warping

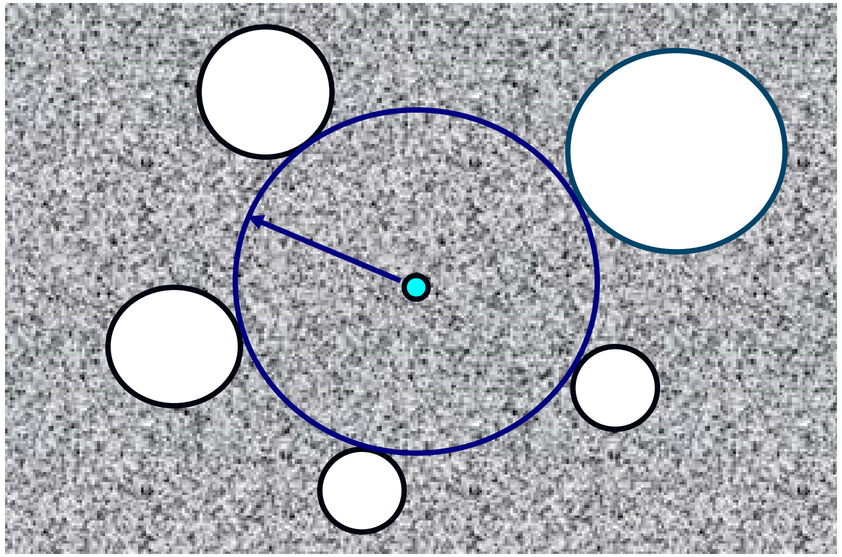
Air-Void System

Why?

- Frost resistance

What are we looking for?

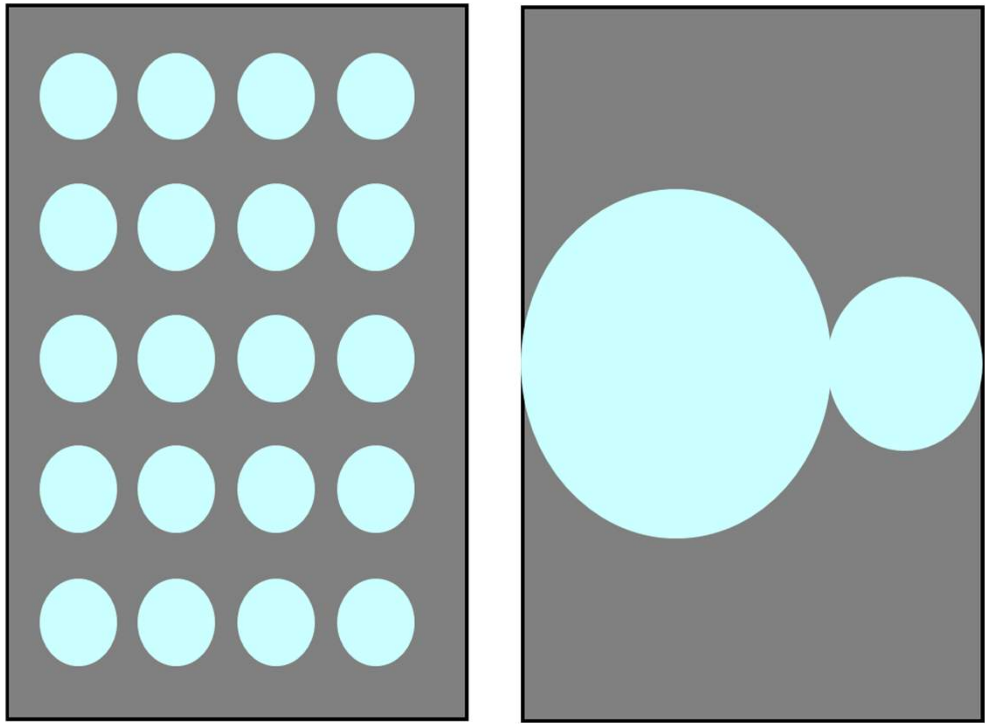
- 9% expansion
- Air void system is more important than total air content



Transport

The ease with which fluids can penetrate concrete

- Significance
  - All durability damage is governed by permeability



- Factors
  - w/cm
  - SCM type and dose
  - Hydration
  - Cracking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Alternative Cementitious Materials

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Why?

- Reduce costs
- Reduce dependence on imports
- Reduce CO_2

Alternative Cements

- Ecocem
  - Contains high levels of limestone as well and slag
- Solidia
  - “Lower proportion of limestone and lower production temperatures”
- CarbonBuilt
  - “Patented materials” cured in CO2
- Brimstone
  - Portland cement from calcium silicate
- Sublime
  - “Produce portland cement from non-carbonate rock by proprietary electrical-chemical processes”
- … and many others

Alternative SCMs

- Supplementary cementitious materials
  - Traditional SCMs
  - Ternary combinations
- Other SCMs
  - Recycled Ground Glass, ASTM C1866
  - Locally processed waste products
  - Harvested fly ash
  - Colloidal silica
  - Iron slag

Alternative SCMs

- New SCMs
  - Carbon Upcycling
    - Grind materials in presence of CO2
  - TerraCO2
    - Synthetic fly ash
  - Carbon Limit
    - Non-calcined mineral admixture with catalyst
  - Fortera
    - Reactive calcium carbonate

MNRoad

- Why build it
- What we did
- How its going

Google maps

Why build it

- FHWA and SHA's are looking to reduce ~~embodied carbon~~ costs
- A variety of systems are being developed and marketed
- But:
  - Can we build with them?
  - Do they work?
  - Do they last?

What we did

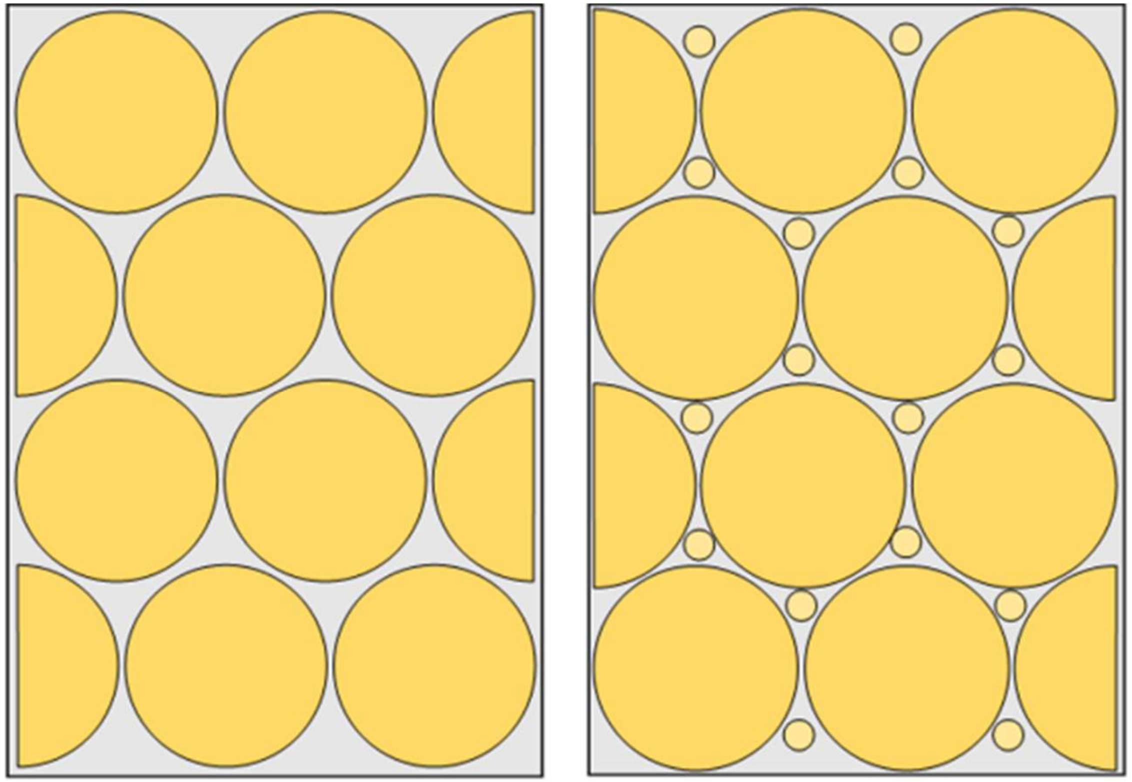
- MNDOT / NRRA agreed to open 24 cells on I94 at MNRoad
- A committee set broad guidelines
  - Enough to build 250 feet of pavement
  - Batch in a ready-mix plant
  - Run through a slipform paver
  - Meet R101 performance metrics

  - Trial batches required

  - Standard design – 270’ x 29’ x 7.5”
  - Same foundation system

What we did 2022

- The plan:
  - 1 control cell
    - Type IL cement
    - 570 pcy cementitious
    - 30% Class F fly ash
    - 0.40 w/cm
  - 1 optimized mixture
    - Optimized gradation
    - 500 pcy



What we did - 2022

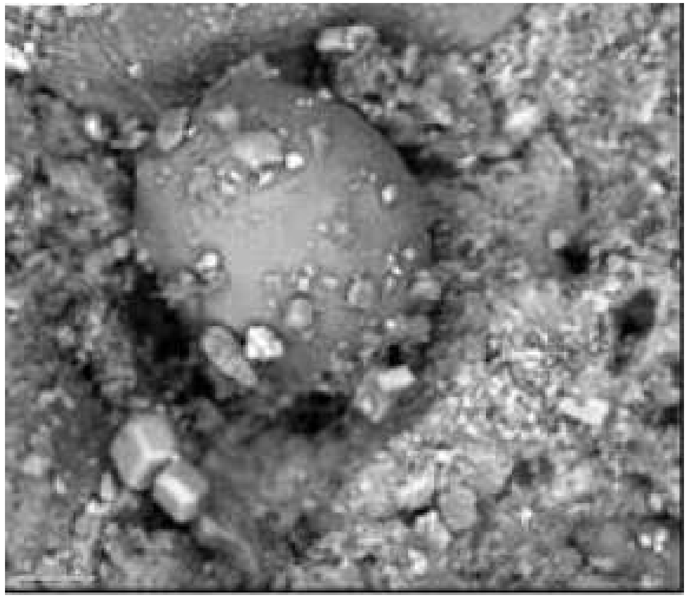
- The plan:
  - 7 alternative (nominal) SCM cells
    - Carbon Upcycling – fly ash ground in CO2 (500 pcy)
    - Urban Mining – recycled glass (570 pcy)
    - Terra CO2 – manufactured fly ash (570 pcy)
    - Carbon Limit - limestone + natural pozzolan (570 pcy)
    - Hess Pumice (570 pcy)
    - 3M – shingles dust (570 pcy)
    - Burgess – metakaolin (570 pcy)

What we did - 2022

- The plan:
  - 3 alternative cements
    - Ash Grove - 30% calcined clay (570 pcy)
    - Continental - 20% limestone (570 pcy)
    - Ultrahigh Materials - non-portland cement (650 pcy)
  - 4 Carbon Injection cells
    - MNRoad mix with and without CO2 (570 pcy)
    - Optimized mix with and without CO2 (558 pcy)

What we did - 2024

- The plan:
  - Control
  - 2 Microsphere cells
  - Ash Grove LC^3
  - Type IL + slag + fly ash + natural pozzolan
  - Slag cement + activator
  - Holcim Ternary
  - Ozinga 1157 cement



What we did

- Watched placeability

What we did

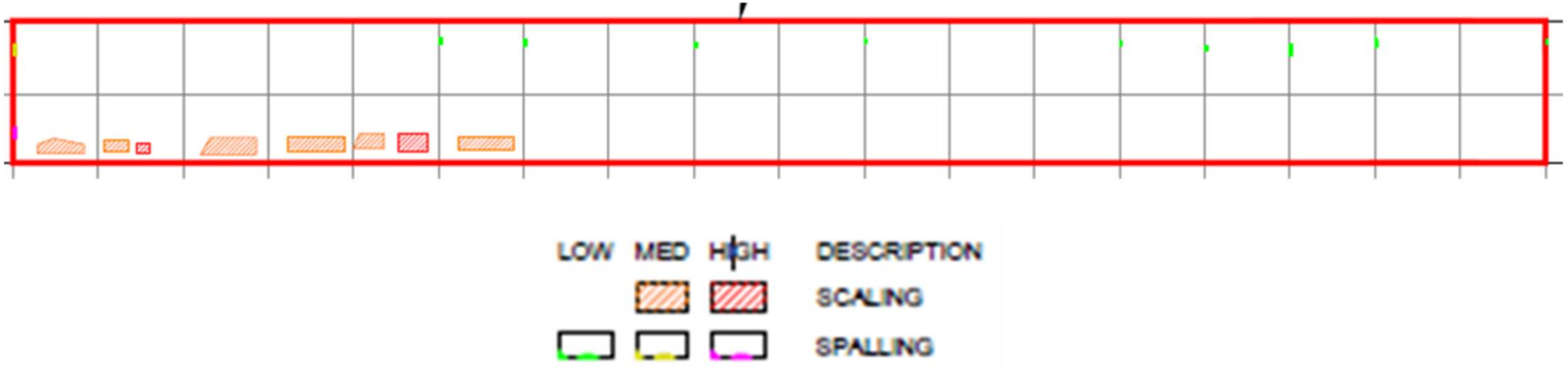
- Tested
  - Fresh properties
  - Hardened properties
  - Durability properties

What we did

- Sensors
  - Strain
  - Moisture
  - Soil suction
  - Frost sensing
  - Joint opening
  - Temperature
  - Dynamic pressure
  - Displacement
  - Joint movement

What we did

- Monitor
  - Surface
  - Ride
  - Cracking
  - Distress



How Its Going

- Preconstruction
  - Availability
  - Delivery of materials
    - Supersacks are a pain
    - Not all were uniform

How Its Going

- Construction
  - Some systems went down easily
  - Others less so

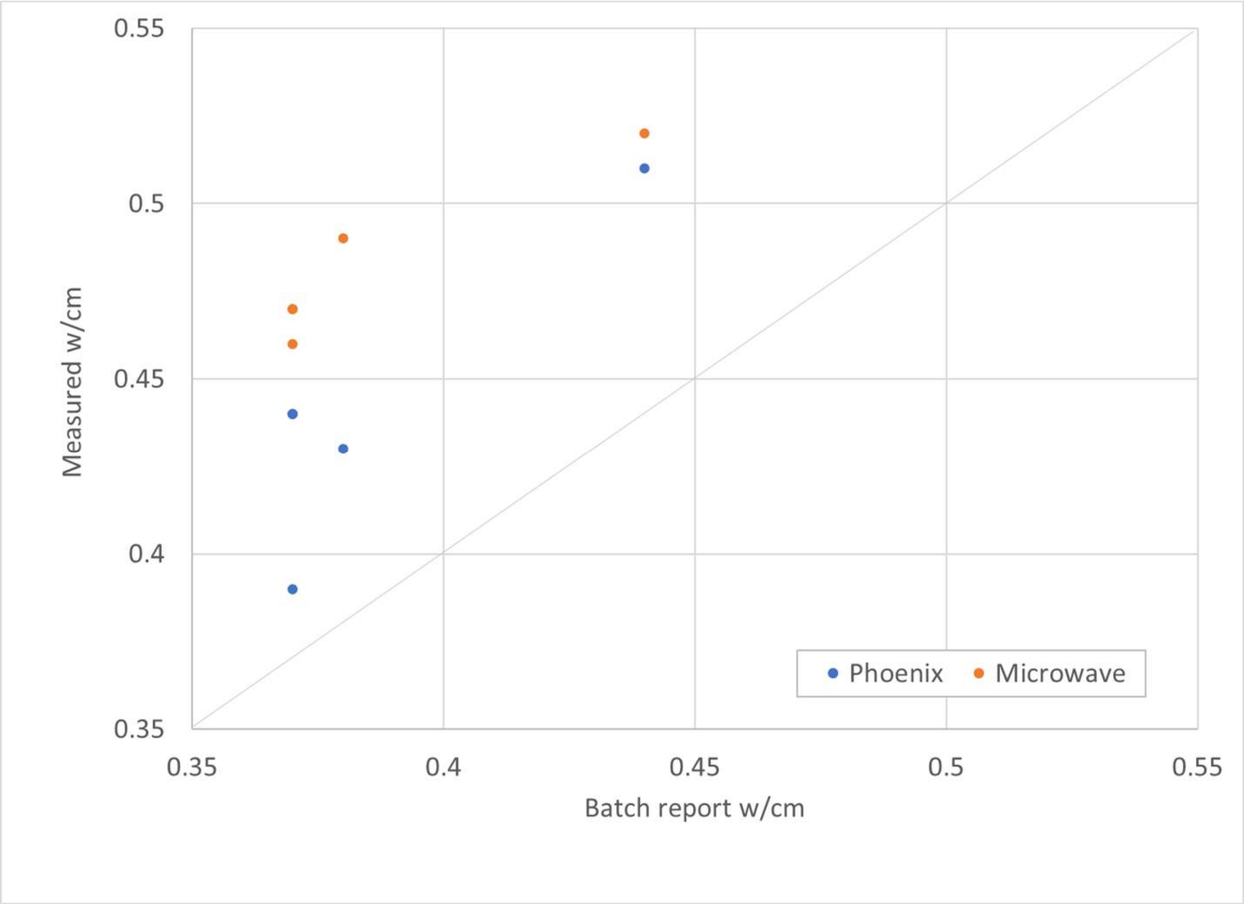
  - Slump loss was different
  - Response to admixtures was different
  - Response to vibration was different

Testing

VKelly = 0.60

VKelly = 0.46

Testing

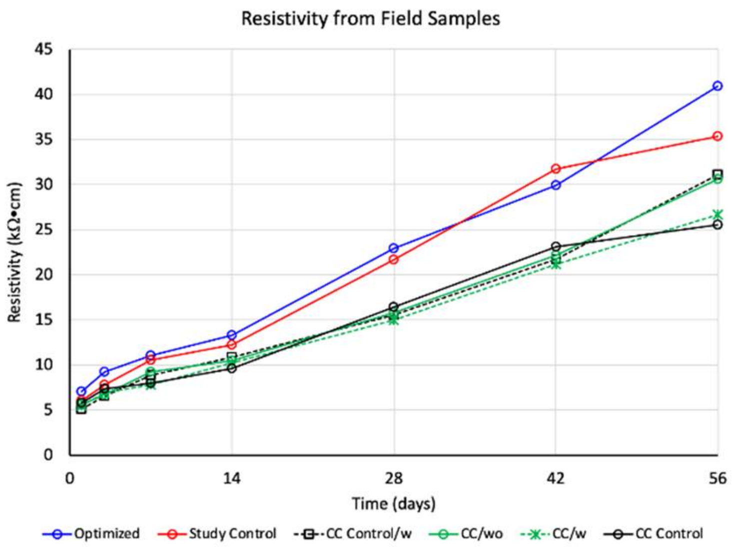


0.55
0.5
0.45
0.4
0.35
Measured w/cm
0.35
0.4
0.45
0.5
0.55
Batch report w/cm
Phoenix
Microwave

GILSON

How Its Going

- Strength
  - Most achieved 3500 psi at 28 days, all at 56 days
- Resistivity
  - Most achieved 20 kohm-cm at 28 days, all at 56 days
- Freeze thaw
  - Mixed lab findings



Annual Reviews

- Some grinding needed for texture
- Some minor spalling
- All seemed to survive the winter(s)

So…

- Some systems are closer to being ready for prime time
- Trial batches / placements are not optional
- Water control is critical
- Fresh behaviors are different
- Hardened properties can be OK
- Durability is OK (so far)

- Same'ol, Same'ol ain't the same

Impacts

- What metrics do states use to decide whether to add a new cement / SCM to their approved materials list?
- What tools can states use to monitor acceptability / uniformity of cements / SCMs being delivered to a site?
- How do concrete suppliers a develop mixtures made with new cements that meet concrete performance requirements/
- How do concrete contractors work with mixtures made with cements / SCMs/

Impacts

- Not bad – but different
- We will have to learn to:
  - Accommodate differences
- Exciting times!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Mixture Proportioning

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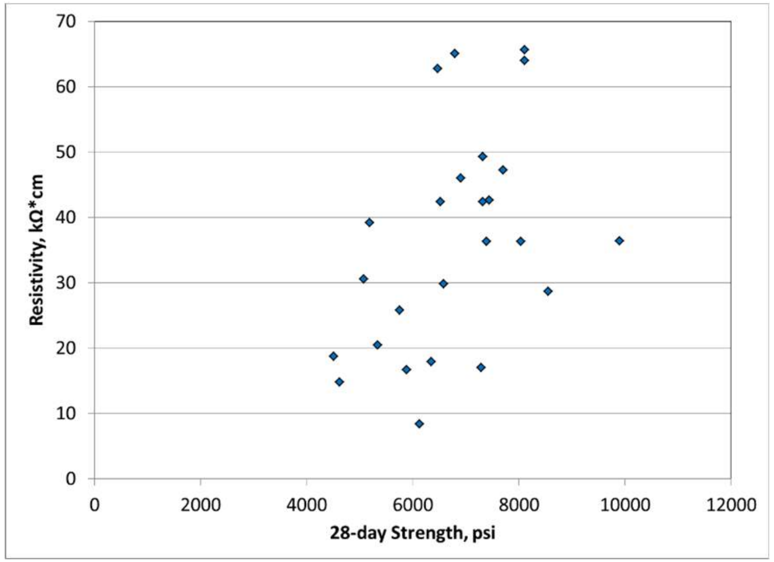
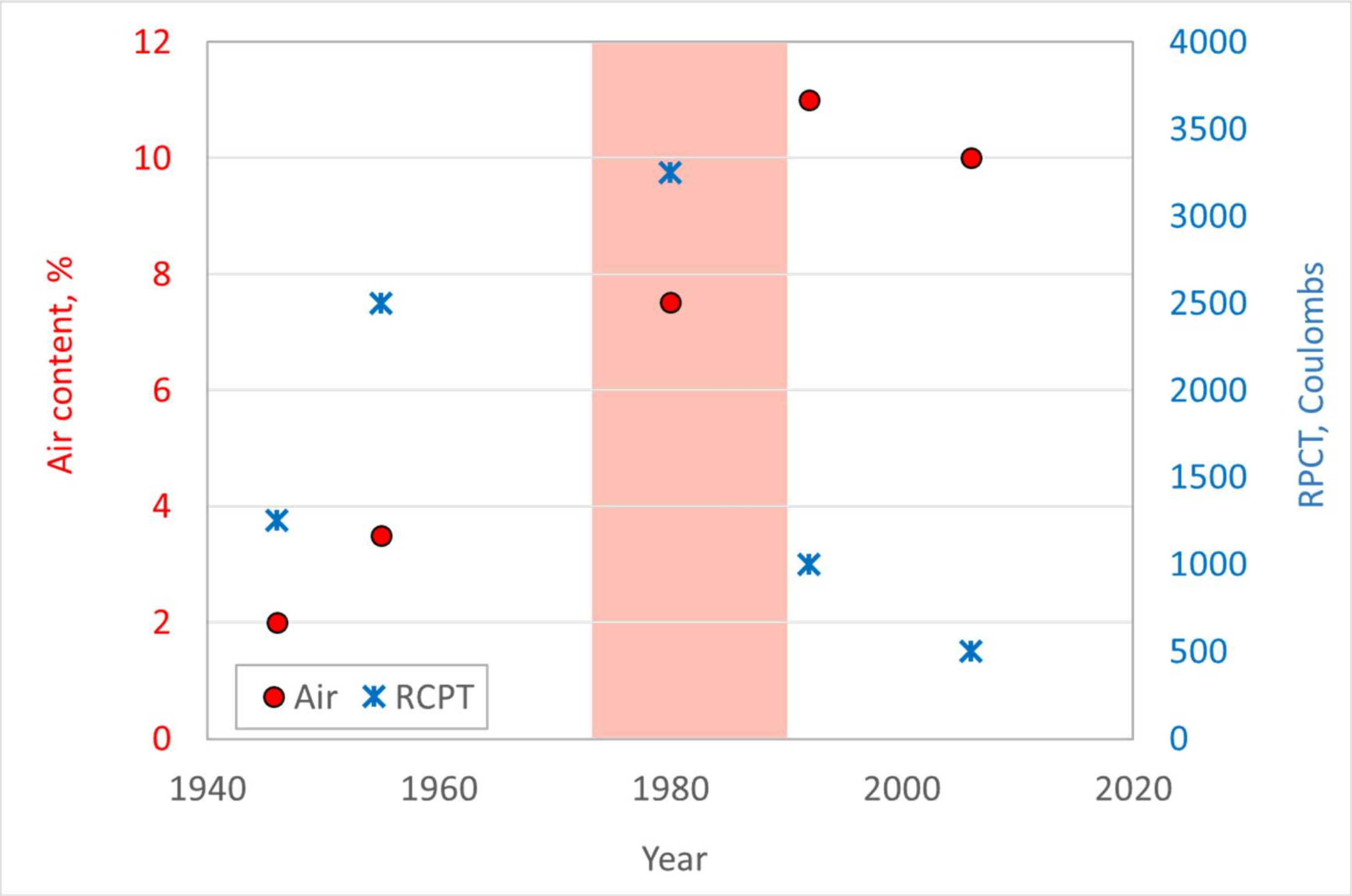
Preconceptions

- Who cares about the concrete as long as it is gray, cracked and hard?
- More cement = more strength
- Strength is everything
- Slump indicates quality
- Gradations of individual aggregate fractions are critical



What is Good concrete?



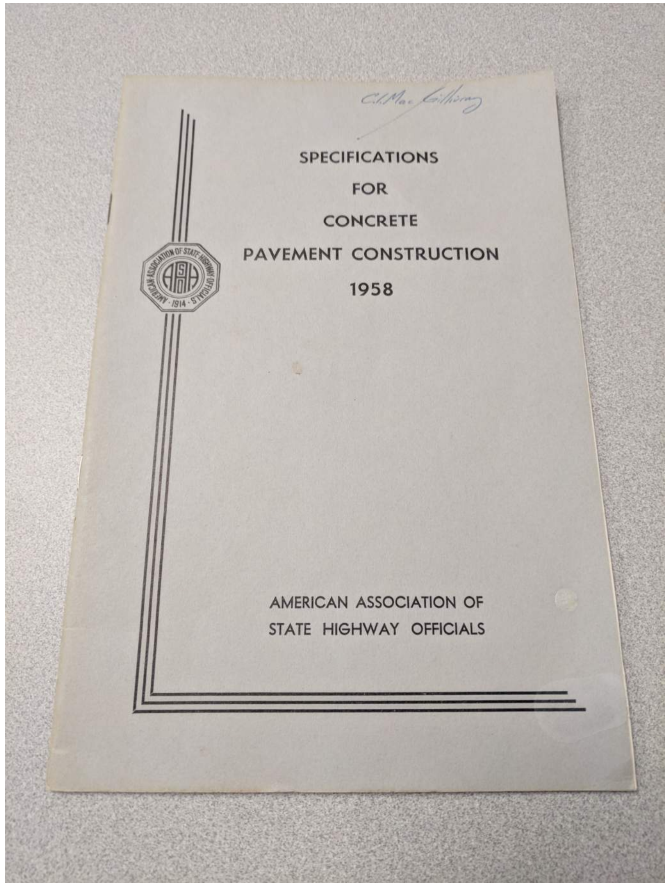
What do we need?

- Transport properties (permeability)
- Aggregate stability
- Cold weather resistance
- Strength
- Shrinkage

- Workability

Proportioning Approaches

- Do what we did last time



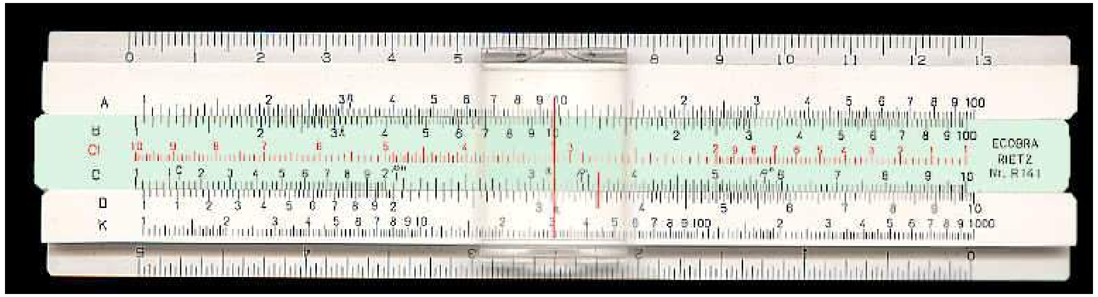
Proportioning Approaches

• Structural concrete	1:2:4
• Other concrete	1:3:6
• Waterproof concrete	Add salt

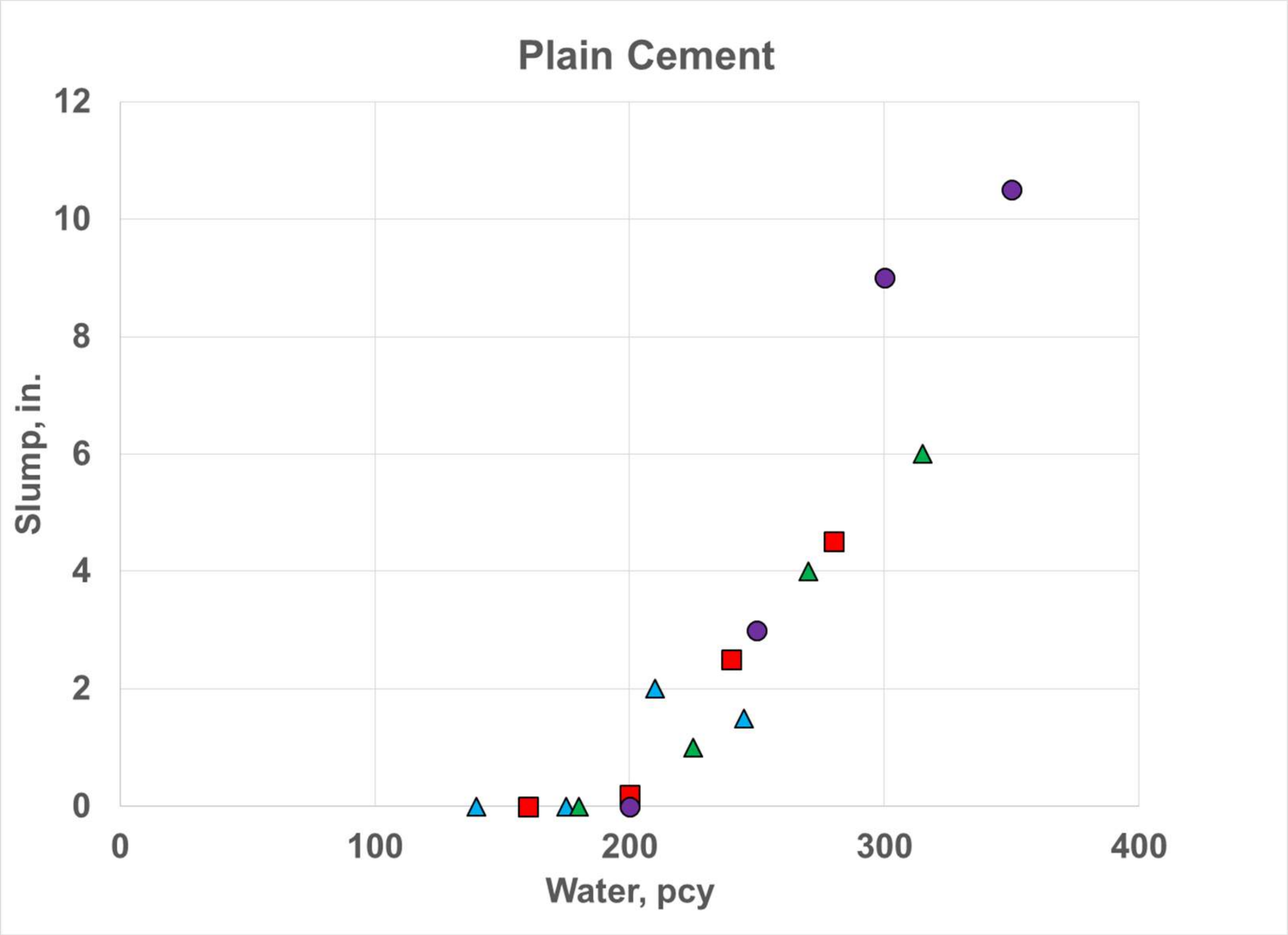
- No chemicals
- No SCMs
- Precision was ugly
- Bulking made it worse

Proportioning Approaches

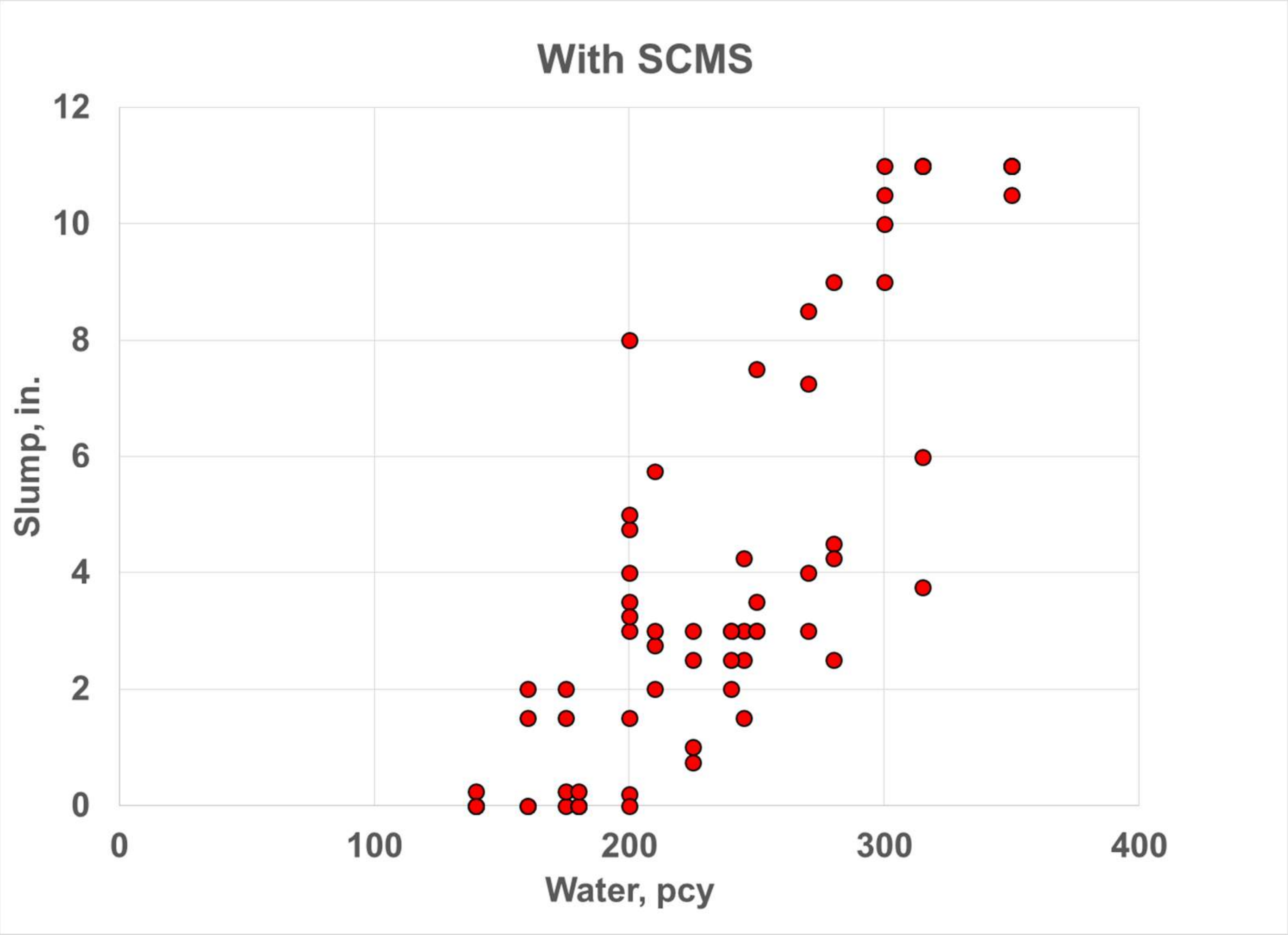
- ACI 211 – ~~1991~~ 2022
- Developed
  - Before water reducers
  - Before supplementary cementitious materials
- Primarily focused on structural concrete
  - 100 mm (4”) slump
  - 30 MPa (~4000 psi)



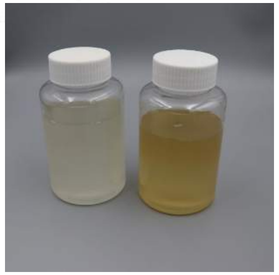
Workability



Workability



Proportioning

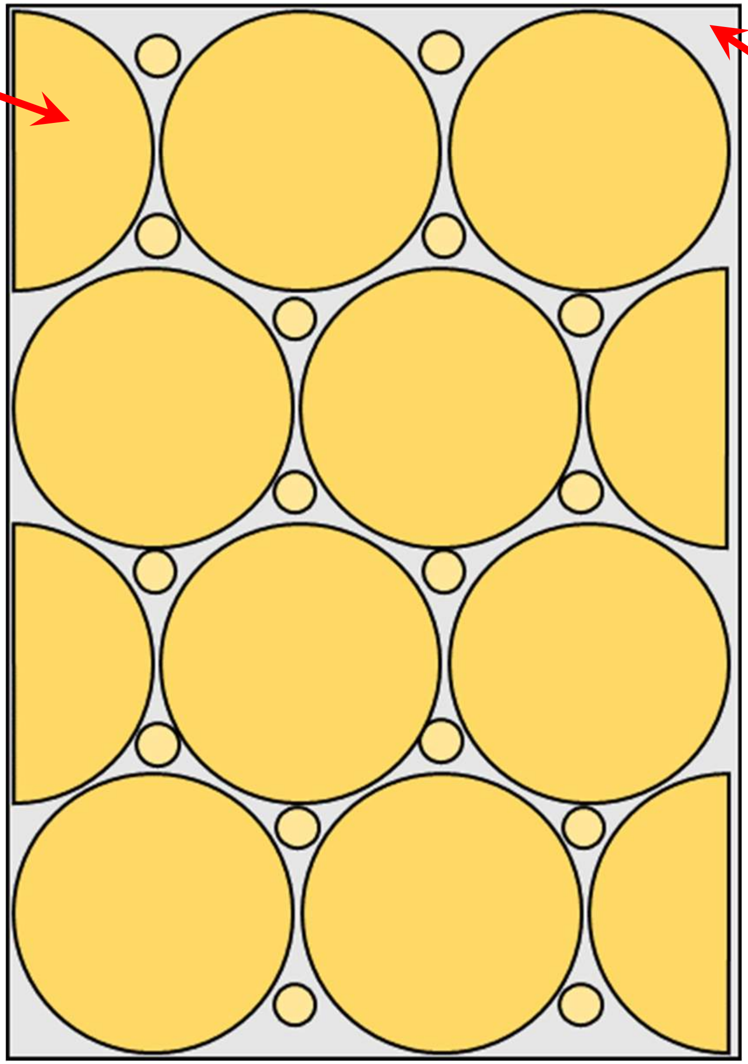


What controls performance?

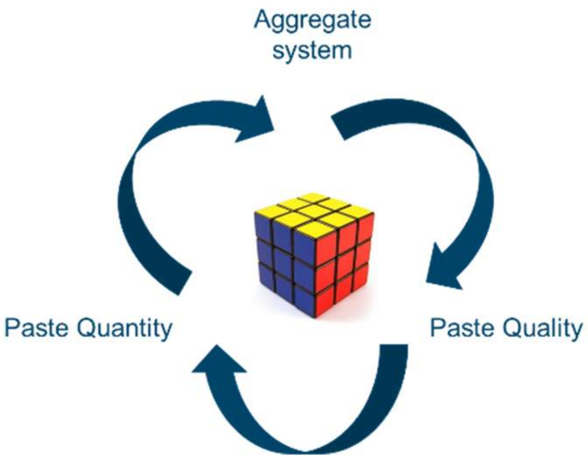
		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Proportioning

Filler
Gradation

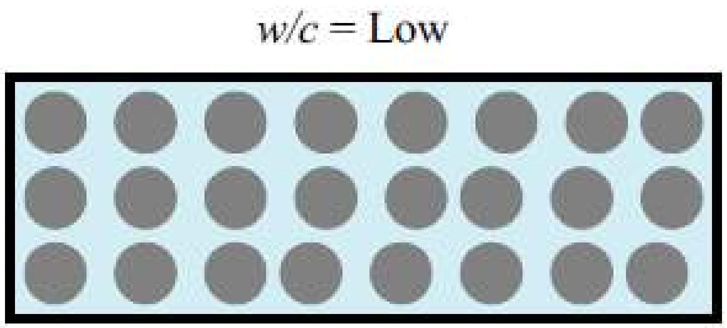


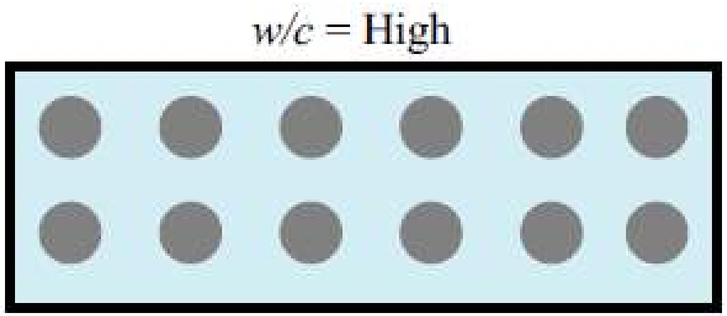
Glue
What sort
How much



Step 1 Paste Quality

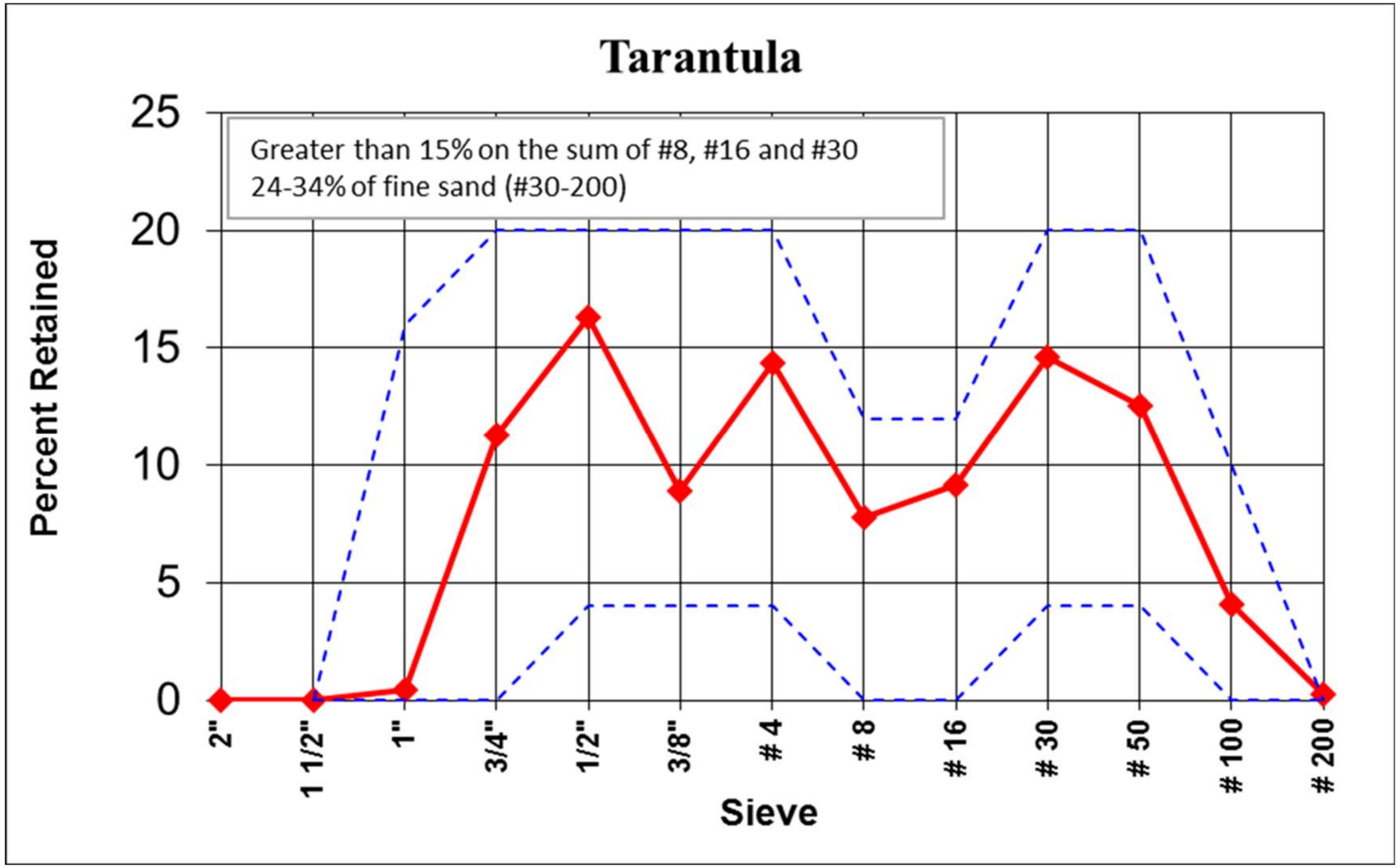
- Binder type
  - Cement type
  - SCM type and dosage
- w/cm
  - Choose for performance
  - System chemistry
- Air void system
  - Small bubbles close together
  - Stable





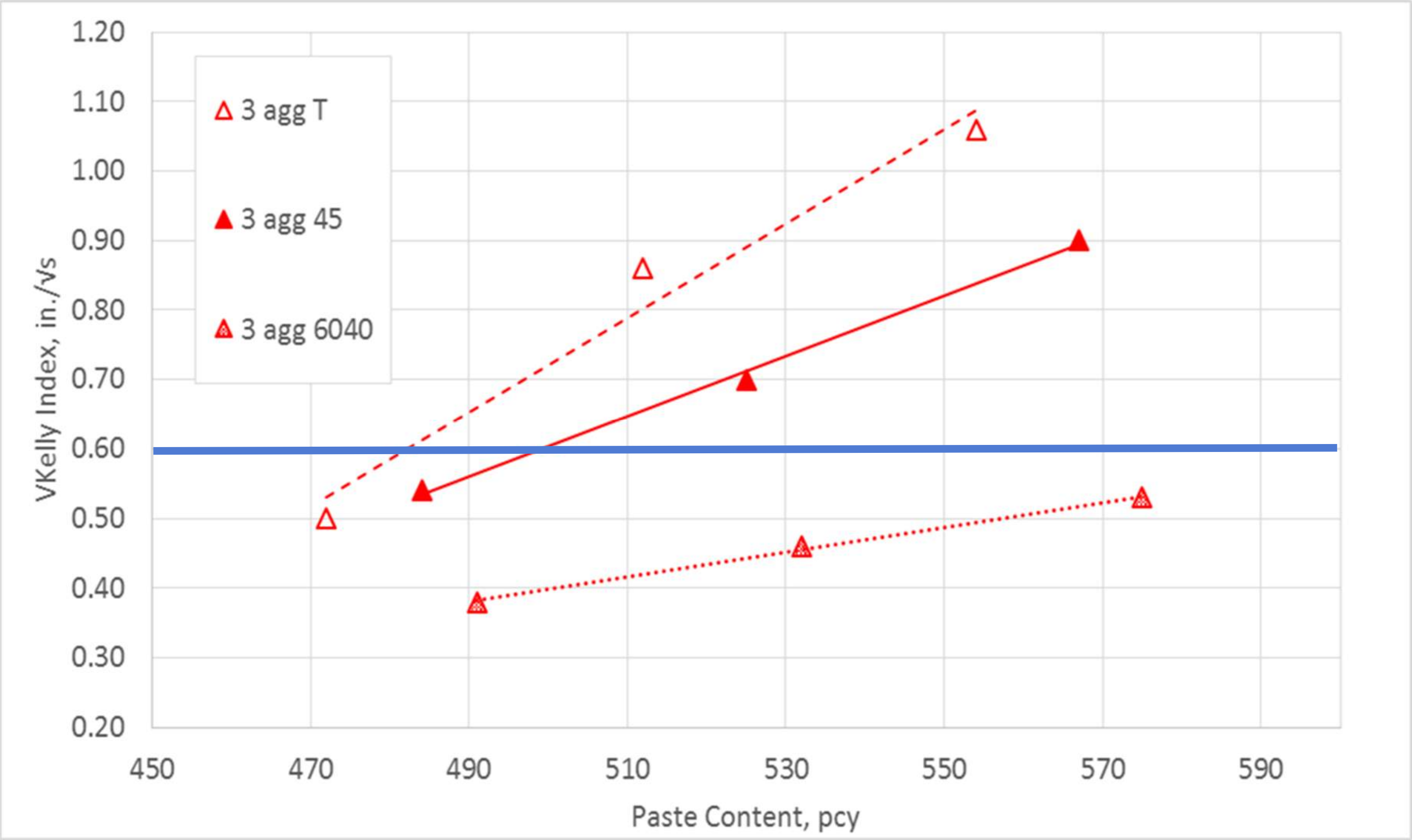
Step 2 Aggregate system

- Choose an aggregate system…

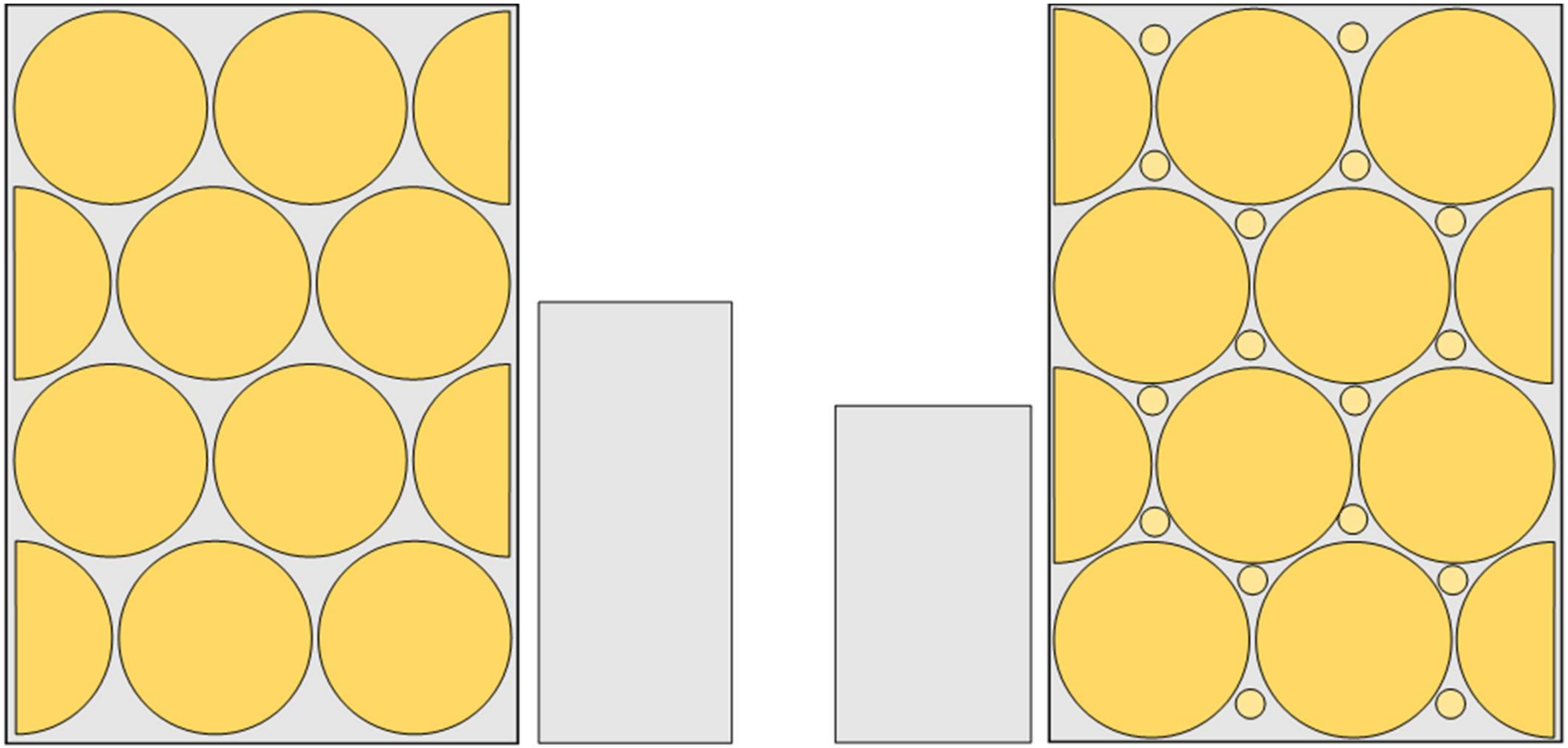


Step 2 Aggregate system

- Choose an aggregate system…



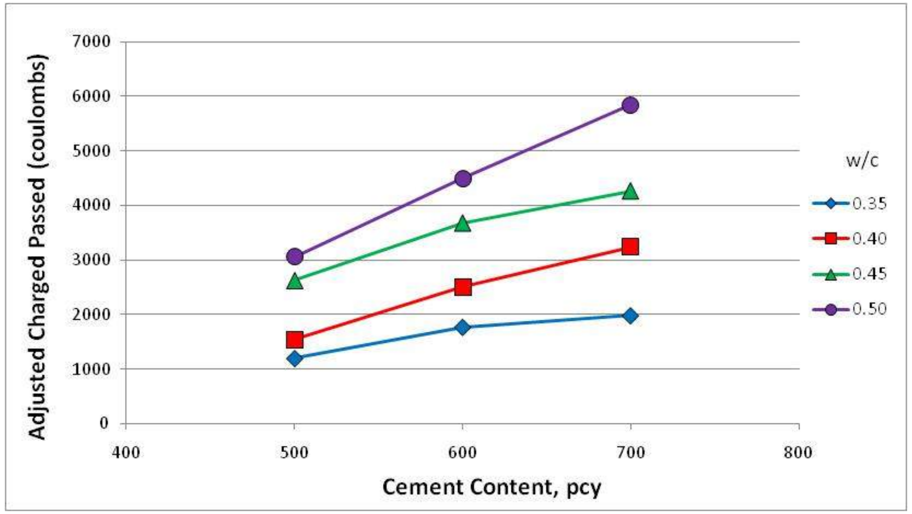
Step 3 Paste Content



Typically Volume of paste ~150-200% of voids

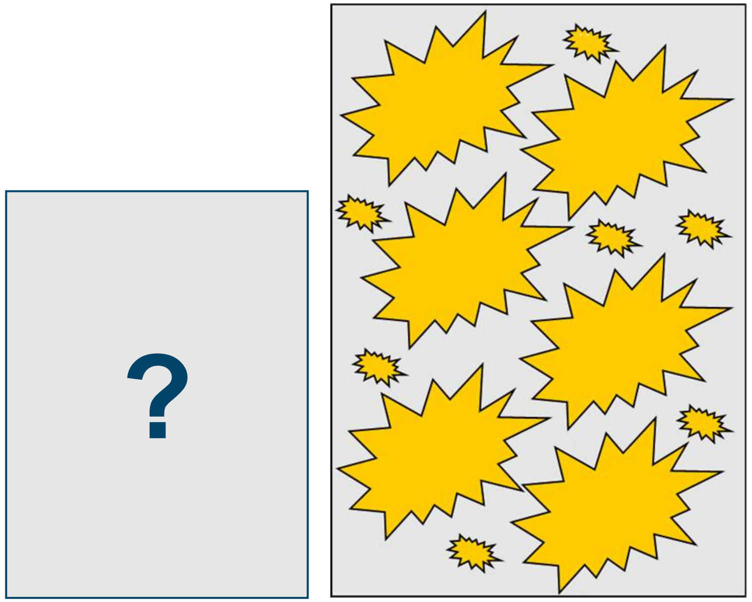
Step 3 Paste Content

- Need a minimum paste for workability
- Excess has a:
  - Small negative effect on strength
  - Negative effect on permeability, shrinkage, cost
  - Negative effect on sustainability
- "Optimum" depends on:
  - Aggregate type
  - Gradation
  - Binder type



Ongoing Work

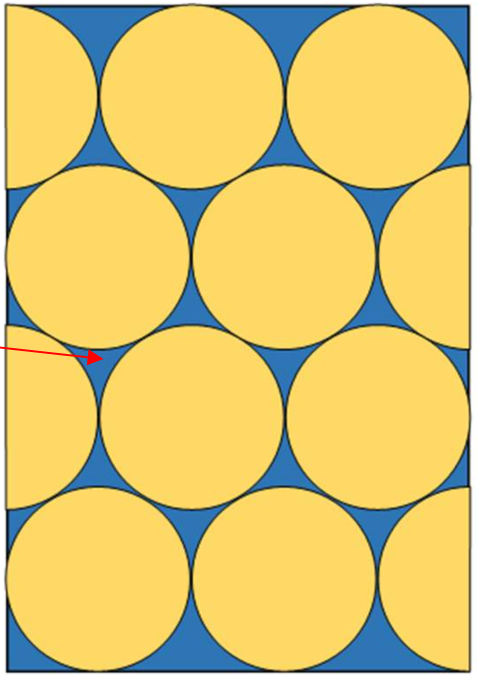
- What void ratios are needed for:
  - Varying aggregate mineralogy
  - Varying aggregate form
  - Varying gradation

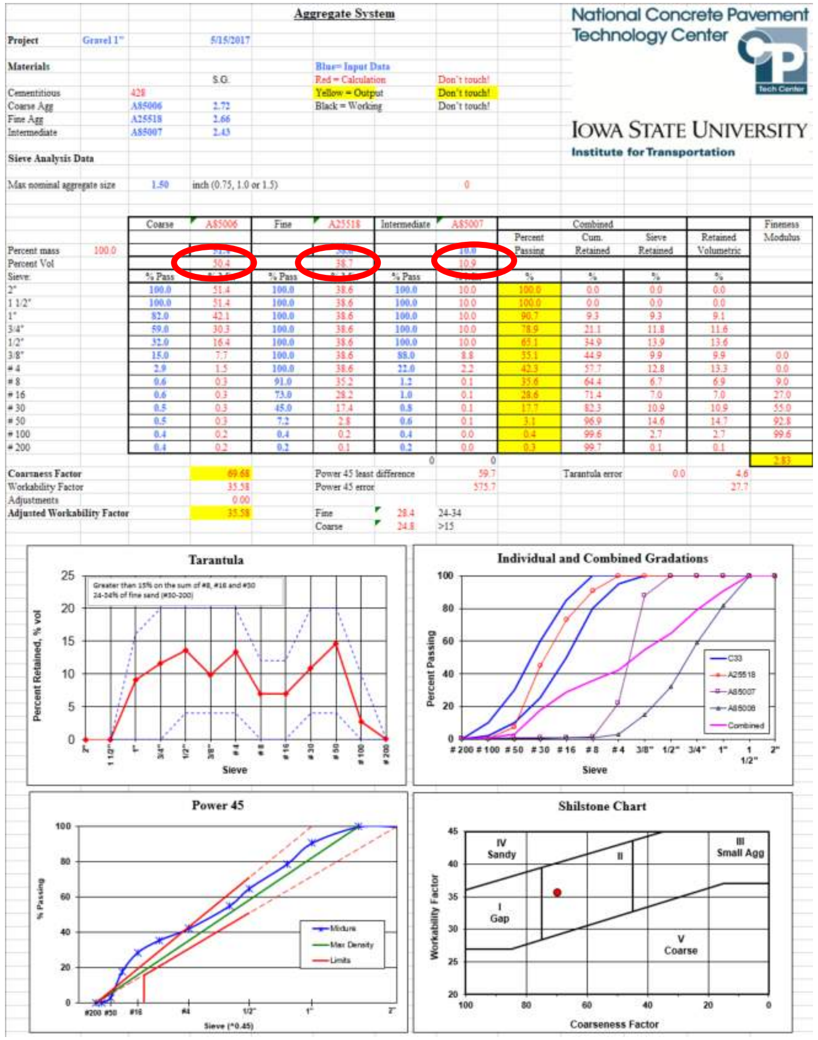


Doing the Sums

The wonders of a spreadsheet and a solver function…

Measure V_a





Doing the Sums

The wonders of a spreadsheet…

Paste Quality

Project	**Gravel 1"**		**5/15/2017**	
Materials				
		Targets		
			R.D.	
Cement	**Type I**		3.15	
SCM 1	**F Ash**		2.65	
SCM 2	**Slag**		1.00	
Coarse Agg	**A85006**		2.72	
Fine Agg	**A25518**		2.66	
Intermediate	**A85007**		2.43	
Water			1.00	
Cementitious		428	pcy	
w/cm		0.42		
Air %		5.0	%	
% SCM 1		20	%	
% SCM 2		0	%	
Voids in aggregate		25.3	%	
Required Vp/Vv		125	%	
Strength		4000	psi	7 days
RCP		1500	coulomb	56 days
Wenner		27	kΩ-cm	28 days

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Blue= Input Data	
Red = Calculation	Don't touch!
Yellow = Output	Don't touch!
Black = Working	Don't touch!

Doing the Sums

The wonders of a spreadsheet…

Mixture Proportions

Project	Gravel 1"		5/15/2017		
Mixture Proportions					
		Targets	**Actual**		
			Pounds	R.D.	Volume
Cement	Type I		342	3.15	1.74
SCM 1	F Ash		86	2.65	0.52
SCM 2	Slag		0	1.00	0.00
Coarse Agg	A85006		1753	2.72	10.33
Fine Agg	A25518		1318	2.66	7.94
Intermediate	A85007		340	2.43	2.24
Water			180	1.00	2.88
Air %			5.0		1.35
			4019		27.00
Cementitious		428	428	pcy	
Volume of paste			24.0	%	
Volume of aggs			76.0	%	
Volume of voids			19.2		
vp/vv		125	125.0		
w/cm		0.42	0.42		
% SCM 1		20	20	%	
% SCM 2		0	0	%	
Mass aggs		3411	3411	pcy	
Excess paste, %			4.8	%	

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Blue= Input Data	
Red = Calculation	Don't touch!
Yellow = Output	Don't touch!
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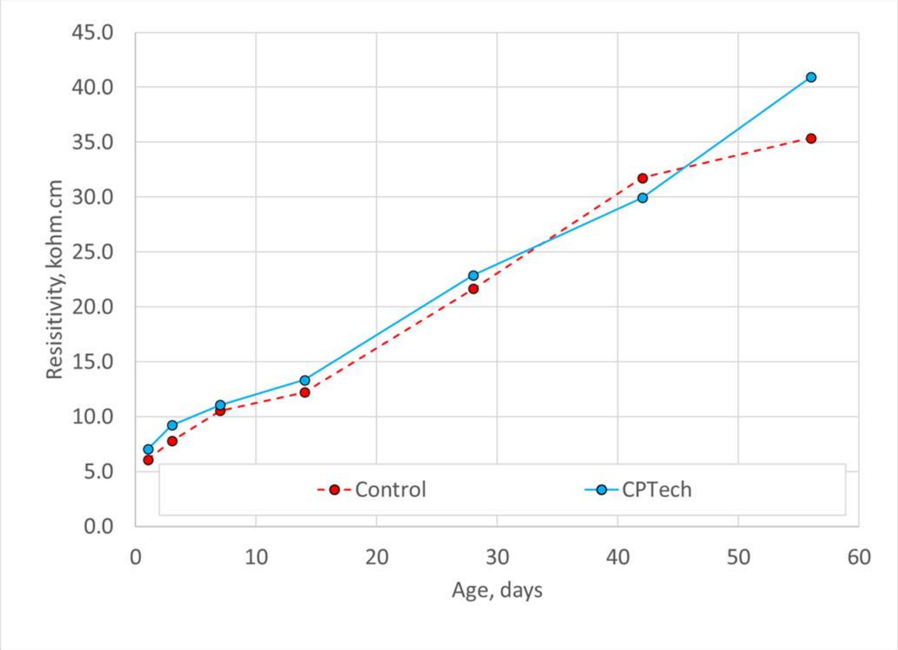
Trial Batches

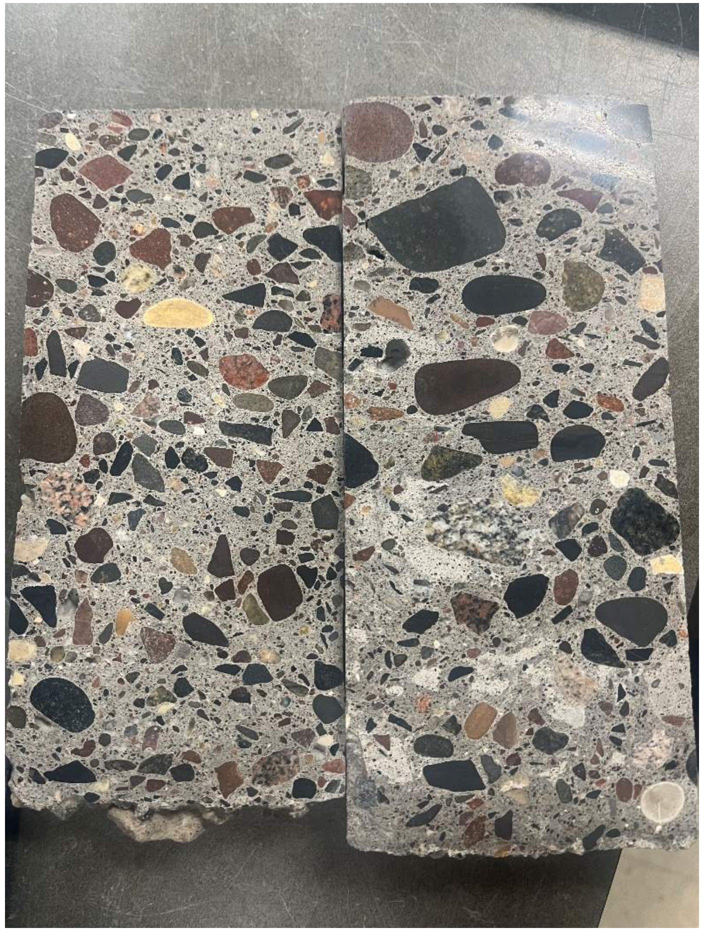
- Workability / Admixture dosages / Void ratio
- Air void system
- Setting
- Strength gain
- Permeability
- …

Does it Work?

- MNRoad

	MNDOT	Optimized
Cement	400	351
SCM 1	170	150
SCM 2	0	0
Coarse Agg	457	662
Fine Agg	1171	1303
Intermediate 1	1167	954
Intermediate 2	244	254
Water	228	200
Air	7.0	7.0
Total	3837	3874
Cementitious	570	501
vp/vv	208	180
w/cm	0.40	0.40
% SCM 1	30	30





What to Specify?

- Not
  - Slump
  - Cement content
  - Individual aggregate gradations
- Maybe
  - w/cm
  - Air void system
  - Paste content
- Definitely
  - Enough strength (and no more)
  - Transport
  - Uniformity
  - Aggregate stability

QC

- Materials
- Dosages
- Aggregate moisture
- Workability
- Unit weight
- Resistivity

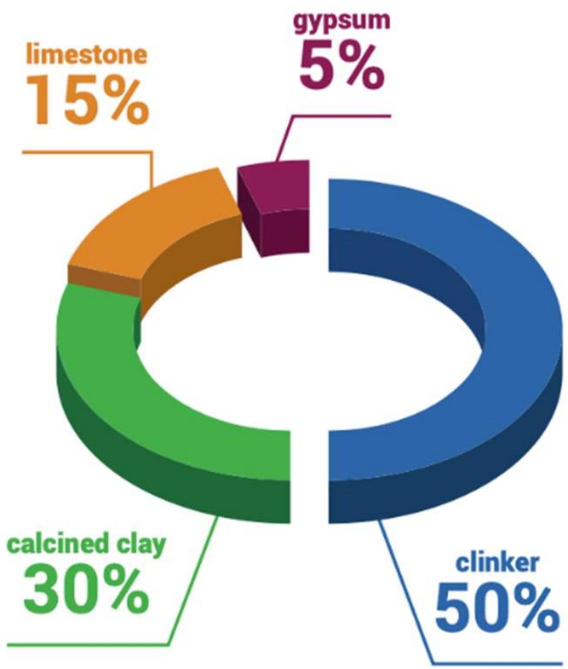
What to Accept?

- Watch
  - Water
  - Cementitious system
  - Uniform workability

- Test
  - Air
  - Resistivity
  - (Strength)

But Wait – There's More

- New materials are coming
  - Harvested fly ash
  - LC3
  - 50% clinker
  - Other powders
- Design assumptions may need to change
  - Shrinkage
  - Modulus of elasticity
- Construction practices may need to change
  - Finishing
  - Curing
  - Sawing



Where next?

- Learning and thinking required
- Target the properties you need
- Do those trial batches
- Stay away from the cliff edge

- Help is available…

Construction

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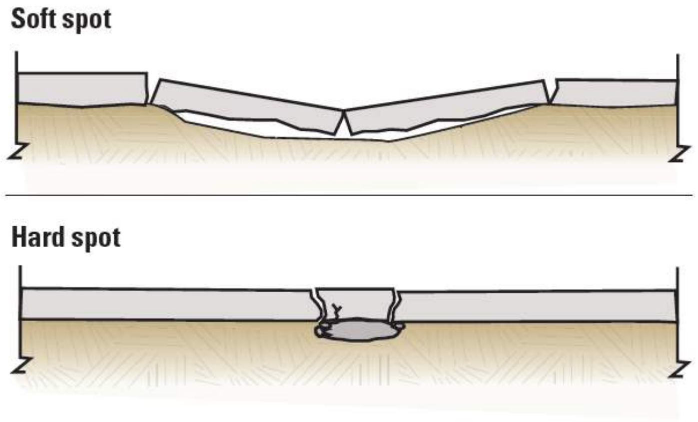
Construction

- Subgrades
- Bases
- Concrete

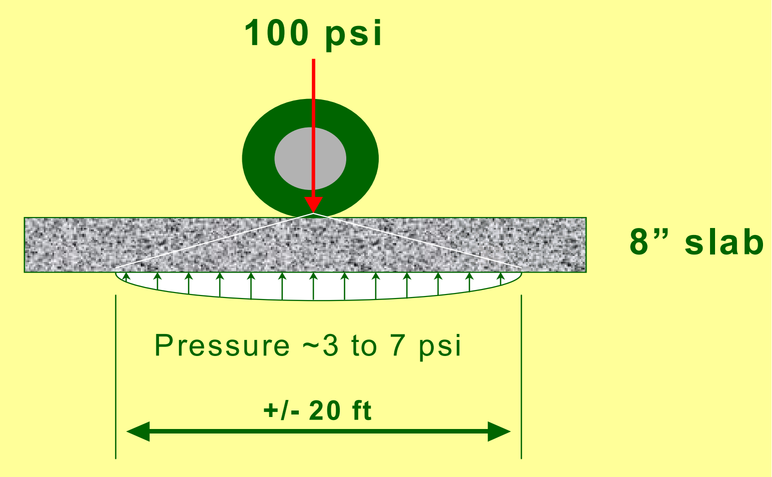
Subgrade

Existing material

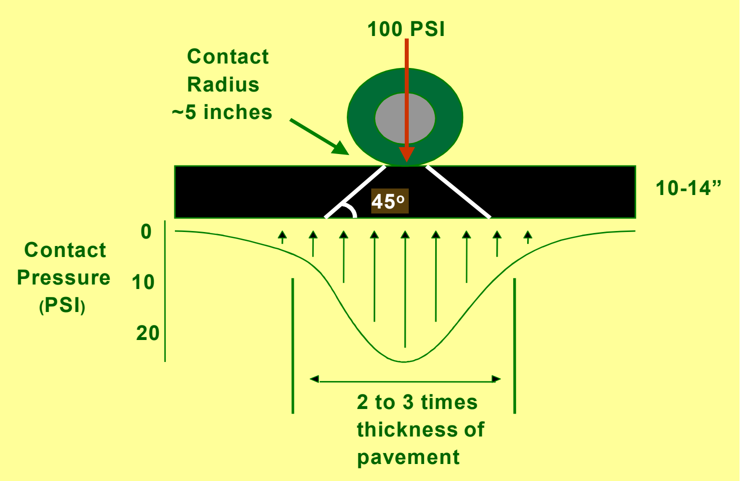
- Desired:
  - Uniformity
  - Stability
  - Some stiffness
  - Drainage



Concrete



Asphalt



Soils

- Gravel and sand
  - Good shear strength
  - Low compressibility
  - High permeability
  - Good workability
- Silt
  - Poor shear strength
  - High compressibility
  - Low permeability
  - Poor workability
- Clay
  - Structures are flat and platy
  - Highly influenced by water
  - Significant volume change

¾ Gravel	>4.75mm
Sand	4.75 to 0.075 mm
Silt	0.075 to 0.002 mm
Clay	< 0.002 mm

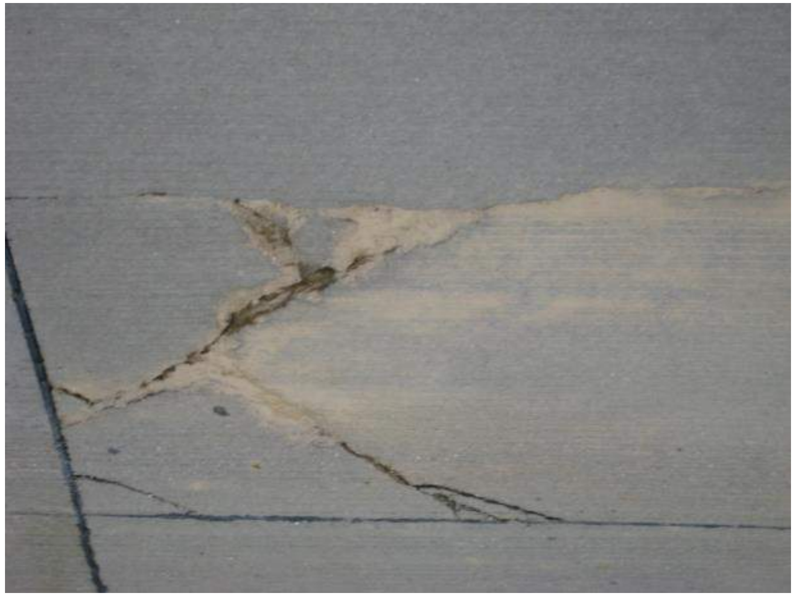
Rutting & Pumping

Rutting

- Subgrade non-uniformity

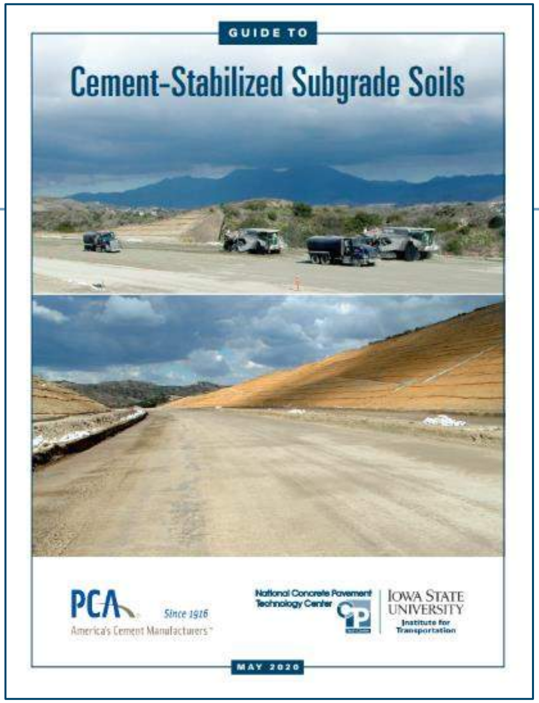
Pumping

- Displacement of soil and water under load
- Leads to displacement of soil and so loss of support



Stabilization

- Purpose
  - Improve strength (not too strong)
  - Reduce swelling
  - Provide construction platform
  - Provide uniformity

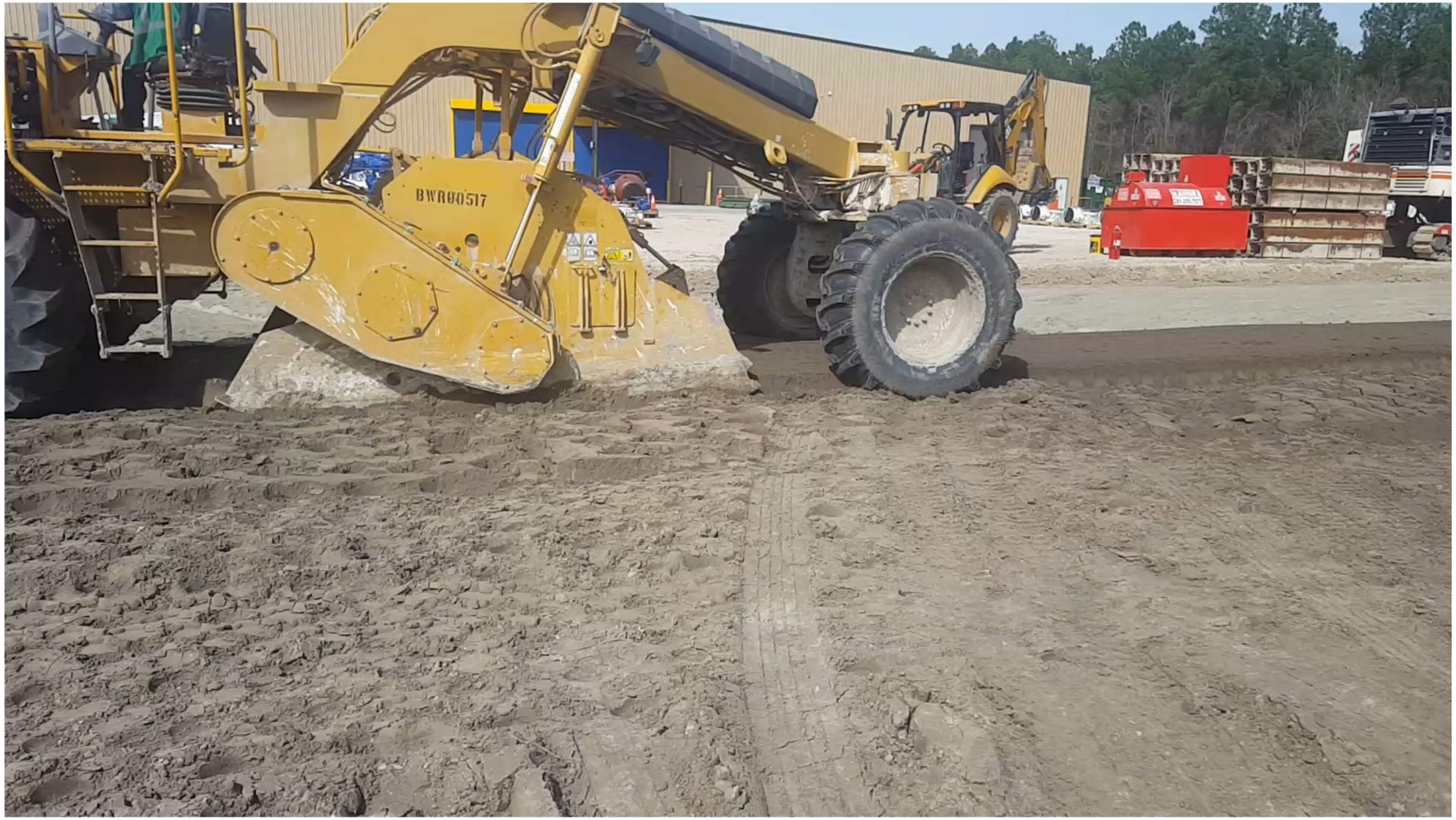


Halsted et al. 2008, © 2008 PCA

Stabilization

- Accomplished using
  - Cementitious materials
    - Cement Stabilized Soils (CSS)
  - Lime, fly ash, others
- Often better option than core-out and replace

CSS Reclaimation



Proof Rolling

- To locate soft areas not detected in the grade inspection
- Heavy, pneumatic-tired vehicle on the prepared grade – observe for rutting or deformation
- Recommended if an unstabilized base is to be use
- MassDOT Section 150.61 Preparation of Foundation Areas

Geogrid

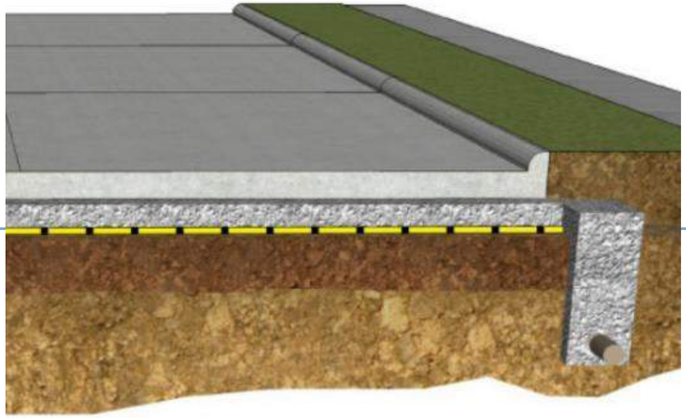
- High strength polymer material
- An alternative to chemical stabilization
  - AASHTO M 288

Source: Geofabrics

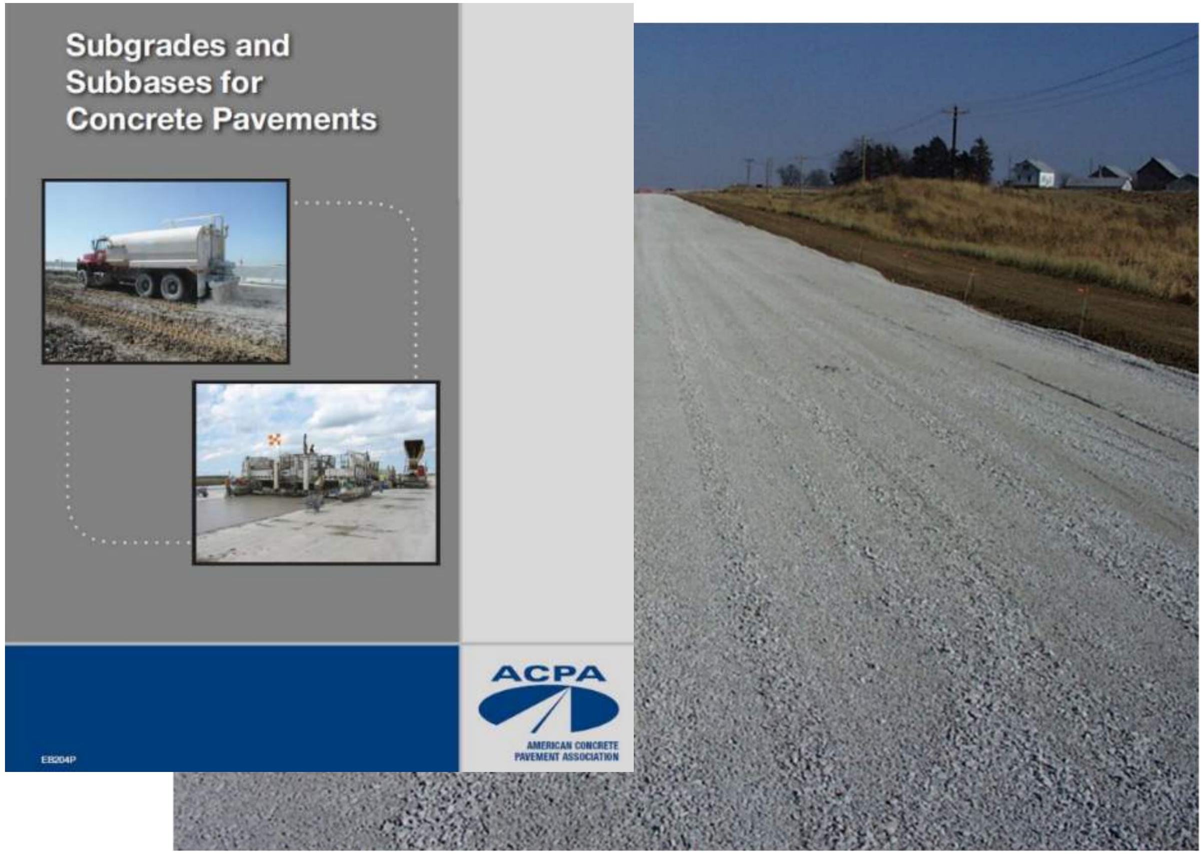
Construction

- Subgrades
- Bases
- Concrete

Base



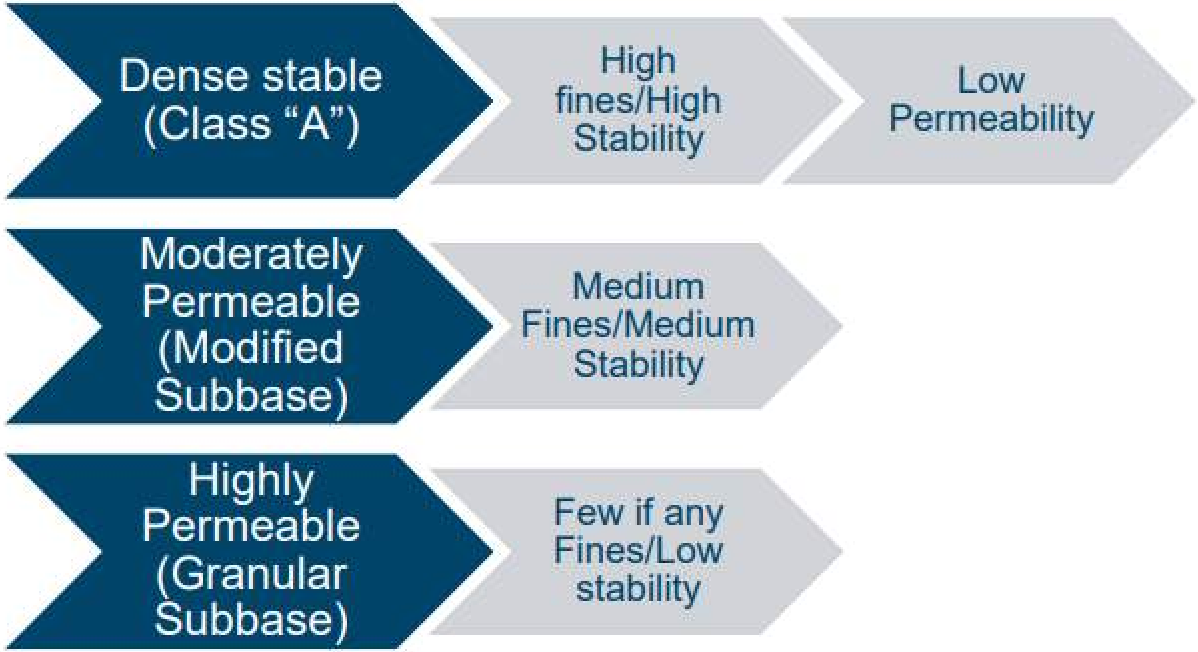
A layer between the subgrade and the concrete
- To provide support
  - Uniform, stable, stiff, draining
- Stable platform for construction
- Provides drainage

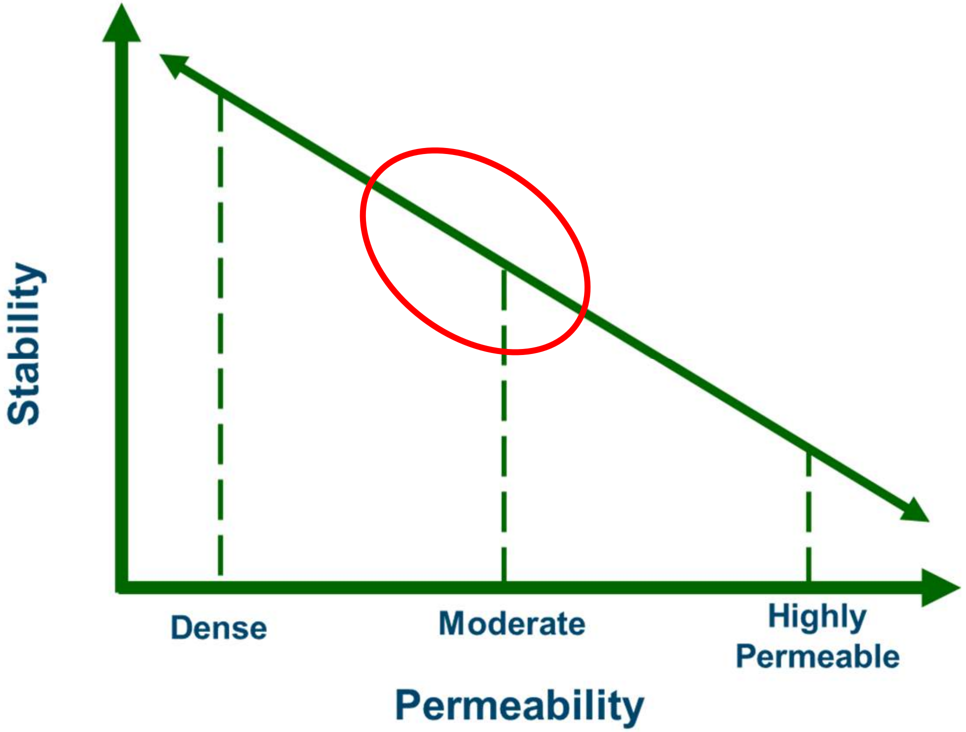


Types
- Unstabilized (limit <#200 material)
  - Recycled concrete
  - Crushed limestone
  - Mixture of gravel, sand, soil
  - Lean concrete
- Stabilized

Base

- Stability should not be sacrificed for the sake of drainage
  - Fines content

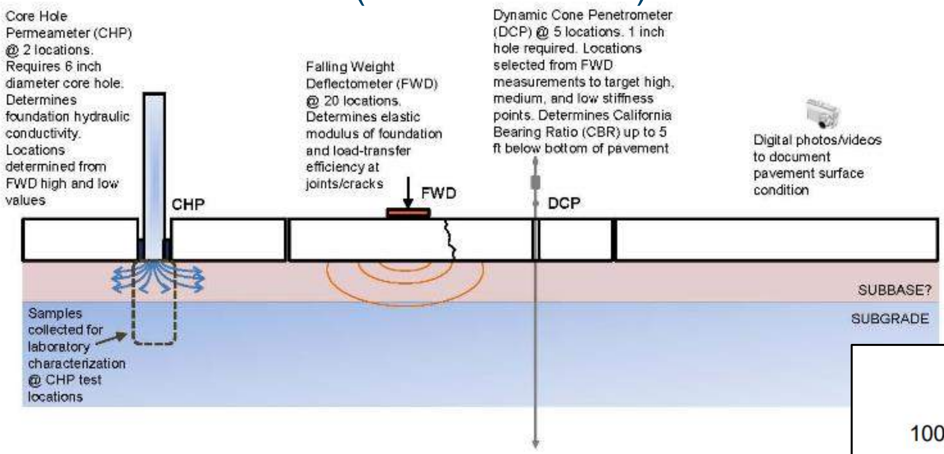


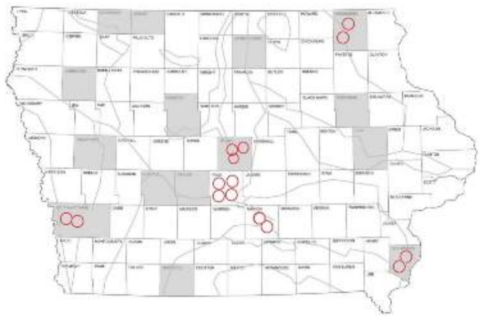


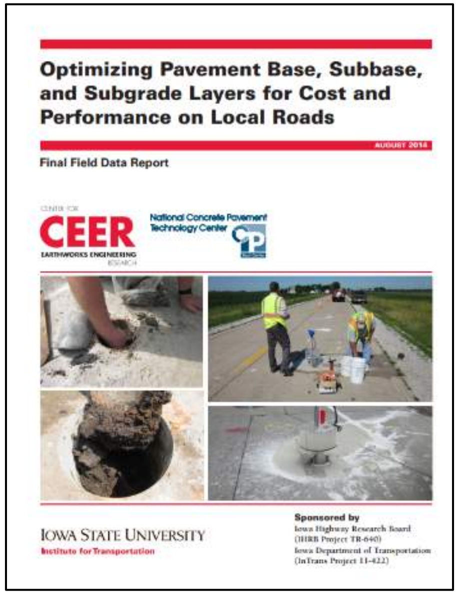
Improved Performance with Base

- IHRB TR-640
- Iowa test sites
- Variance in k-values
- Lower CBR values
- Drainage coefficient - sensitive variable

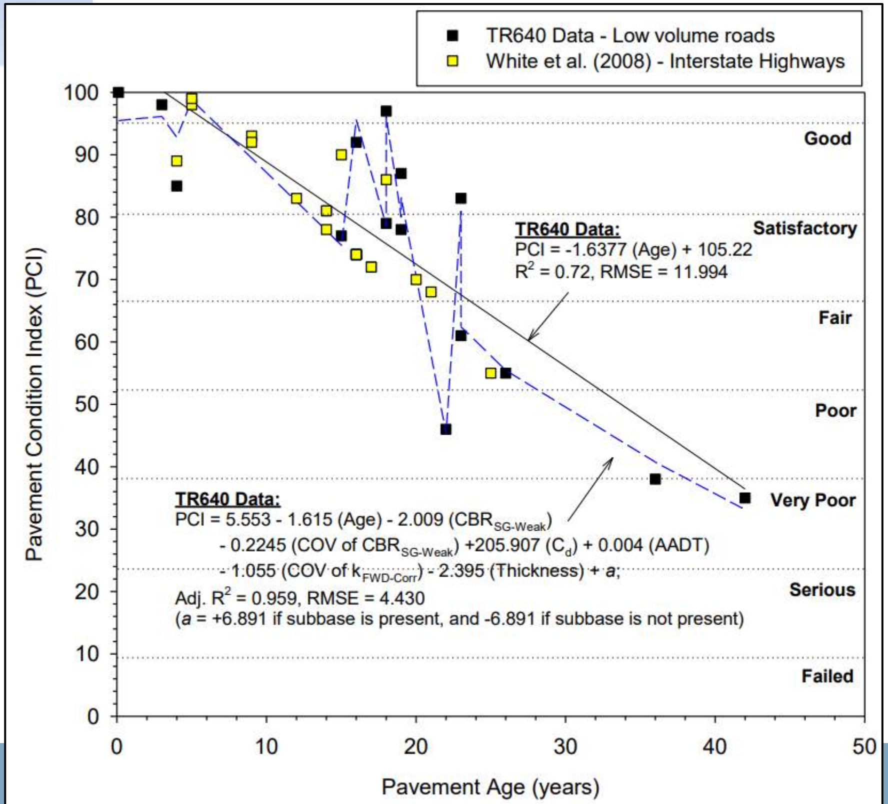
Test Plan(Dr. David White)



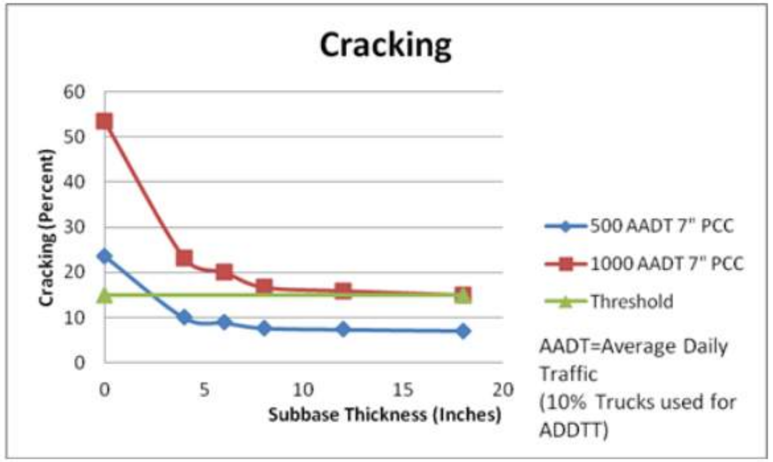


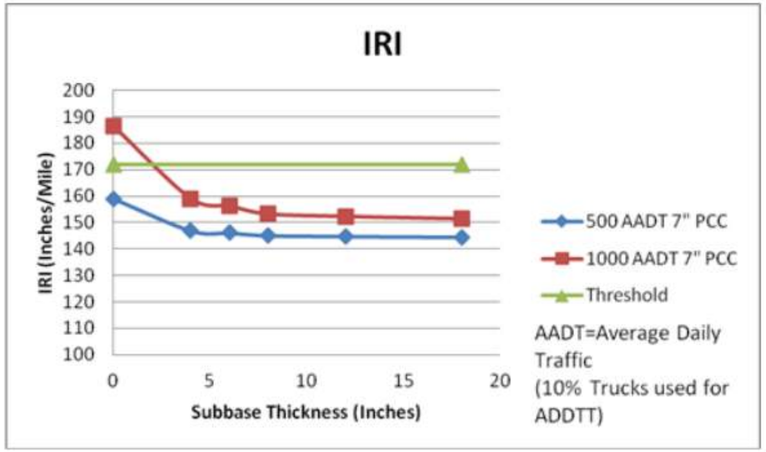


PCI Prediction (Dr. David White)

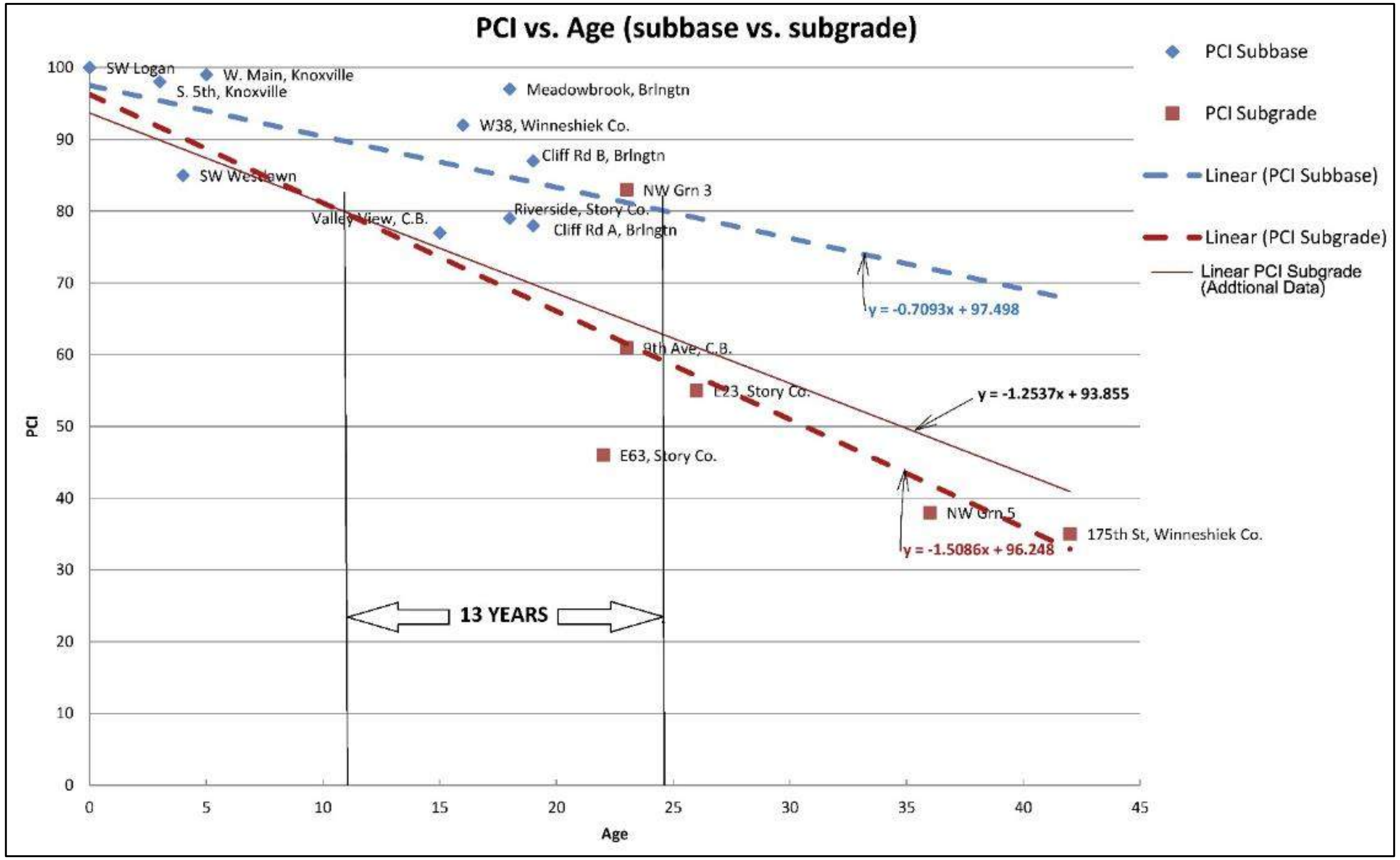


Improved Performance with Base





Modeling – PavementME



Field Data

Trackline

- ~3ft wide additional base
- Path for the paving machine
- Improves smoothness
- Support for shoulders or curbs

What other areas at the paving site need to be stable and maintained?

Why do we do this?

- Why do we sprinkle the subbase with water?
- We want to make sure the support layer doesn't pull water out of the mixture

Construction

- Subgrades
- Bases
- Concrete

Field Verification

- Test mixture properties (before and during construction)
- Use production equipment
- Follow specified testing frequencies

Concrete Production

Plant location

- Safety
- Materials delivery
- Concrete delivery
- Site suitability
- Testing
- Operation
- Environmental impact

Plant Checklist

- Stockpiles for separation and drainage
- Check scales
- Check water meter
- Check for leakage
- Check capacity of boilers and chillers
- Check admixture dispensers
- Check mixers for hardened concrete
- Inspect concrete hauling units for cleanliness
- Check to ensure that all materials have been approved (and labeled)
- Set up stockpiling operations
- Review aggregate moisture tests
- Observe batching operations

Does MassDOT have a concrete plant checklist?

Handling Materials

- Control
  - Cementitious materials
    - Dry and cool
    - Avoid putting the wrong product in the wrong silo
  - Aggregates
    - Segregation
    - Crushing
    - Moisture uniformity
    - Mud balls
  - Admixtures
    - Store as recommended

Batching

- Calibrate scales
- Adjust batching sequence
- Avoid segregation
- Adjust for moisture variations
- Adjust for weather

- Retempering? No

Concrete Mixing and Delivery

Mixture must be thoroughly mixed
- Uniform batch
- Air has been entrained
- Depends on equipment and mixture

Batch rate to match paving rate
- Place the right amount in front of the paver

Allow for changes during transport

Allow for traffic

Field Adjustments

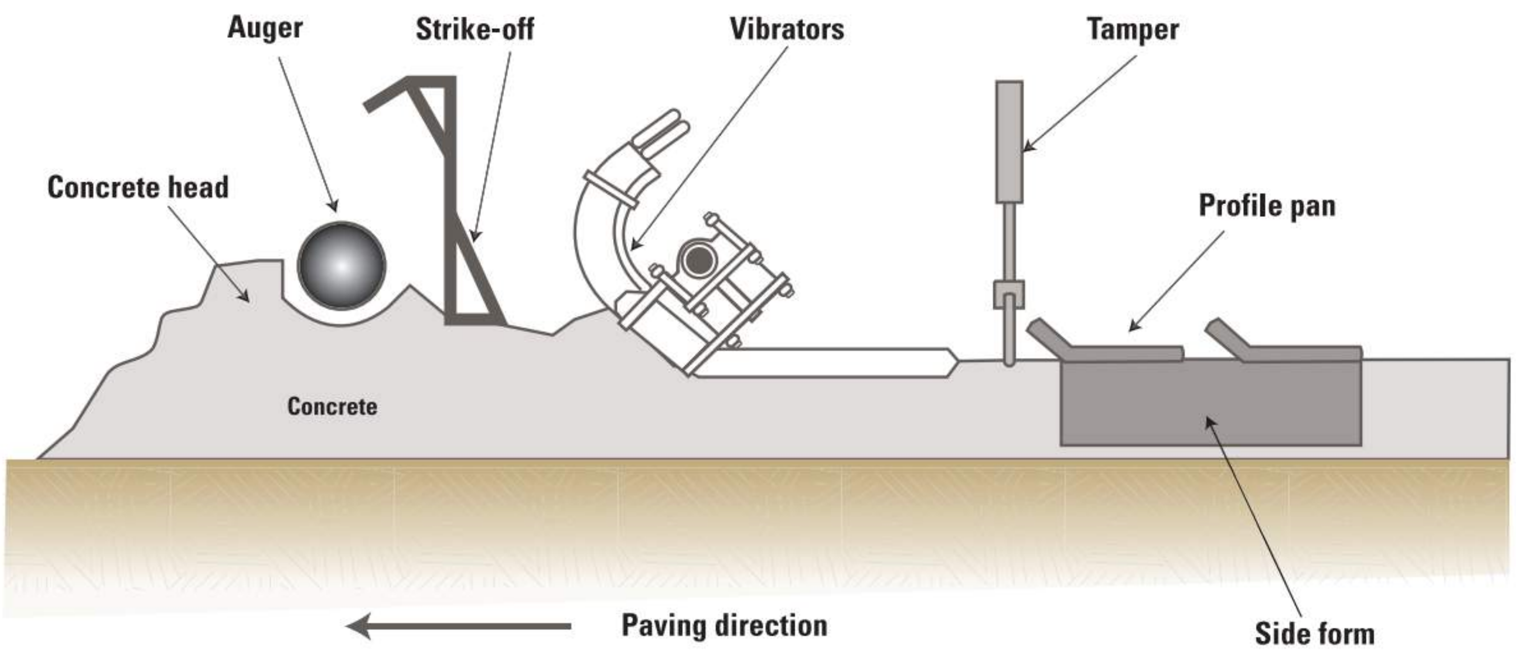
- Ambient temperatures
  - Hot = Fast
- Material variability
- Material supply changes
  - Not all fly ash is the same
  - Know your likely sources
  - Have a back-up plan

Fixed Form

- Good for short sections and odd shapes
- Placed using:
  - Self propelled vibratory screeds
  - Tube finishers
  - Form riding machines
- Keys
  - Uniform concrete placement in front of machine
  - Avoid using vibrator to move concrete

Slipform Paving

- Good for long sections and smoothness
- Concrete is extruded
  - Spreader
  - Strike off plate
  - Vibrators
  - Tamper bar
  - Profile pan
- Followed by
  - Texture machine
  - Curing cart



ACPA, used with permission

Slipform Paving

Slipform Paving

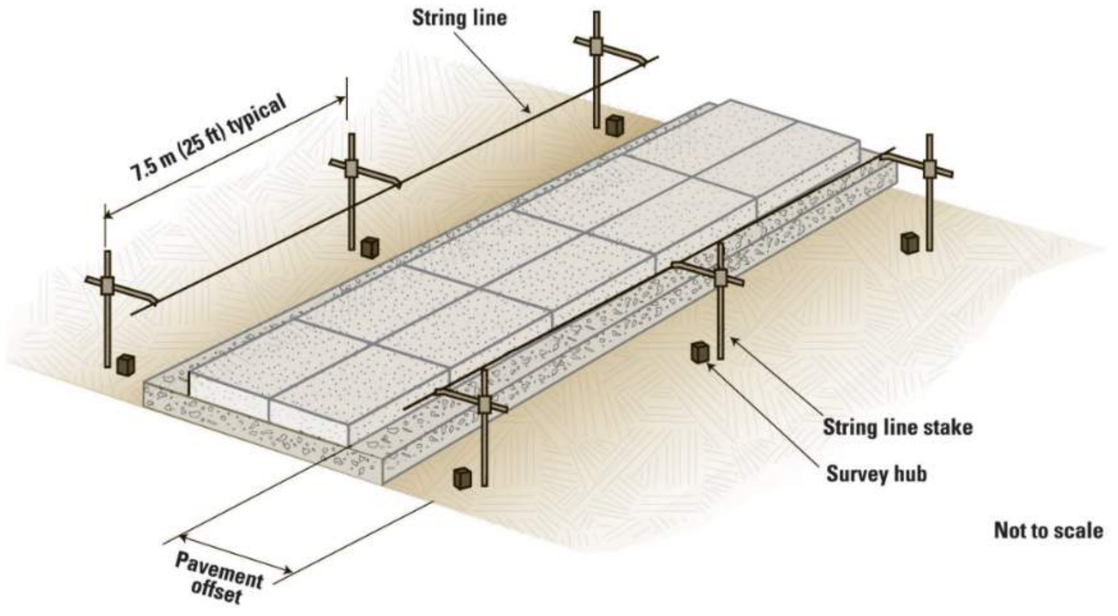
Consolidation

- The vibrators on the paver fluidize the concrete
  - Too much – impact air void system
  - Too little – unconsolidated sections
  - ~5000 – 8000 vpm
- Vibration effort must be tied to paver type and speed
- Adequate consolidation required
  - Especially around dowels and tie bars
- Vibrator monitors are recommended

MassDOT Section 476.39.E.2

Stringlines

- Control steering and elevation of the paver
- Effect pavement thickness and smoothness
- Beware the person who bumps it



ACPA 2003b, used with permission

Stringless Paving

- Reduced clutter
- Safety
- Smaller footprint
- Total station based

- Requires a 3D model

Dowel Bars

- Smooth bars in transverse joints
- To provide load transfer
- To limit faulting
- Pre-placed bars
  - Staking is required
  - Location is important
- Inserted bars
  - Mixture may affect ability to place

Dowels?

Alignment?

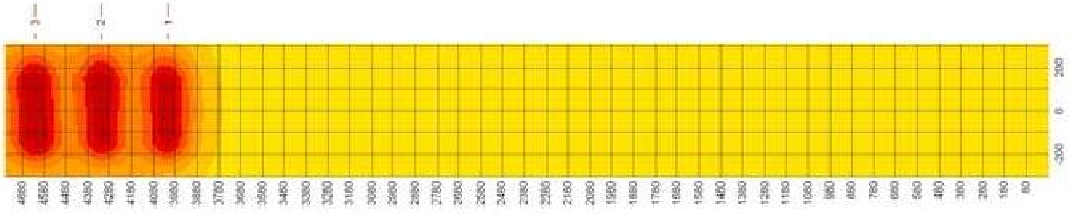
Are we in spec.?

Tiebars

- Deformed bars in longitudinal joints
- To prevent slabs separating
- To promote aggregate interlock

Bars

- Evaluation
    - MIT-Scan2
    - Data results without shipping wires cut



Finishing

- Hand finishing should be limited
- Hand finishing can help correct bumps
- Don’t add water!

Texturing

- Provides friction and skid resistance
  - Drag textures
  - Longitudinal tining
  - Transverse tining
  - Diamond grinding
- Affects noise
  - Minimize positive texture

Texturing Equipment

Texture

- Burlap Drag

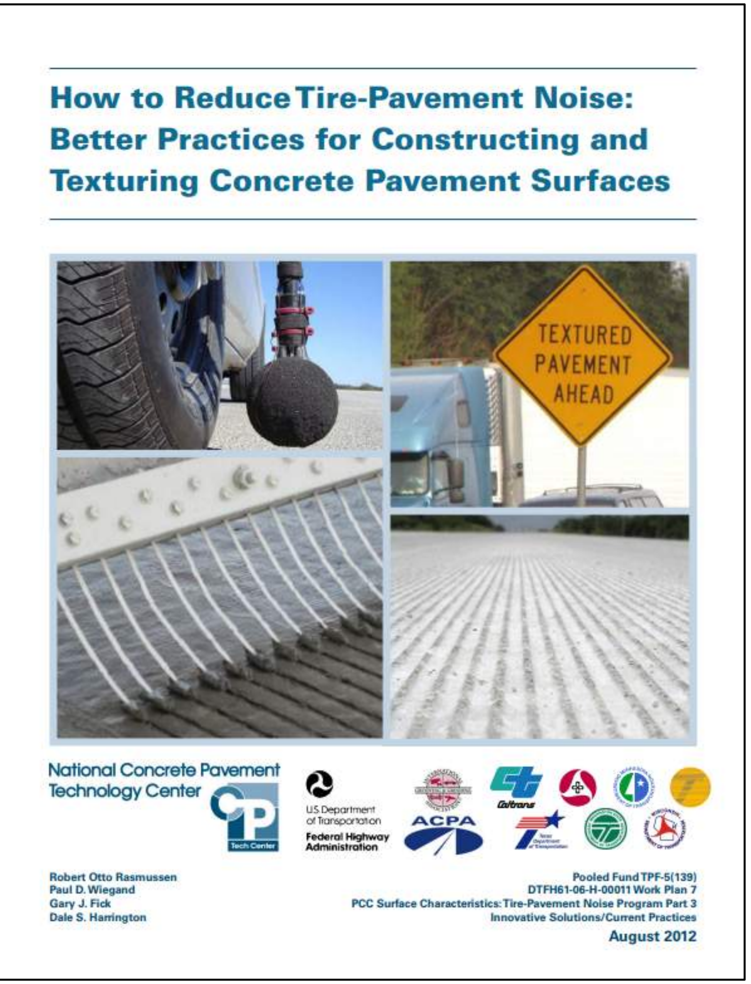
  microtexture

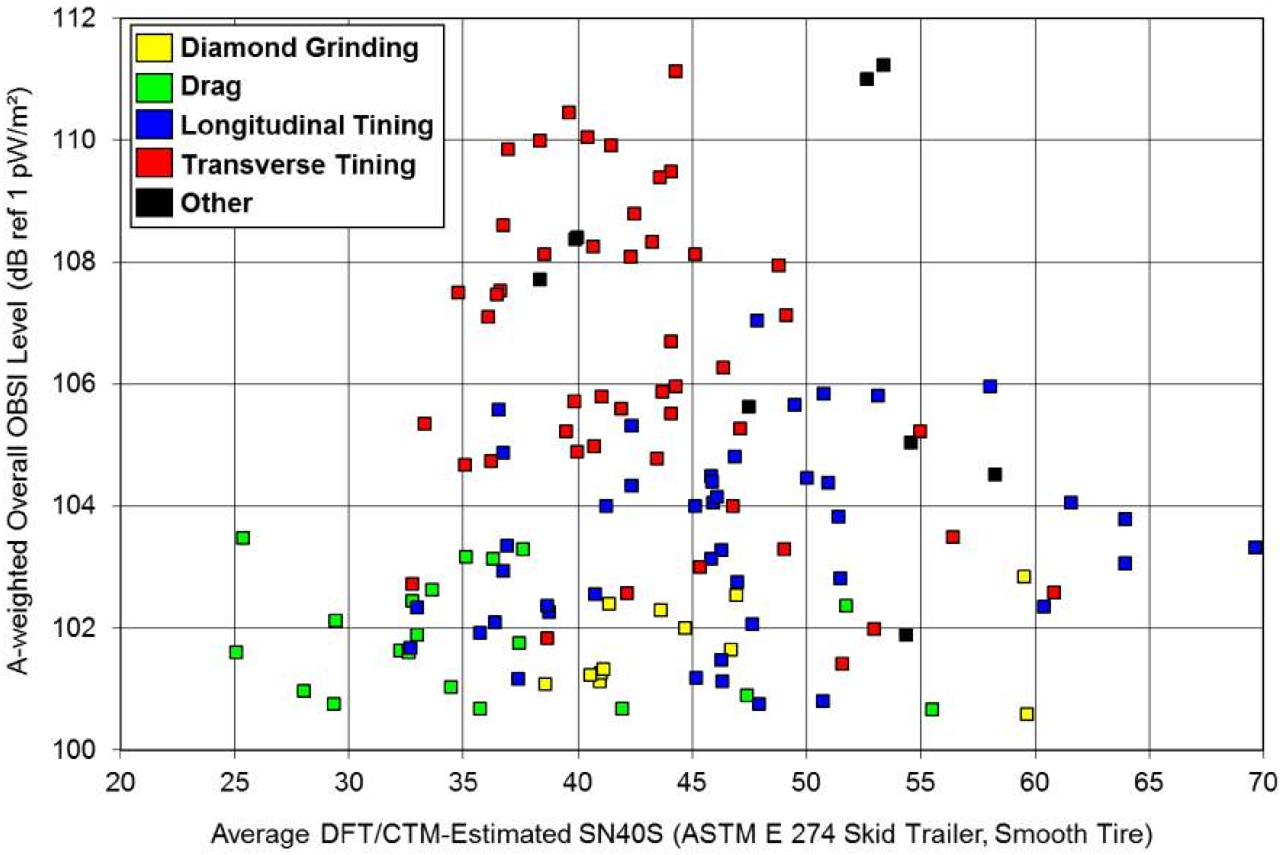
Texturing Equipment

Texture

- Turf Drag
  microtexture

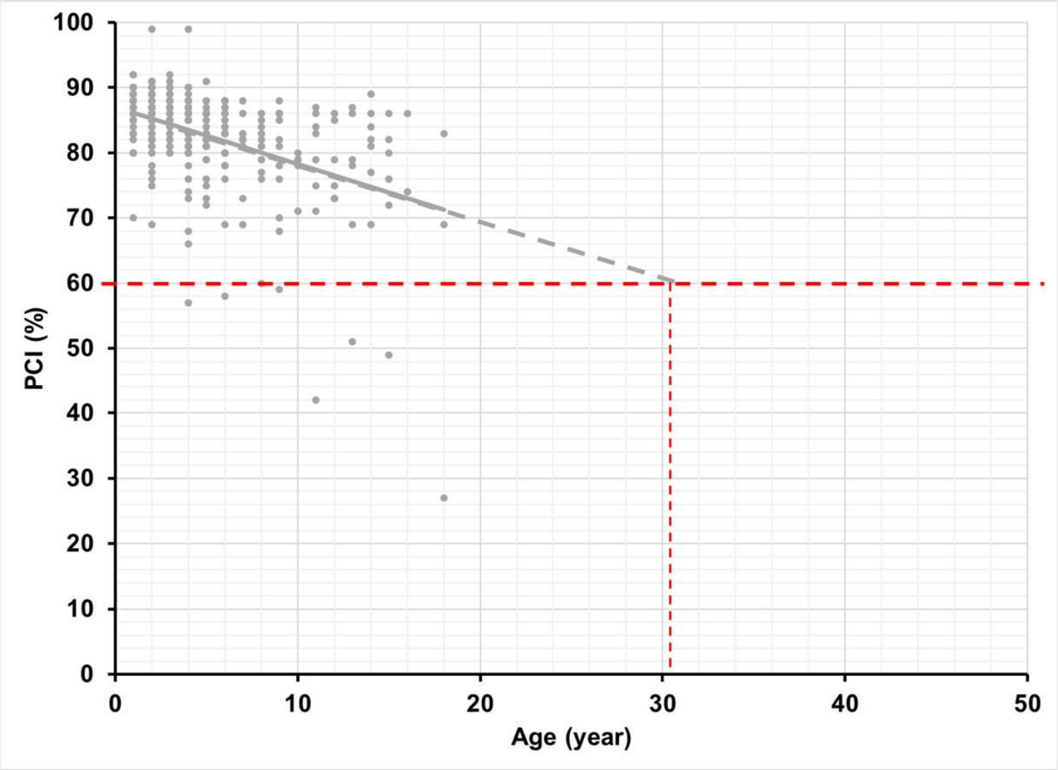
Texture & Noise





Smoothness

- Used as a measure of pavement condition
- Affected by
  - Foundation system
  - Surveying
  - Machine control system
  - Mixture
  - Stopping and starting
  - … everything



Smoothness

- Measurement
  - Inertial profiler
  - Real time smoothness

Smoothness

- In most cases, smooth pavements last longer
- Mixture factors
  - workability, finishability, edge stability, uniformity
- Paving factors
  - design (Staging, schedule, geometry)
  - project (paving sequence track line clearance)
  - equipment
- Human factors
  - experience, training, communication, fatigue


Implementation of Best Practices for Concrete Pavements

Guidelines for Specifying and Achieving Smooth Concrete Pavements

Final Report
December 2019

National Concrete Pavement Technology Center

Sponsored by
Federal Highway Administration
Office of Infrastructure

IOWA STATE UNIVERSITY
Institute for Transportation

Curing

- Keep it wet, keep it warm
  - Curing compound
    - Reduces the rate of moisture loss
    - Needs complete coverage (2 coats)
    - More needed for rough surfaces
    - PAMS
  - Plastic sheeting
    - Beware of wind tunnels
    - Can mar the surface

Weather Considerations

- Hot weather concreting
  - Hydration is faster
  - Evening cold fronts can set up thermal stresses
- Cold weather placement
  - Set is delayed – but shrinkage isn't
- Rain
  - The surface may be compromised

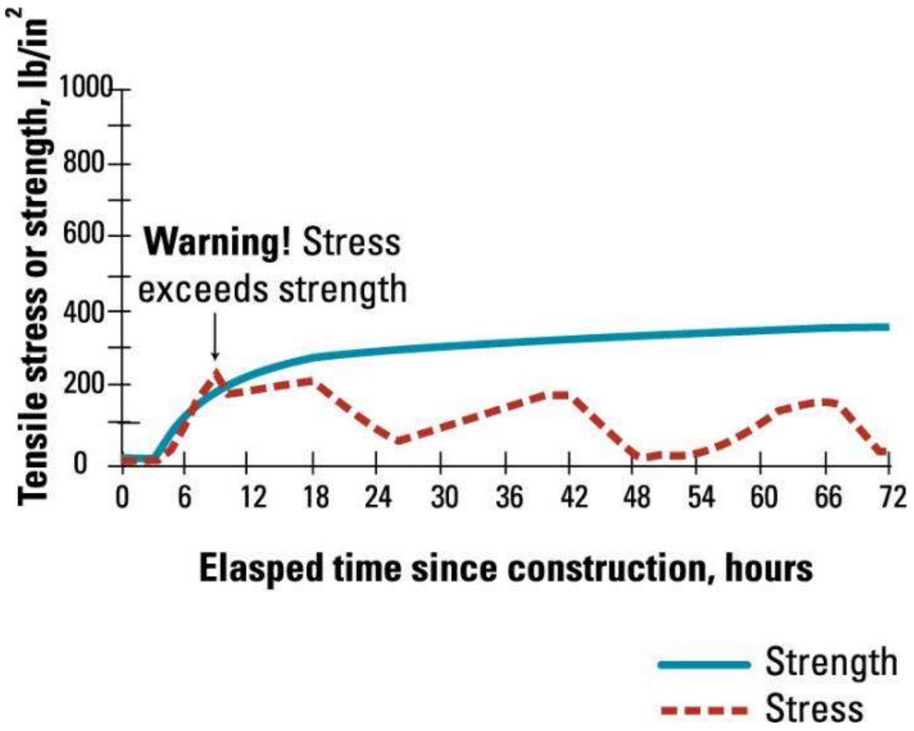
Crack Risk Analysis with HIPERPAV

Free to download

Factors considered in the program

- Temperature
- RH
- Shrinkage
- Restraint
- Strength, MOE
- CTE

  Concrete will move ~2/3 inch over a distance of 100' with temperature change of 90 deg. F

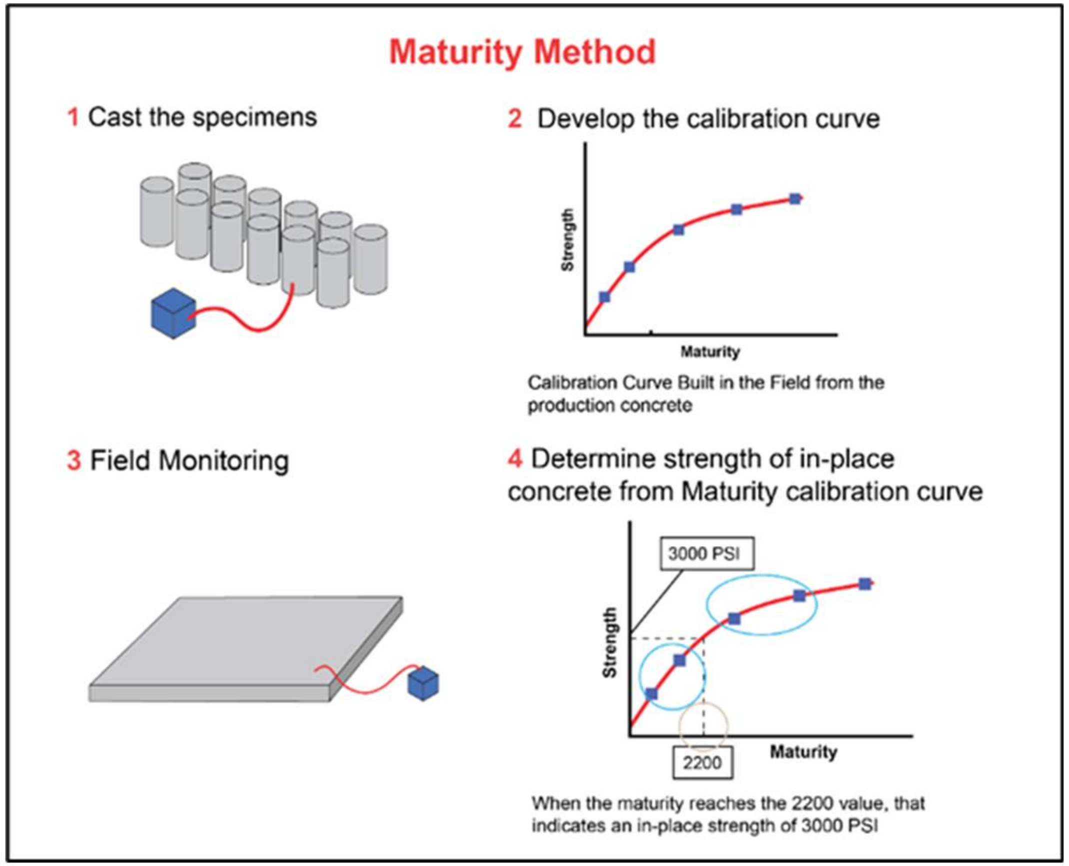


Maturity Method

NEW AASHTO T413 – Maturity Method (update from T325)

- Beams or Cylinders
- Minimum 2 samples at 4 ages
- First test within 24 hours, as early as 18 hours
- First test must be less than 85% of target opening strength
- Permitted to use production concrete

- CP Tech Webinar: Estimating Opening Strength for Concrete Pavement Using Maturity



NRRA Research

MnRoad research on early loading (2017)

- ¾ ton pickup truck at **2 hours** (73 psi):

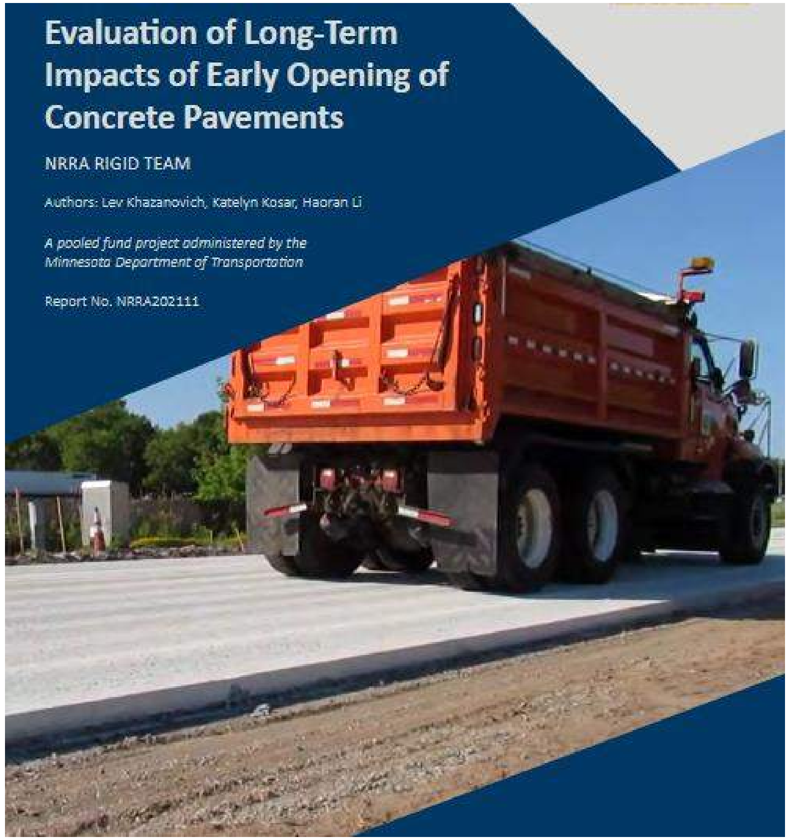
https://www.youtube.com/watch?v=ZyNy2UA9mSs

Report No. NRRA202112

Images: MnDOT

NRRA Research

“Web-based tool”

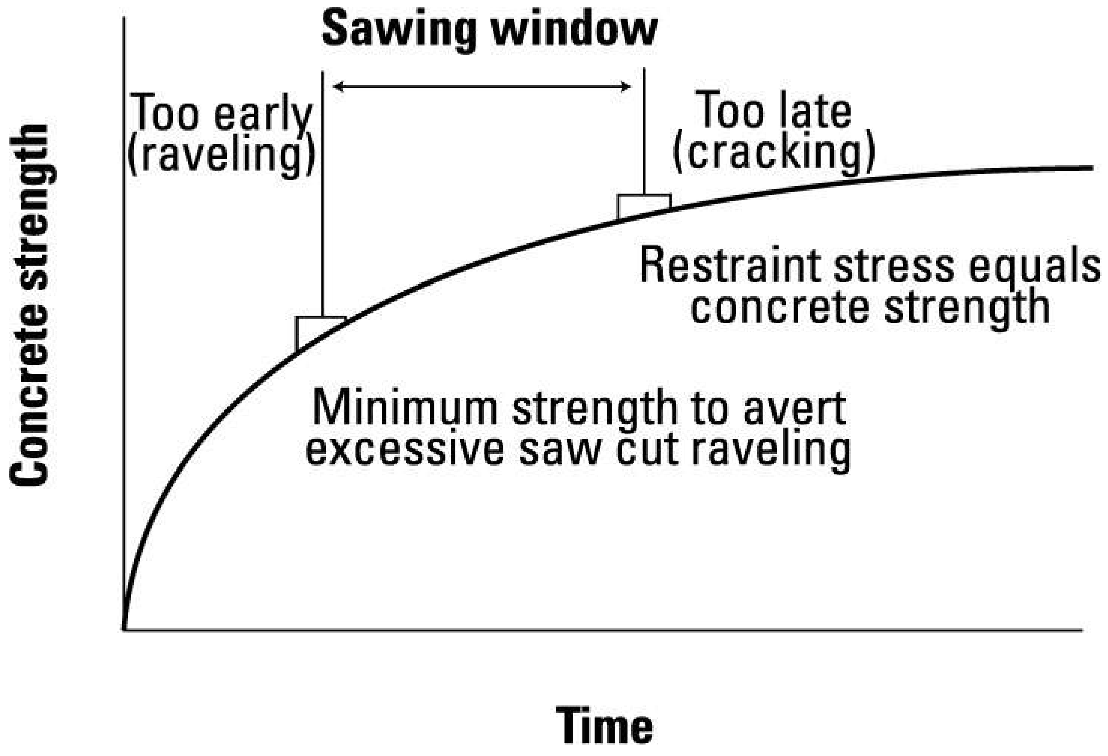


MnDOT Study - [TPF-5(341), Evaluation of Long-Term Impacts of Early Opening of Concrete Pavements]

August 2021

Joint Sawing

- Saw timing
  - Sawing window
  - When is it too early / too late?
  - Size 12 boot
  - UPV
  - Effect of weather
  - Effect of mixture



Joint Sawing

Equipment

- Conventional
  - May need to be sawing overnight
  - Deeper for longitudinal & transverse doweled joints (T/3)
    - T/3 for placed thickness (superelevation example)
  - Shallower for un-doweled joints (T/4)
  - Early entry – transverse only
    - Choose the right blade
    - Maintain shoe/skid plate
    - Tricky with hard aggregates
    - Shallower cut (1 ¼” +/- ¼”)

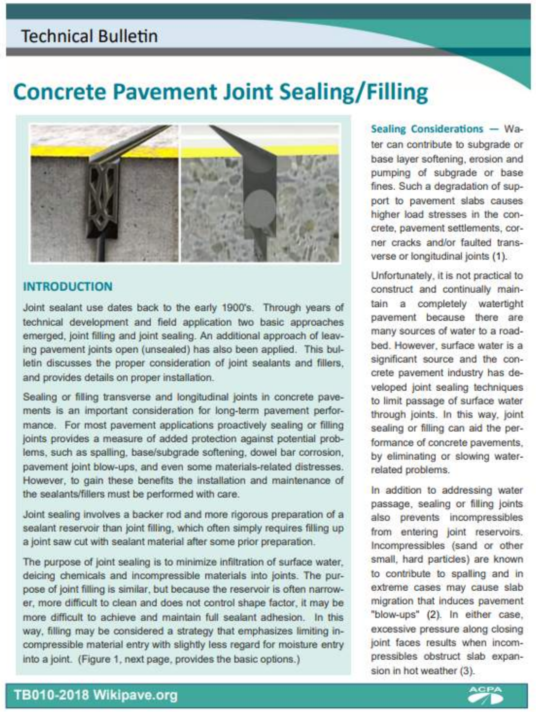
Joint Sawing

Why saw?

- Control random cracking

Joint Sealing / Filling

- Minimize infiltration of water
  - Ensure water that penetrates can get away
- Prevent hard materials in the joint
- Maintenance is required



Technical Bulletin

Concrete Pavement Joint Sealing/Filling

INTRODUCTION

Joint sealant use dates back to the early 1900's. Through years of technical development and field application two basic approaches emerged, joint filling and joint sealing. An additional approach of leaving pavement joints open (unsealed) has also been applied. This bulletin discusses the proper consideration of joint sealants and fillers, and provides details on proper installation.

Sealing or filling transverse and longitudinal joints in concrete pavements is an important consideration for long-term pavement performance. For most pavement applications proactively sealing or filling joints provides a measure of added protection against potential problems, such as spalling, base/subgrade softening, dowel bar corrosion, pavement joint blow-ups, and even some materials-related distresses. However, to gain these benefits the installation and maintenance of the sealants/fillers must be performed with care.

Joint sealing involves a backer rod and more rigorous preparation of a sealant reservoir than joint filling, which often simply requires filling up a joint saw cut with sealant material after some prior preparation.

The purpose of joint sealing is to minimize infiltration of surface water, deicing chemicals and incompressible materials into joints. The purpose of joint filling is similar, but because the reservoir is often narrower, more difficult to clean and does not control shape factor, it may be more difficult to achieve and maintain full sealant adhesion. In this way, filling may be considered a strategy that emphasizes limiting incompressible material entry with slightly less regard for moisture entry into a joint. (Figure 1, next page, provides the basic options.)

Sealing Considerations — Water can contribute to subgrade or base layer softening, erosion and pumping of subgrade or base fines. Such a degradation of support to pavement slabs causes higher load stresses in the concrete, pavement settlements, corner cracks and/or faulted transverse or longitudinal joints (1).

Unfortunately, it is not practical to construct and continually maintain a completely watertight pavement because there are many sources of water to a roadbed. However, surface water is a significant source and the concrete pavement industry has developed joint sealing techniques to limit passage of surface water through joints. In this way, joint sealing or filling can aid the performance of concrete pavements, by eliminating or slowing water-related problems.

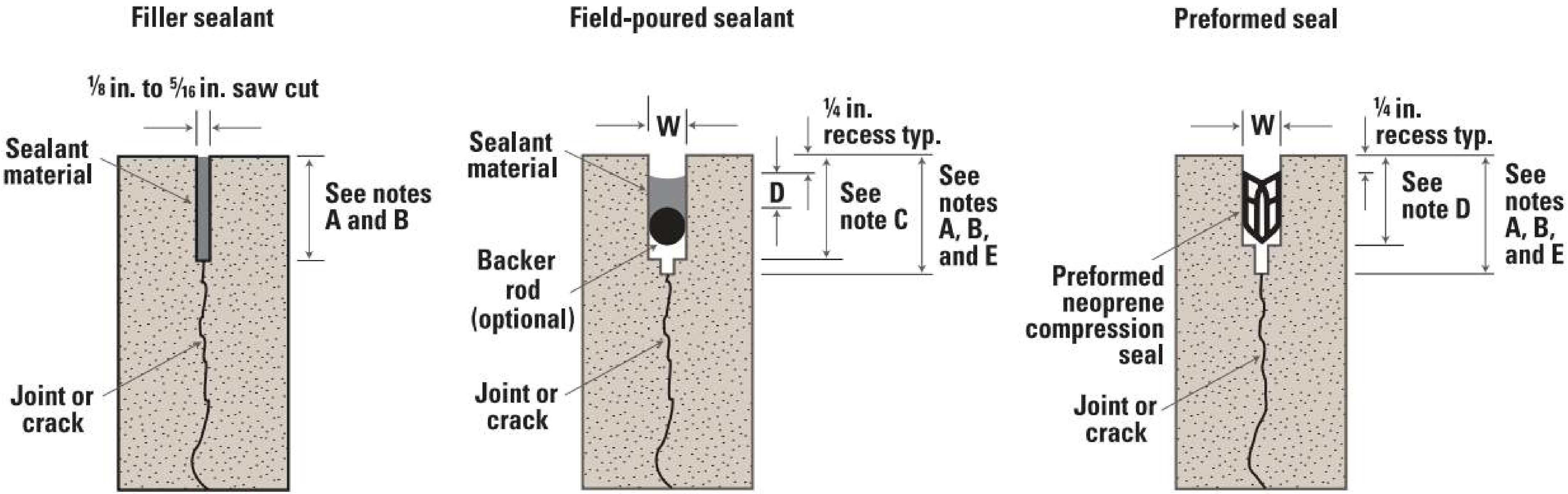
In addition to addressing water passage, sealing or filling joints also prevents incompressibles from entering joint reservoirs. Incompressibles (sand or other small, hard particles) are known to contribute to spalling and in extreme cases may cause slab migration that induces pavement "blow-ups" (2). In either case, excessive pressure along closing joint faces results when incompressibles obstruct slab expansion in hot weather (3).

TB010-2018 Wikipave.org

Table 8-8. Potential joint performance based on sealing option

	STREETS/ROADS/HIGHWAYS							
	Any posted speed limit (unless indicated by note)							
Layer below slab	Dense-graded base or subgrade soil				Nonerodible (2) or free-draining layer (3)			
Climatic zone	Dry no-freeze		Other		Dry no-freeze		Other	
Joint spacing	≤ 6 ft	> 6 ft	≤ 6 ft	> 6 ft	≤ 6 ft	> 6 ft	≤ 6 ft	> 6 ft
Open reservoir cut	NR	NR	NR	NR	NR	NR	NR	NR
Open narrow saw cut	▮	▮	▮	NR	▯	▯	▮ (4,5)	▮ (5)
Filled saw cut or reservoir	▯	▯	▮ (6)	▮ (6)	▯	▯	▮ (6)	▮ (6)
Sealed saw cut or reservoir	▯	▯	▯	▯	▯	▯	▯	▯

Joint Sealing / Filling

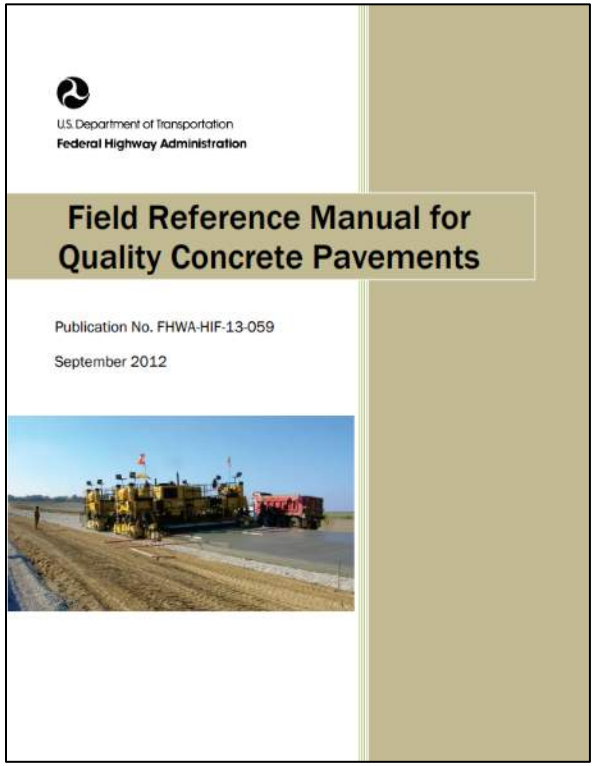


Hot-poured sealant: D/W = 1.0 (typical)
Silicone sealant: D/W = 0.5 (typical)
Two-component material cold poured: D/W = 0.5 (typical)

Preformed compression seal: W = sized for slab and climate

Resources


PCC Paving Field Inspection
2025
Iowa Department of Transportation
Construction and Materials Bureau
Technical Training and Certification Program


U.S. Department of Transportation
Federal Highway Administration
Field Reference Manual for Quality Concrete Pavements
Publication No. FHWA-HIF-13-059
September 2012


Concrete Paving Field Inspection Workshop
Access our "Webinars and Videos" directory
Concrete Paving Field Inspection Workshop
from Institute for Transportation
1 of 10
1. Why are we here?
National Concrete Pavement Technology Center
Iowa State University
Institute for Transportation
www.cptechcenter.org
vimeo

Discussion


National Concrete Pavement
Technology Center
CP
Tech Center
IOWA STATE UNIVERSITY
Institute for Transportation

Breakout #2

- 4 Groups
- 15 minutes to discuss the question
- 15 minutes to report back

Breakout #2

- #2
- What should inspectors be looking for?

Testing

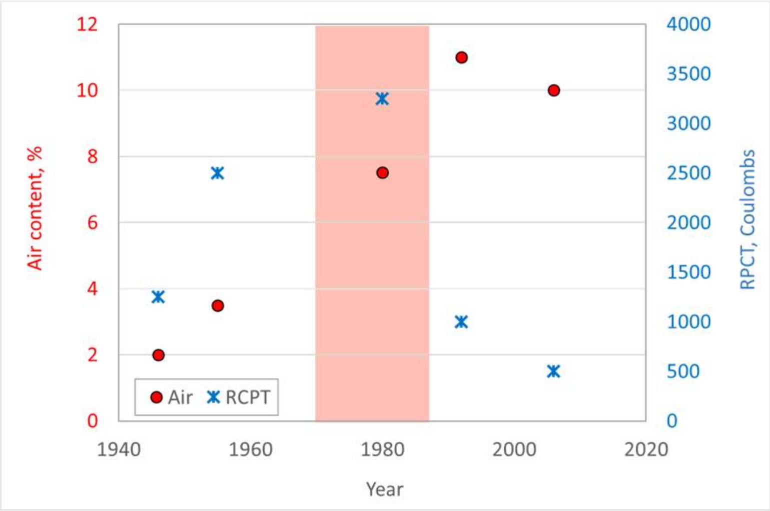
National Concrete Pavement Technology Center

Why Test?

- Three criteria:
  - Quality Characteristics
    (What do we want?)
  - Quality Measures
    (How do I measure it?)
  - Quality Limits
    (How much is enough?)

What is Good concrete?

- Constructible (Workable)
- Dimensionally stable
  - Aggregates
  - Shrinkage
- Impermeable (Transport properties)
- Cold weather resistant
  - Freeze thaw
  - Salt attack
- Strong (enough)



Workability

- Slump
  - Great for uniformity
  - Cheap, fast and familiar
  - 1” ± 1”
  - Does not tell about response to vibration

  - QC

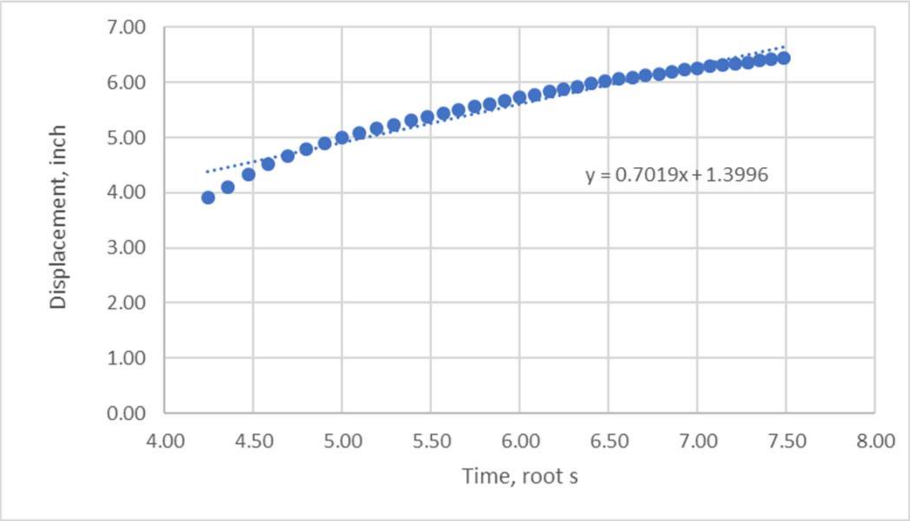
Workability

- VKelly
  - Does tell about response to vibration
  - Adjust aggregate gradation and paste content to achieve desired numbers

  - Prequalification

VKelly

- Measure initial slump (initial penetration)
- Start vibrator for 36 seconds at 4000 vpm
- Record depth periodically
- Plot on root time
- Calculate slope = VKelly Index



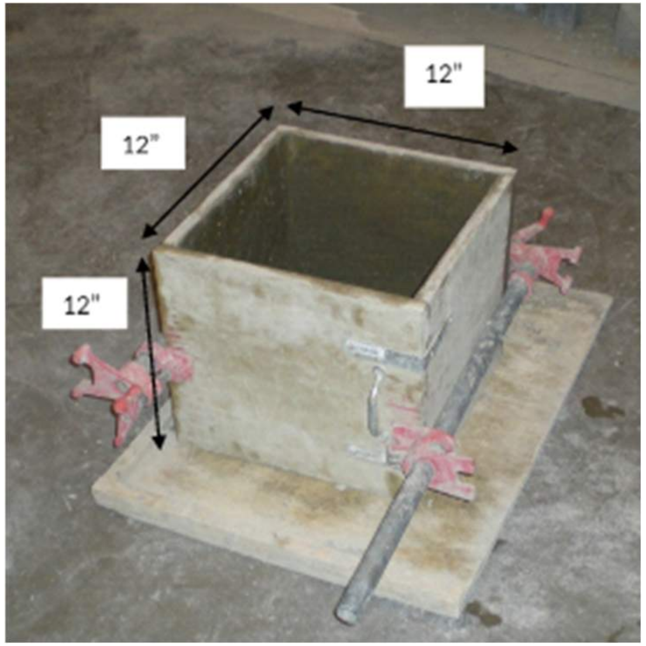
Workability

- Finishability

Workability

- Box
  - Does tell about response to vibration
  - Adjust aggregate gradation and paste content to achieve desired numbers
  - Subjective

  - Prequalification



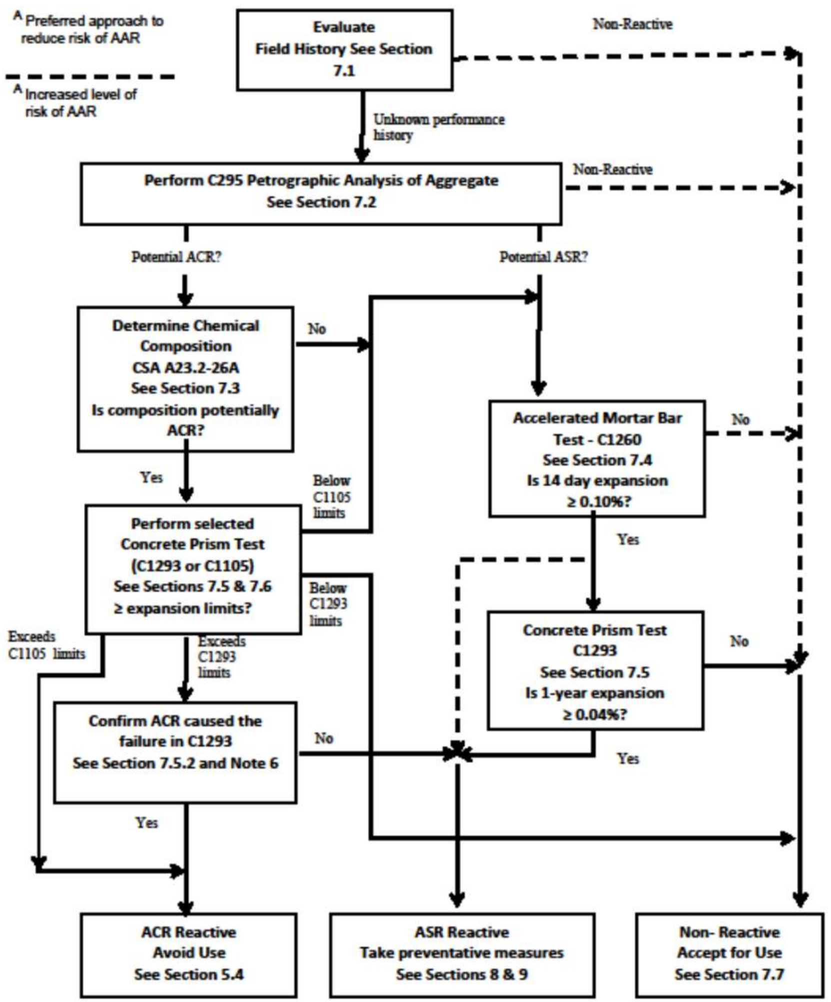
Workability

- What if it is bad?
  - Aggregate gradation (Tarantula)
  - Paste content
  - Admixture choice and dosage
  - Cementitious system

  - Don’t add water!

Aggregate Stability

- Alkali aggregate reaction
  - AASHTO R80 / ASTM C 1778



Aggregate Stability

- What if it is bad?
  - Change aggregates
  - If alkali reactive, investigate SCM dosage
    - ASTM C1260 for the individual aggregates
    - ASTM C1567 for the concrete mix

Shrinkage

- Paste content (read the batch sheet)
  - Easy
  - Fast

Project	**Gravel 1"**		**5/15/2017**		
Mixture Proportions					
		Targets		**Actual**	
			Pounds	R.D.	Volume
Cement	Type I		342	3.15	1.74
SCM 1	F Ash		86	2.65	0.52
SCM 2	Slag		0	1.00	0.00
Coarse Agg	A85006		1753	2.72	10.33
Fine Agg	A25518		1318	2.66	7.94
Intermediate	A85007		340	2.43	2.24
Water			180	1.00	2.88
Air %			5.0		1.35
			4019		27.00
Cementitious		428	428	pcy	
Volume of paste			24.0	%	
Volume of aggs			76.0	%	
Volume of voids			19.2		
vp/vv		125	125.0		
w/cm		0.42	0.42		
% SCM 1		20	20	%	
% SCM 2		0	0	%	
Mass aggs		3411	3411	pcy	
Excess paste, %			4.8	%	

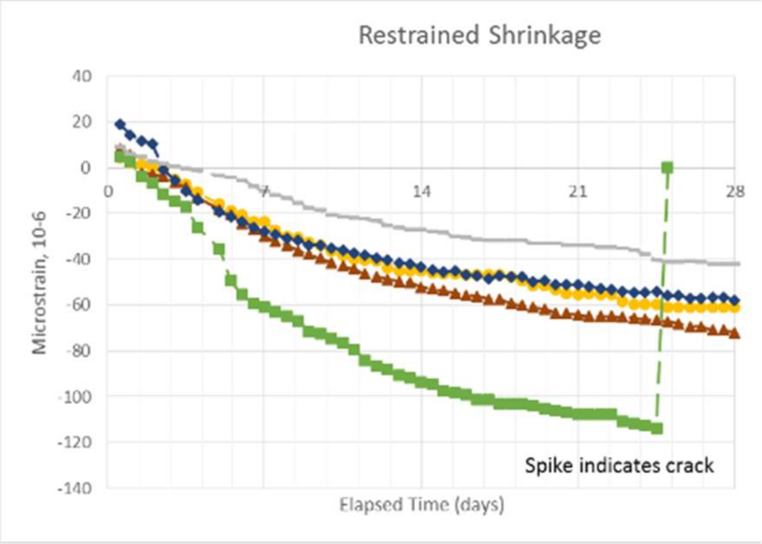
Shrinkage

- Ring test
  - Indicates cracking risk starting from minutes after mixing
  - Tricky
  - Poor repeatability

  - ASTM and AASHTO methods are not the same

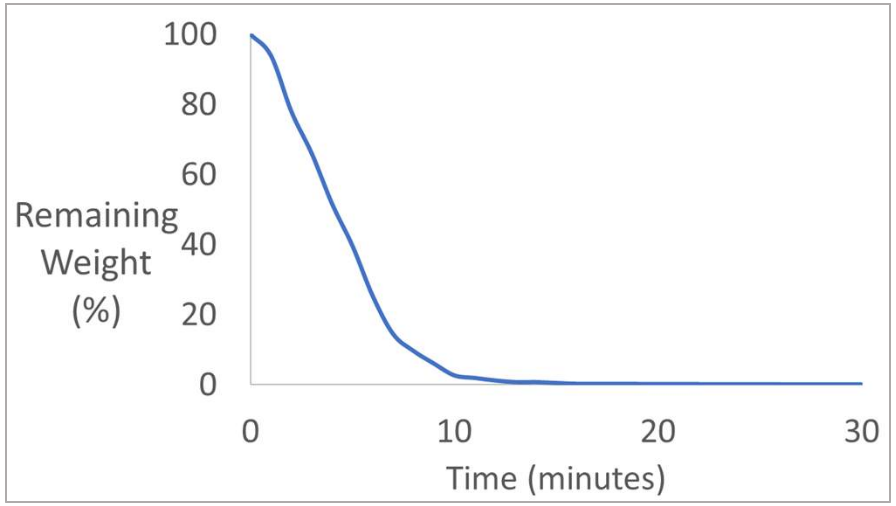
Shrinkage

- What if it is bad?
  - Reduce paste content
  - Check clay content of aggregate
  - Consider internal curing
  - Consider shrinkage reducing admixtures



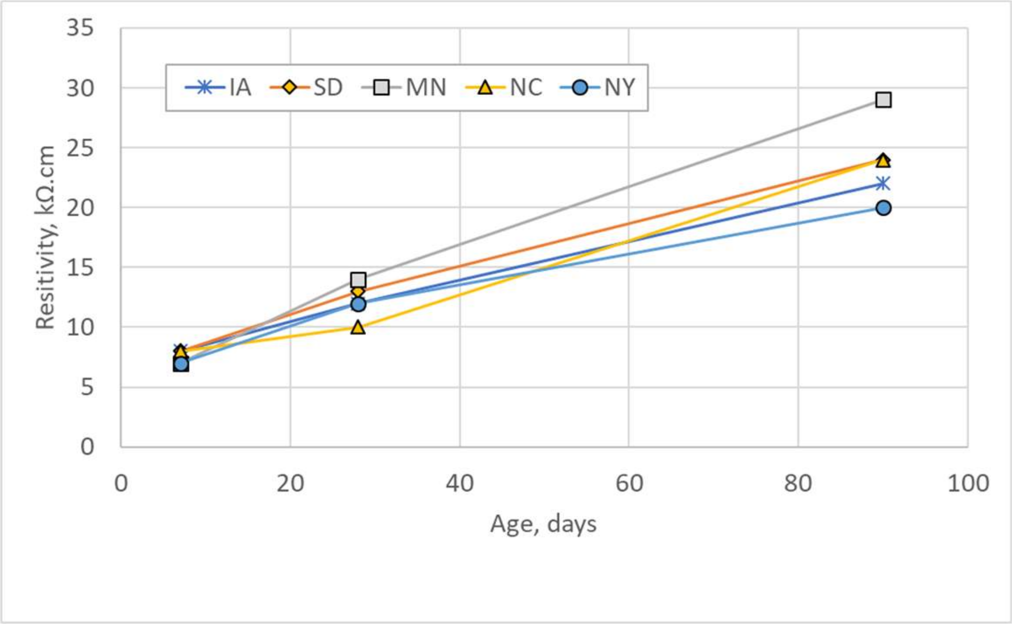
Water Content

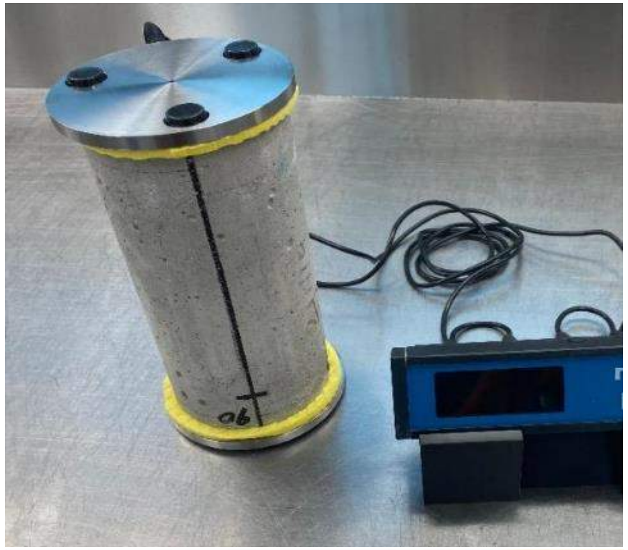
- Record batch ticket and aggregate properties
- Make and weigh 6”x 3.75” cylinder (1640 cm3)
- Dump cylinder into pan and weigh
- Heat for 15 min
- Weigh pan



Transport

- Resistivity
  - Curing: Fog room
  - Pull out at desired age
  - Read and put back
  - Repeat





Transport

- What if it is bad?
  - Review w/cm
  - Review SCM type and dose

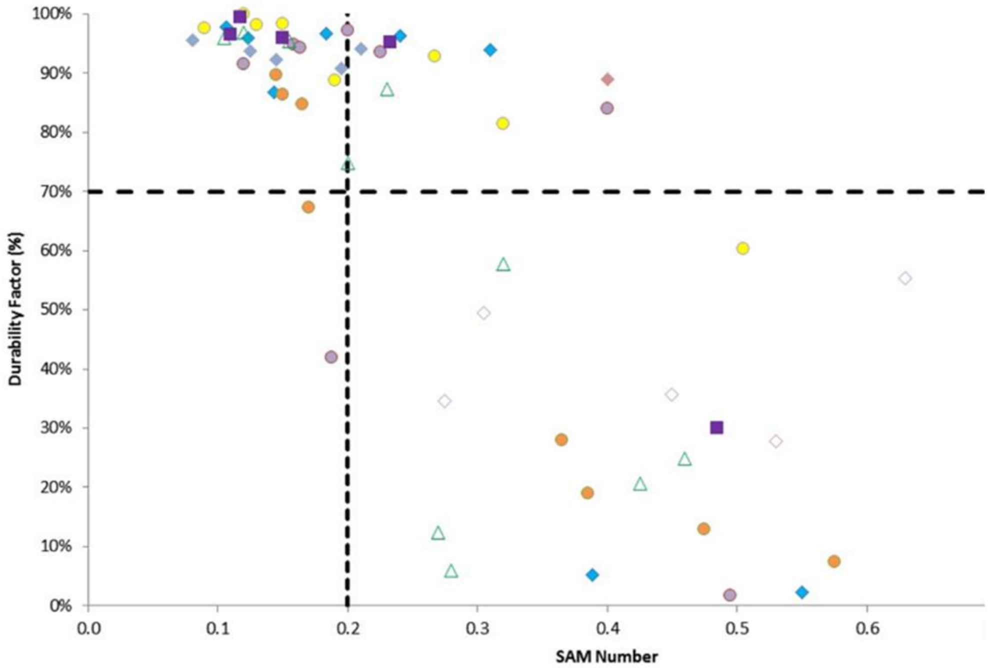
Cold Weather

- Freeze-thaw
  - Saturation
  - Entrained air
- De-icing salts
  - Sufficient SCM

Super Air Meter

- Reports an index that correlates with F/T performance
- Training and machine maintenance are critical

- Prequalification
- QC
- Acceptance (later)

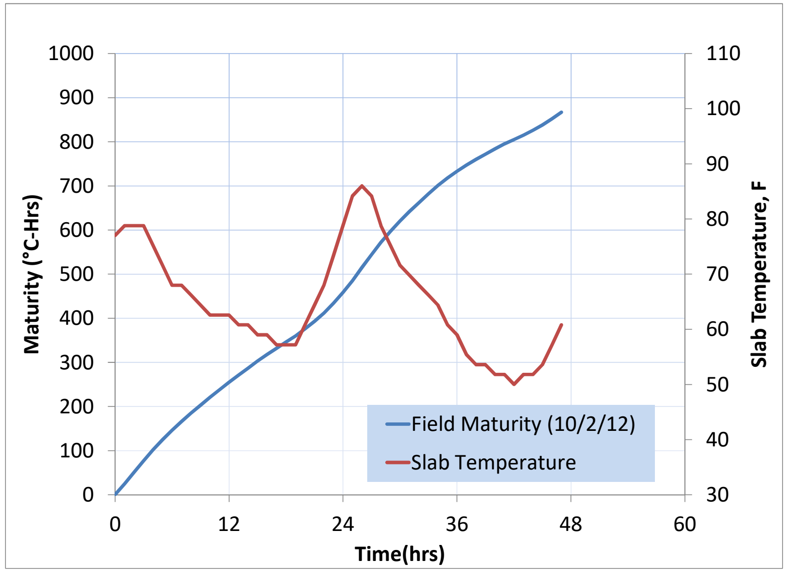


Strength

- Strong enough to carry loads
  - Cylinders
  - Beams
  - Maturity
- Prequalification

Maturity

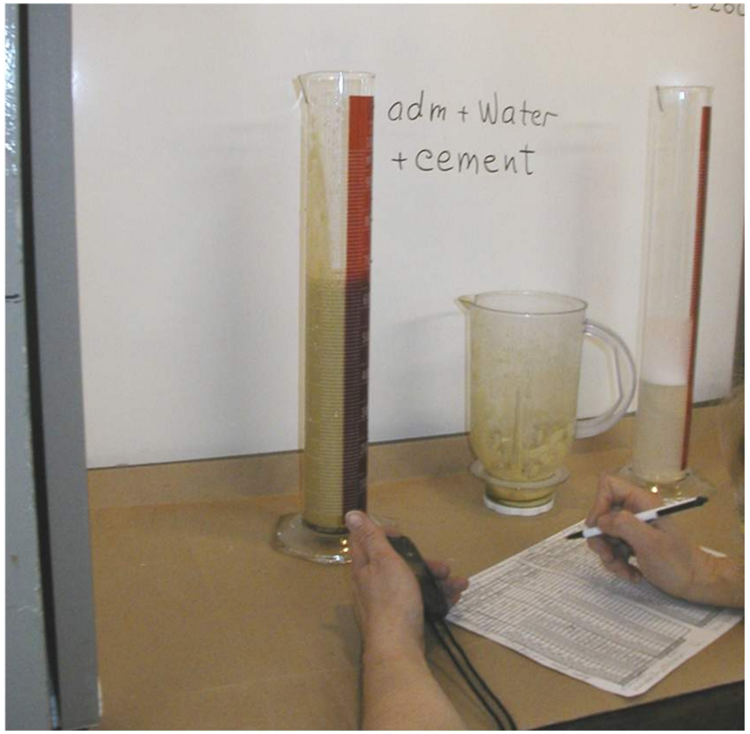
- Maturity readings
  - Sensors in the pavement determine in-place maturity and thereby strength for opening
  - AASHTO T413



Foam Drainage

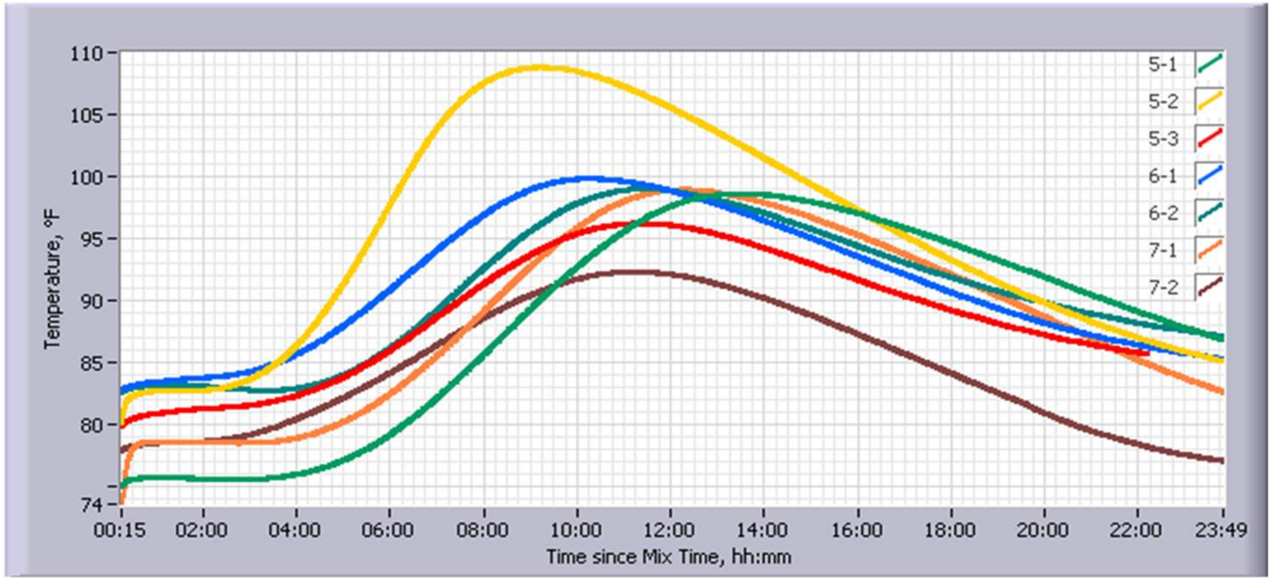
- Assesses stability of air void system
- Depends on system chemistry

- Prequalification



Calorimetry

- Calorimetry tells us about
  - The chemistry of the system (Uniformity)
  - Set time



Unit weight

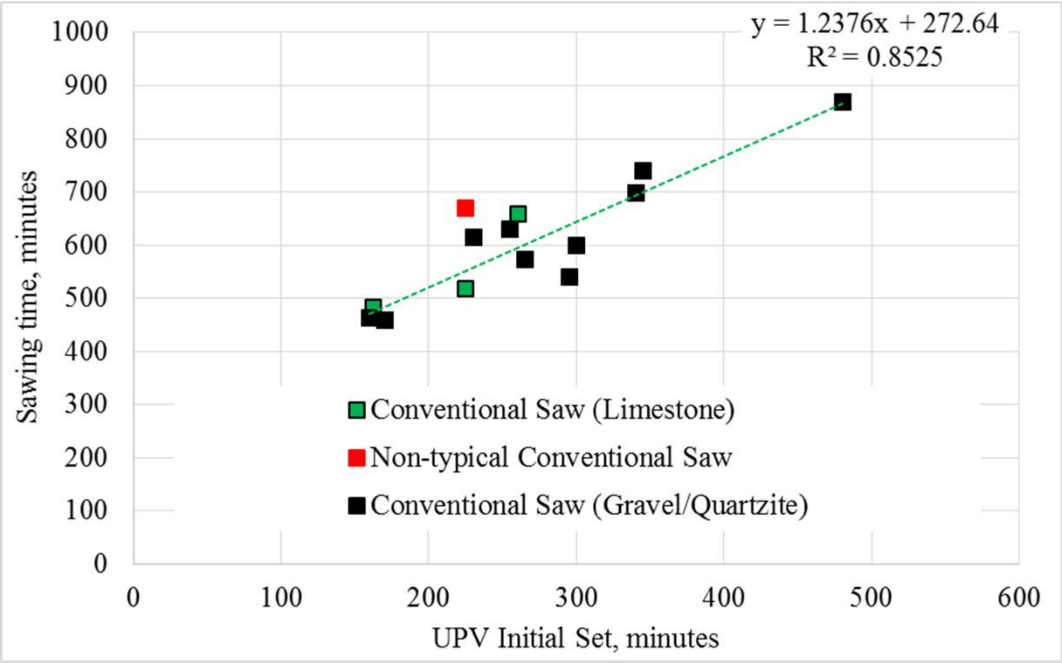
- Uniformity
    - Affected by air and water

Other Parameters

- Curing

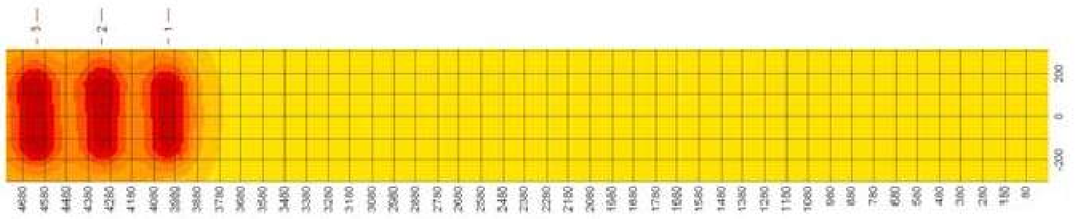
Other Parameters

- Saw timing



Bars

- Evaluation
  - MIT-DOWEL-SCAN Dowel Bar Scanner
  - No need to cut shipping wires



Thickness Measurement

- Cores
- Probing
- MIT-SCAN-T3
  - Within ± 0.1 inch of core thickness

Smoothness

- Measurement
  - Real time smoothness
  - Inertial profiler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Quality & Inspection

National Concrete Pavement Technology Center

Tech Center

Outline

- What is quality?
- Who cares?
- The Agency
- The Contractor
- Inspection

Defining Quality

- Simple Definition (Philip Crosby)
  - Quality: “Conformance to requirements”
  - Quality is defined by our customers

- QA = “Making sure the quality of a product is what it should be”

Why Should I Care

- Traditional Position: Money!
  - Penalties vs Incentives
  - Contractor has to make money to be in business

- It is not just about the money!!
  - Reputation
  - Staff
  - Equipment

CONTRACTOR

Why Should I Care

- Better working environment
  - Project partners are qualified
  - Contractor knows how the Agency will accept/pay for the product
  - QC Plans remove some of the daily stress
- Product you paid for

OWNER

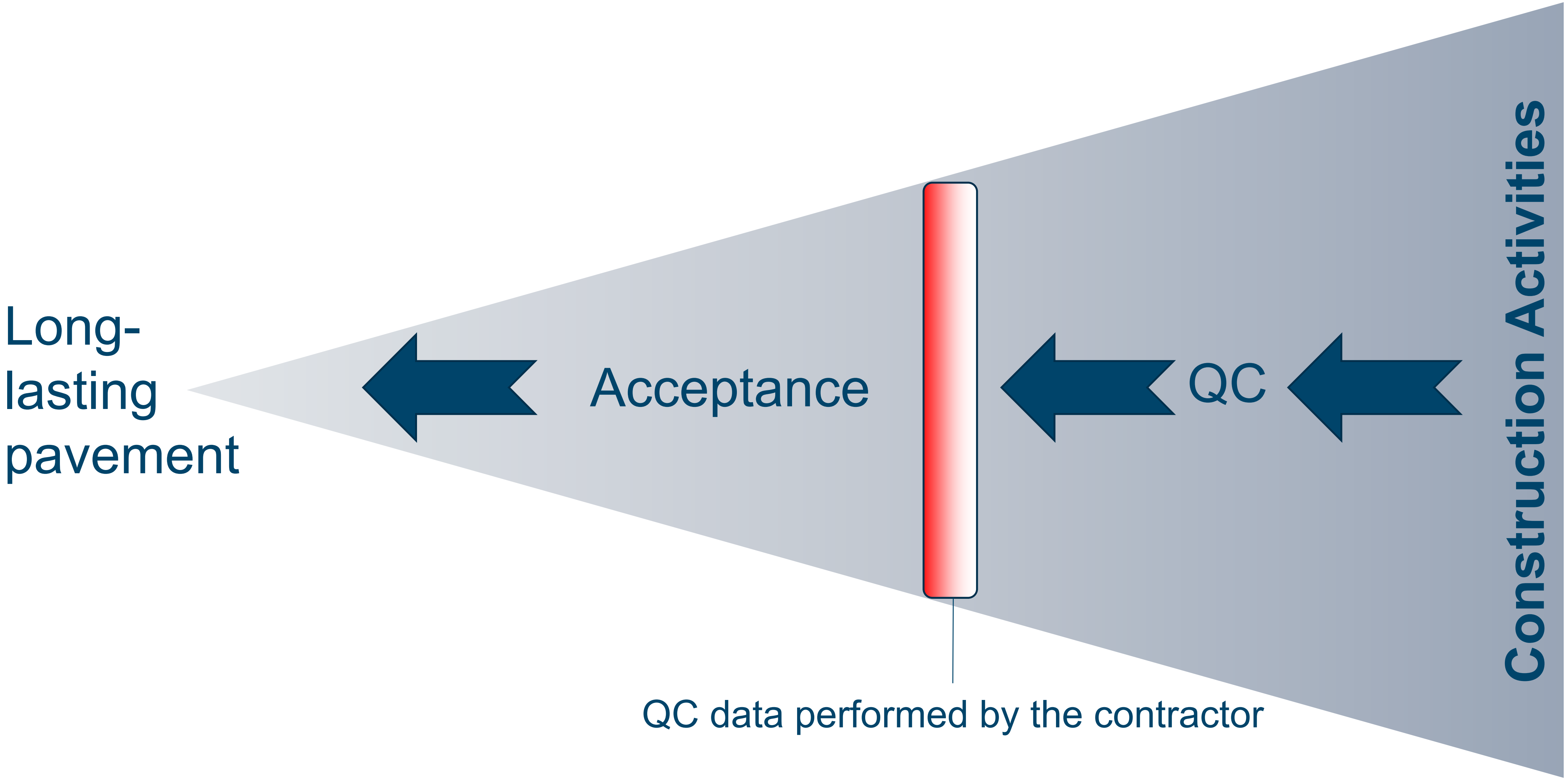
Quiz

Which of the following people affect quality?

- Designer/Specifier
- Agency Inspector
- QC Technician
- Loader Operator at the concrete plant
- Truck Driver
- Paver Operator
- Concrete Finisher
- Texture/Cure Machine Operator

Core Elements of an Agency QA Program

The Goal…


Long-
lasting
pavement
Acceptance
QC
Construction Activities
QC data performed by the contractor

Building Blocks

- Agency Acceptance – Measuring the things that matter
- Contractor Quality Control - Material and Process

- Qualified Laboratories - Testing
- Qualified Personnel - Sampling and Testing
- Independent Assurance - Sampling and Testing
- Dispute Resolution - Sampling and Testing

Acceptance

- Agency to carry out all acceptance activities
  - Inspection
    - Equipment
    - Environmental Conditions
    - Materials
    - Product Workmanship
  - Testing

Point of Acceptance

- The contractor’s concrete until the agency tests it
- Are you testing the final product?

Contactor’s concrete | Agency’s concrete

At the plant

In front of the paver

Behind the paver

Haul

Lose air

Through the paver

Lose air

Contractor's concrete

Common point of acceptance

This is what counts!

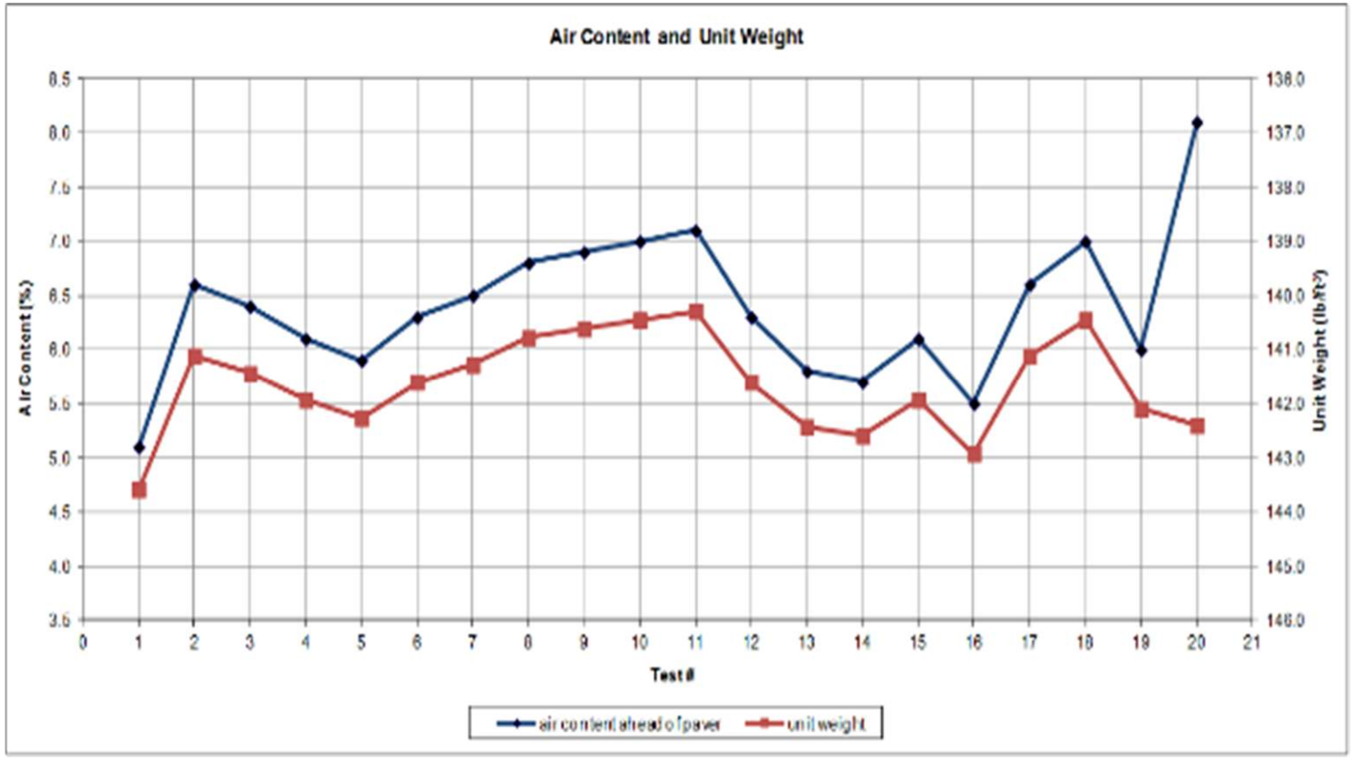
Quality Control

- Contractor's QC system should address:
  - Materials production processes
  - Materials transportation and handling
  - Field placement procedures
  - Calibration and maintenance of equipment
  - Watching the process
  - Fixing the process

Quality Control

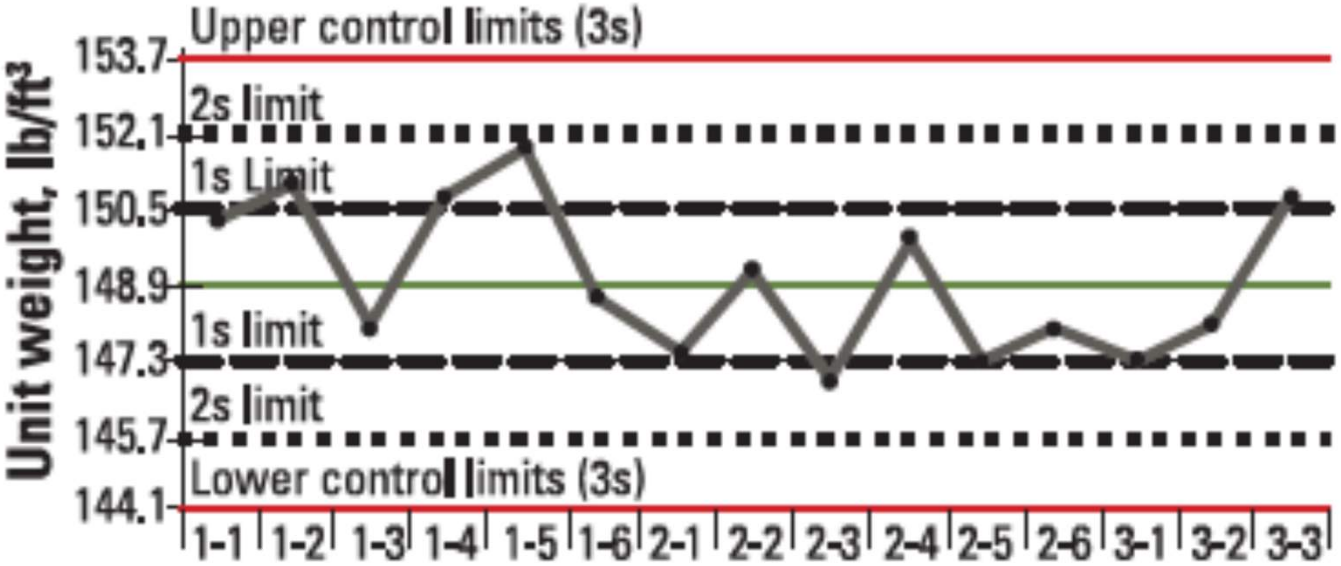
- Aim of QC is assure contractor that the mixture is going to be accepted.
- A QC plan should include
  - Unit weight
  - Calorimetry
  - Maturity
  - Strength development
  - Air void stability

  - Thickness
  - Ride



Control Charts

- Track data over time
  - Warning limit
  - Action limit
  - Watch for out-of-control conditions



How Do We Evaluate the Mixture?

- Measure everything during prequalification
  - Constructible (Workable)
  - Dimensionally stable
    - Aggregates
    - Shrinkage
  - Impermeable (Transport properties)
  - Cold weather resistant
    - Freeze thaw
    - Salt attack
  - Strong (enough)

Table 9-3. Recommended laboratory tests during prequalification of a mixture

Concrete property	Test description	Test method	Comments
Workability	Aggregate gradation	ASTM C136/AASHTO T 27 ASTM C566/AASHTO T 255	• Use the individual gradations and proportions to calculate the combined gradation
	Combined gradation	Tarantula curve	• Adjust combined gradation to achieve optimum workability
	Paste content	Batch sheet	• Adjust paste content to find minimum paste needed while still workable • Confirm that total is below maximum permitted for shrinkage
	VKelly or Box	AASHTO TP 129/PP 84 X2	• Confirm that the mixture responds well to vibration • Adjust aggregate gradation and water content to achieve desired performance
	Slump at 0, 5,10,15, 20, 25, and 30 minutes	ASTM C143/AASHTO T 119	• Look for excessive slump loss due to incompatibilities, which is more likely at elevated temperatures • Determine approximate water-reducing admixture (WRA) dosage
	Segregation	—	• Look for signs of segregation in the slump samples
Air void system	Foam drainage	—	• Assess stability of the air-void system for the cementitious/admixture combination proposed • Select alternative admixture combinations if instability is observed
	Air content	ASTM C231/AASHTO T 152, T 196	• Determine approximate air-entraining admixture (AEA) dosage
	Super Air Meter (SAM)	AASHTO TP 118	• < 0.2 target
	Clustering	Retemper a sample and use optical microscopy to assess clustering	• This can affect strength • Air content can also jump with retempering
	Hardened air	ASTM C457	• Assess compliance with specification
Unit weight	Unit weight	ASTM C138/AASHTO T 121	• Indicates yield of the mixture and provides a rough estimate of air content • Establish basis for QC monitoring
Strength development	Compressive or flexural strength	ASTM C39/AASHTO T 22 and/or ASTM C78/AASHTO T 97 at 1, 3, 7, 28, and 56 days	• Calibrate strength gain for early age QC • Calibrate flexural with compressive strengths • Adjust w/cm ratio to ensure sufficient strength
	Maturity	ASTM C1074	• Calibrate the mixture so maturity can be used in the field to determine opening times
Transport	Resistivity/F-factor	Soak/store samples in salt solution	• Determine development of F-factor over time • Adjust w/cm ratio to achieve required performance
	Sorption	ASTM C1585	• Determine time to critical saturation
	W/cm ratio	Microwave	• Calibrate microwave test with batch data
Other	Hydration	Semi-adiabatic calorimetry	• Determine hydration rates of mixture • Set a baseline for QC • Assess risk of incompatibilities if supplementary cementitious materials (SCMs)/admixtures/temperatures change • Adjust SCM source, WRA type, or operating temperature if incompatibility is observed
	Oxychloride risk	LT-DSC on paste	• Assess risk of joint deterioration if salts are used • Increase SCM dose if risk is excessive
	Coefficient of thermal expansion (CTE)	AASHTO T 336	• Confirm that assumptions used in structural design are appropriate
	Mortar content	Vibrate a container (air pot) for 5 minutes and measure depth of mortar at the top surface	• This provides information on the coarse aggregate content—maximum is ~¼ in.

How Do We Evaluate the Mixture?

- Some things we measure during construction for acceptance
  - Transport
  - Air void system
  - Strength

Table 9-4. Field setup tests

Concrete property	Test description	Test method	Comments
Workability	Aggregate gradation	ASTM C136/AASHTO T 27 ASTM C566/AASHTO T 255	• Use the individual gradations and proportions to calculate the combined gradation
	Combined gradation	Tarantula curve	• Adjust combined gradation to achieve optimum workability
	Slump	ASTM C143/AASHTO T 119	• Determine WRA dosage range
Air-void system	SAM	AASHTO TP 118	• Determine AEA dosage range
Unit weight	Unit weight	ASTM C138/AASHTO T 121	• Confirm basis for QC monitoring
Strength development	Compressive or flexural strength	ASTM C39/AASHTO T 22 and/or ASTM C78/AASHTO T 97	• Confirm strength development
Transport	Resistivity/F-factor	Soak samples in salt solution	• Confirm development of F-factor over time
Other	Hydration	Semi-adiabatic calorimetry	• Confirm baseline for QC

How Do We Evaluate the Mixture?

- Contractor also needs to watch how things are developing
  - Unit weight
  - Calorimetry
  - Maturity
  - Strength development
  - Air void stability

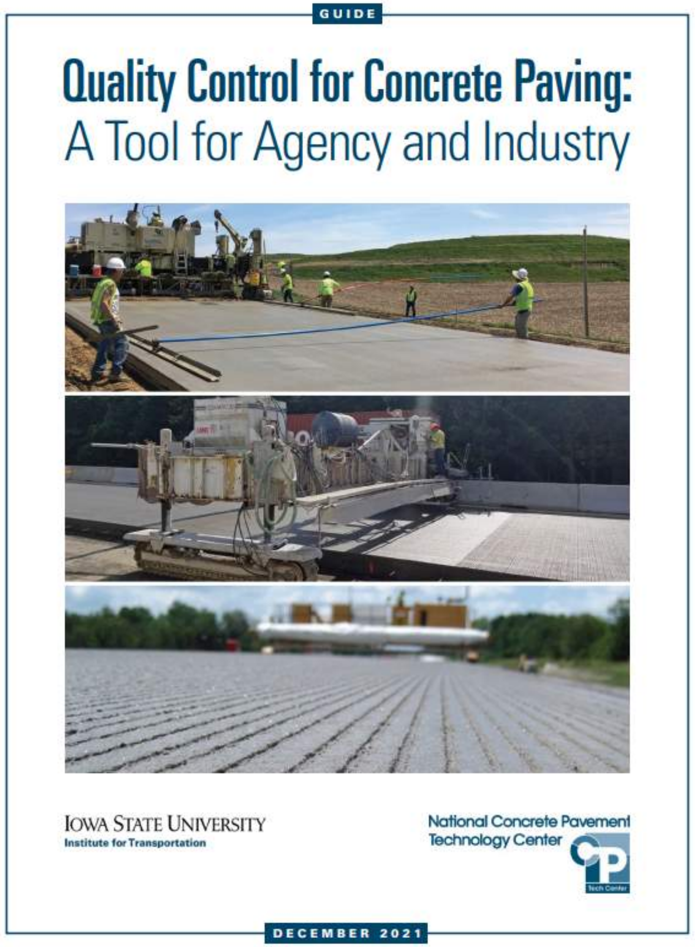
QC during Construction

Table 9-5. Mixture QC tests

Concrete property	Test description	Test method	Comments
Workability	Aggregate gradation	ASTM C136/AASHTO T 27 ASTM C566/AASHTO T 255	• Use the individual gradations and proportions to calculate the combined gradation
	Combined gradation	Tarantula curve	• Monitor uniformity
	Aggregate moisture content	ASTM C29	• Affects w/cm ratio and workability
	Slump	ASTM C143/AASHTO T 119	• Indicates uniformity batch to batch
Air-void system	SAM	AASHTO TP 118	• Indicates uniformity batch to batch
Unit weight	Unit weight	ASTM C138/AASHTO T 121	• Indicates uniformity batch to batch
Strength development	Compressive or flexural strength	ASTM C39/AASHTO T 22 and/ or ASTM C78/AASHTO T 97	• Indicates uniformity batch to batch
	Maturity	ASTM C1074	• Opening times
Transport	Resistivity/F-factor	Soak samples in salt solution	• Monitor over time • Indicates uniformity batch to batch
Other	Hydration	Semi-adiabatic calorimetry	• Indicates uniformity batch to batch

Quality Resource

- Tool for agency and industry
- Gives contractors flexibility to develop QC
- Agency QC Requirements
- Model QC plan
- Control Charts



Inspection

National Concrete Pavement Technology Center

What is the inspector’s role?

- Not a foreman
- Represent the owner
- Catch the things the tests miss
- Actions:
  - Early warning / communicate
  - Request adjustments
  - Stop!!!

Inspector's Role

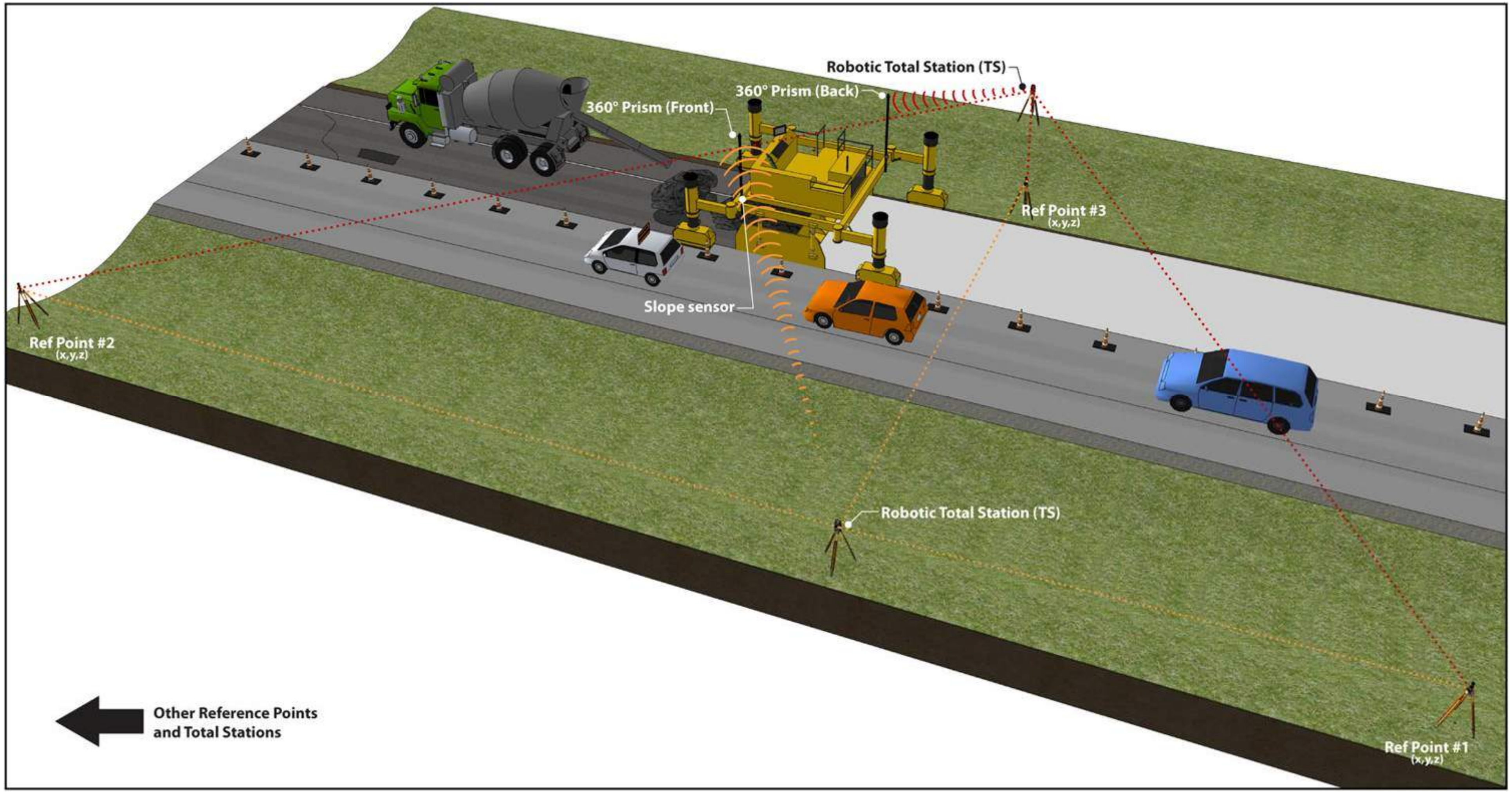
1. Safety & Traffic Control
2. Grade
3. Geometry
4. Concrete Delivery & Placement
5. Fresh Concrete Testing
6. Vibration
7. Steel Placement
8. Finish
9. Texture
10. Curing
11. Sawing/Sealing
12. Documentation

As the inspector, these are the minimum recommended items to check.

Grade - Stringline

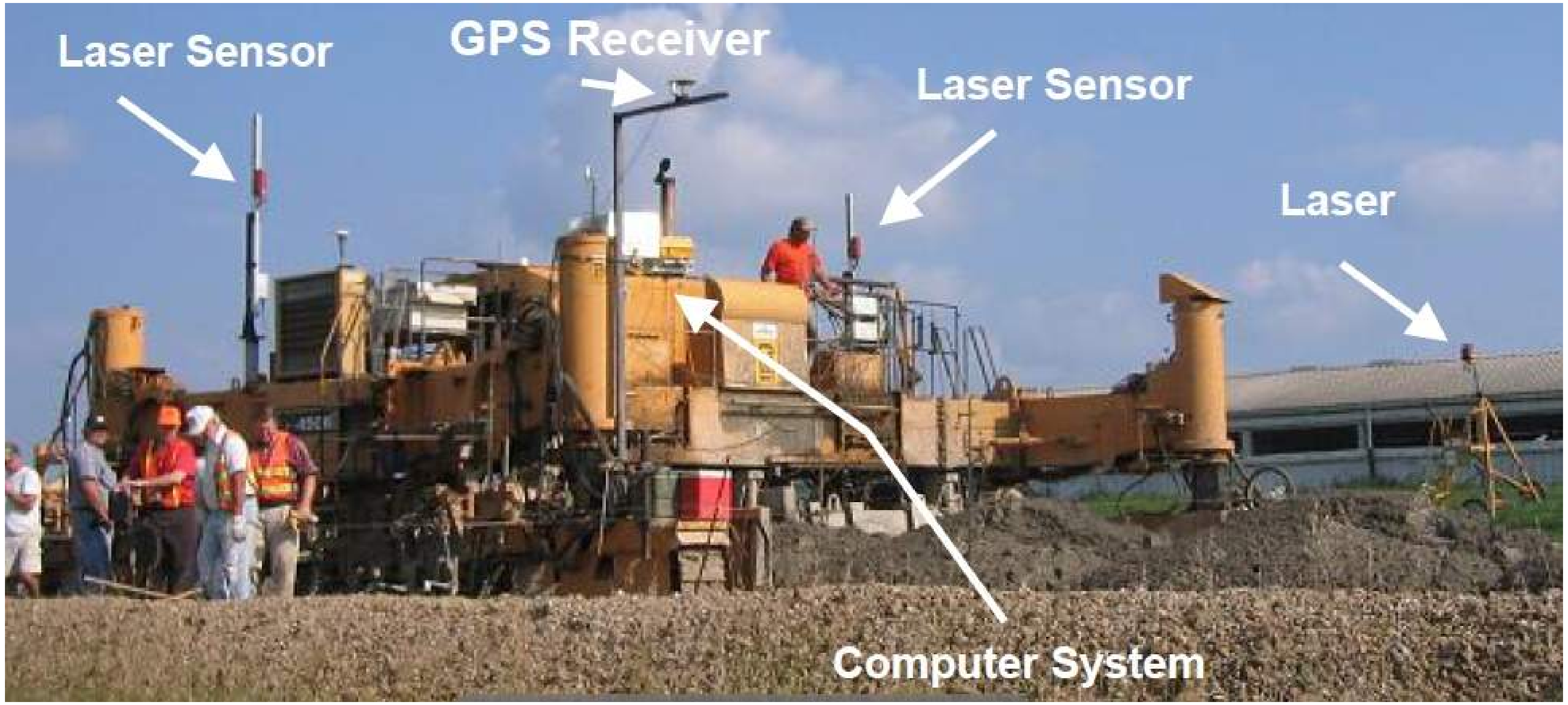
- Check the string regularly
  - Tension (Don’t touch, ask contractor)
  - Bumped stakes
  - Haul road stability

Stringless Paving



Stringless Paving

- Contractor provides grade verification with total station / prism for inspector



Grade - Moisture

- Base ahead of the paver should be moist
- Watch for excessive water loss into the base
  - Workability
  - Cracking

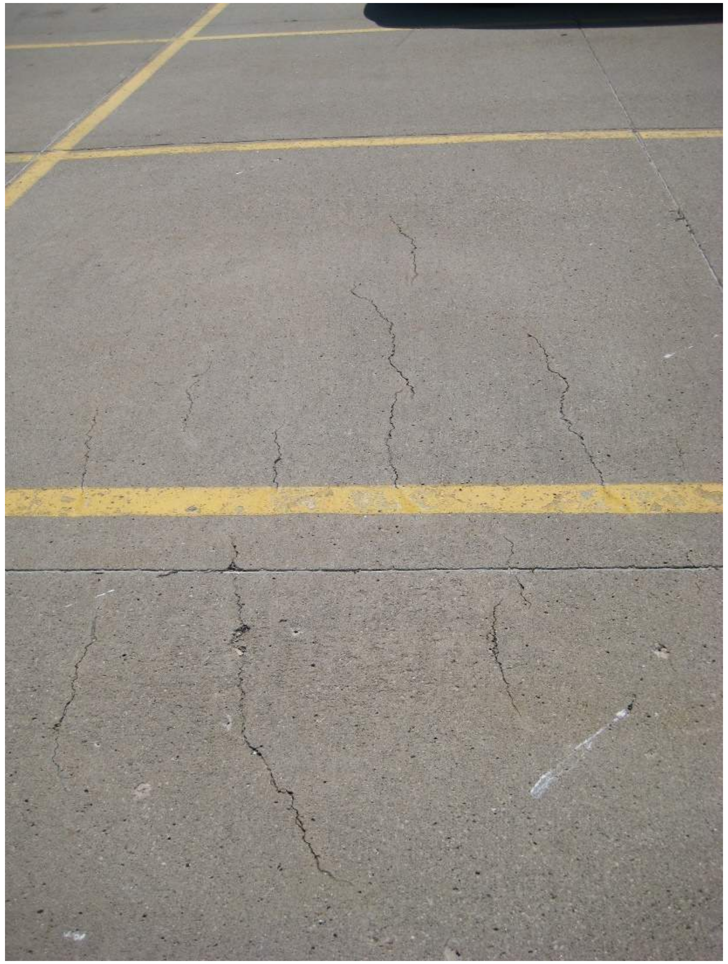
Geometry

- Check width - morning
- Check thickness - hourly
- Check cross-slope - morning and through transitions

Delivery and Placement

Temperature

- When weather is cold
  - Slower hydration
  - Increased risk of cracking
  - Frozen subgrade/subbase?
- When the weather is hot/windy
  - Rapid hardening
  - Rapid moisture loss
- Follow the specifications for limits



Mixture Uniformity

Homogeneous

- Thoroughly mixed
- No segregation
- Uniform workability

Concrete Proportions

- Compare proportions to the approved mix design
  – three times per day

Job	SD OL
Ticket No.	1041
Date	3/26/2011
Time	15:30
Batch Size (yd^3)	8
Formula #	2

	Target	Actual	MC
Portland Cement	3680	3670	
Fly Ash (lb)	920	920	
Coarse Agg (lb)	10910	10920	3.0%
Intermediate Agg (lb)	3460	3450	2.7%
Fine Agg (lb)	10460	10480	3.8%
AEA (oz)	40	40	
Water Reducer (oz)	304	305	

Mix Water (gl)	119	120
Trim Water (gl)	10	10
Water from Agg (gl)	98	98
Total Water (gl)	227	228

Aggregate Moisture

- Aggregate weights should include absorbed water
- Moisture contents should be adjusted as needed
- Check batch tickets to look for changes
- E Tickets?

Job	SD OL
Ticket No.	1041
Date	3/26/2011
Time	15:30
Batch Size (yd^3)	8
Formula #	2

	Target	Actual	MC
Portland Cement	3680	3670	
Fly Ash (lb)	920	920	
Coarse Agg (lb)	10910	10920	**3.0%**
Intermediate Agg (lb)	3460	3450	**2.7%**
Fine Agg (lb)	10460	10480	**3.8%**
AEA (oz)	40	40	
Water Reducer (oz)	304	305	

Mix Water (gl)	119	120
Trim Water (gl)	10	10
Water from Agg (gl)	98	**98**
Total Water (gl)	227	228

Added Water

Water:Cementitious (w/cm) ratio is critical

- Transit mixed concrete
  - Monitor water added on site
  - Reject the load if the max. w/cm is exceeded

- Central mixed concrete
  - Assure that trim water is thoroughly mixed and included on the batch tickets

Delivery Time

- Check transit time

Job	SD OL
Ticket No.	551
Date	3/23/2011
Time	**11:30**
Batch Size (yd^3)	8
Formula #	2

	Target	Actual	MC
Portland Cement	3680	3670	
Fly Ash (lb)	920	920	
Coarse Agg (lb)	10860	10850	2.5%
Intermediate Agg (lb)	3470	3460	2.9%
Fine Agg (lb)	10500	10510	4.2%
AEA (oz)	40	40	
Water Reducer (oz)	304	305	

Mix Water (gl)	119	120
Trim Water (gl)	10	2
Water from Agg (gl)	98	98
Total Water (gl)	227	220

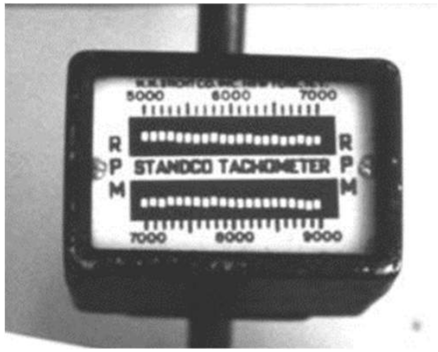
Grade Yield

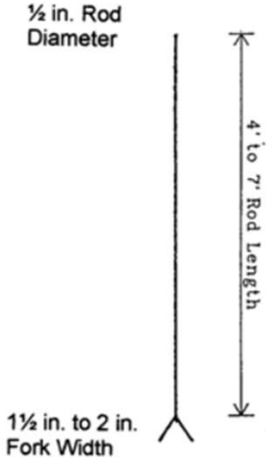
- Concrete used / concrete required (expressed as %)
  - Example: 256 cy/240 cy = 107%
- Almost always greater than 100%
- If less than 100%
  - Deficient thickness (thin slab)?
  - Incorrect concrete proportions?

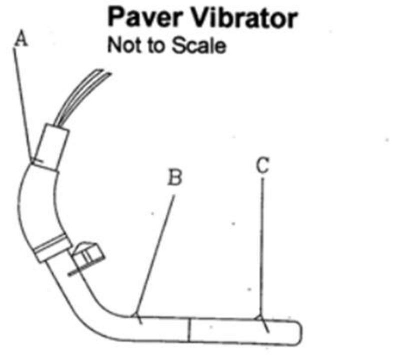
Vibration

- Stay between 5,000 and 8,000 vibrations per minute (VPM)
  - Excess speed causes segregation
  - Vibrator frequency should be adjusted for paving speed
- Ensure all vibrators are running
- Stop vibration if forward progress stops

Internal Vibration Checks







For vibration readings, make fork contact at:
A – First Choice
B – Second Choice
C – Third Choice

Video

Vibration Monitors

Steel Placement

Dowel bar inserter (DBI)

Watch for

- Locations
- Surface voids

Dowel Placement

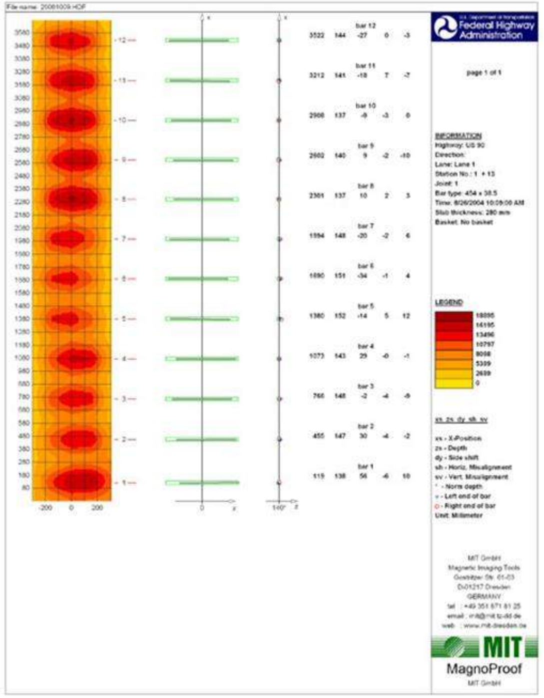
Baskets or DBI

- Manually verify bar location (min. 2x per day)

Dowel Placement

Evaluation

- MIT-Dowel-Scan
- Data without shipping wires cut



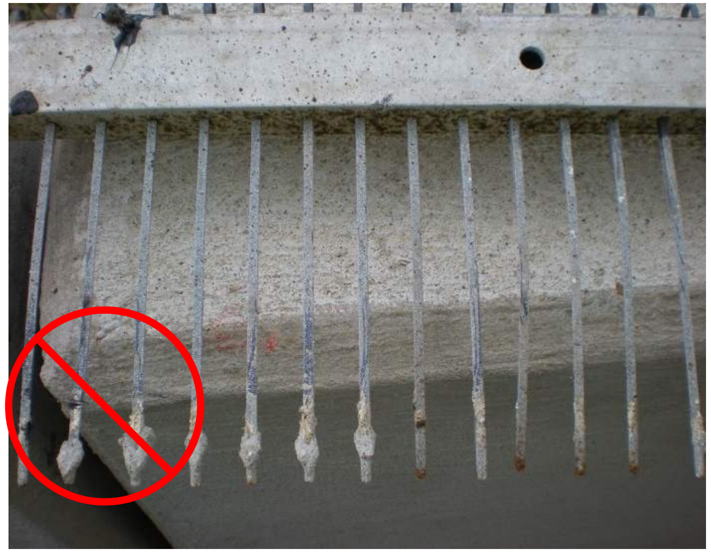
Tie Bar Placement

Tie Bar Inserters

- Check general locations of placement (timing of insertion)
- Observe contractor is physically verifying locations

Texturing

- Maintain straight tines
- Uniform distance between paver and tining bridge
- Clean mortar buildup from the burlap drags and tines
- Avoid positive texture (noise generator)



Turf Drag

- Watch for cleanliness

Video

Longitudinal Tining & Curing

Video

Curing

- Check material on site
- Note spacing of totes

Curing

- Avoid hand sprays
- Applied close behind the paver
- Specified coverage rate allowing for texture
  - Uniform coverage (no gray streaks)
  - Like a white sheet of paper
  - Two coats are better than one
- Beware of wind

Sawing

- Timing
  - Too late = Cracking
  - Too early = Severe raveling
  - Just right = Limited raveling
- Sawcut depth
  - T/3 to T/4
- Location
  - Over the dowels

a) No raveling—sawed later in the window

b) Moderate raveling—sawed early in the window

c) Unacceptable raveling—sawed too early

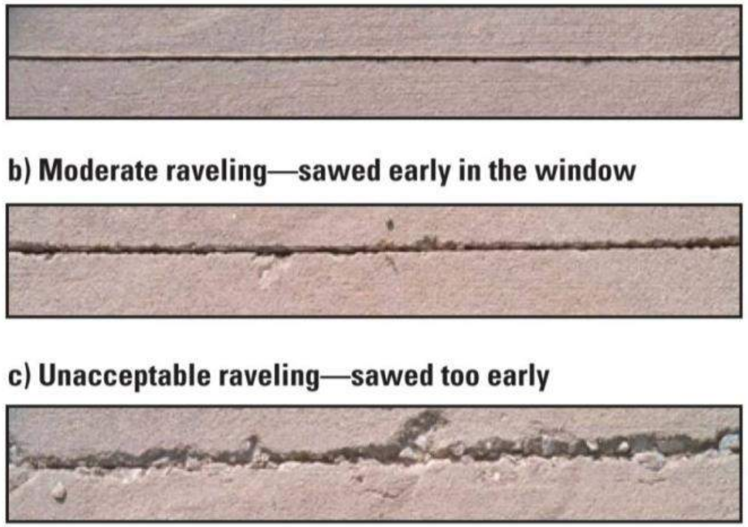
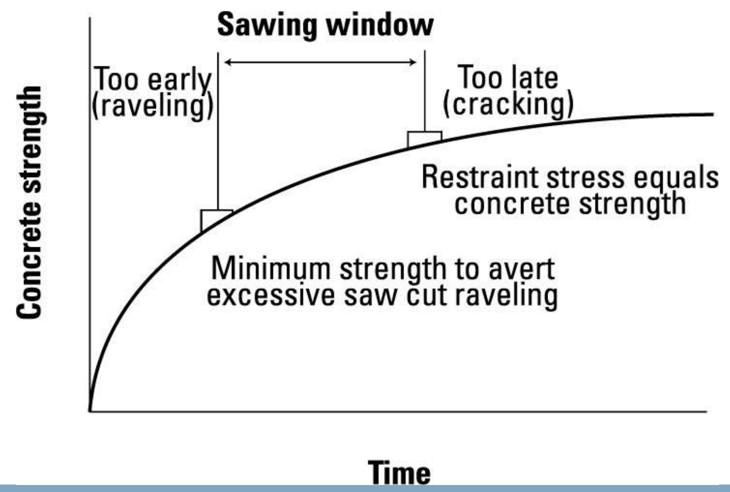


Figure 8-23. Close-up of different degrees of raveling caused by joint sawing (ACPA)

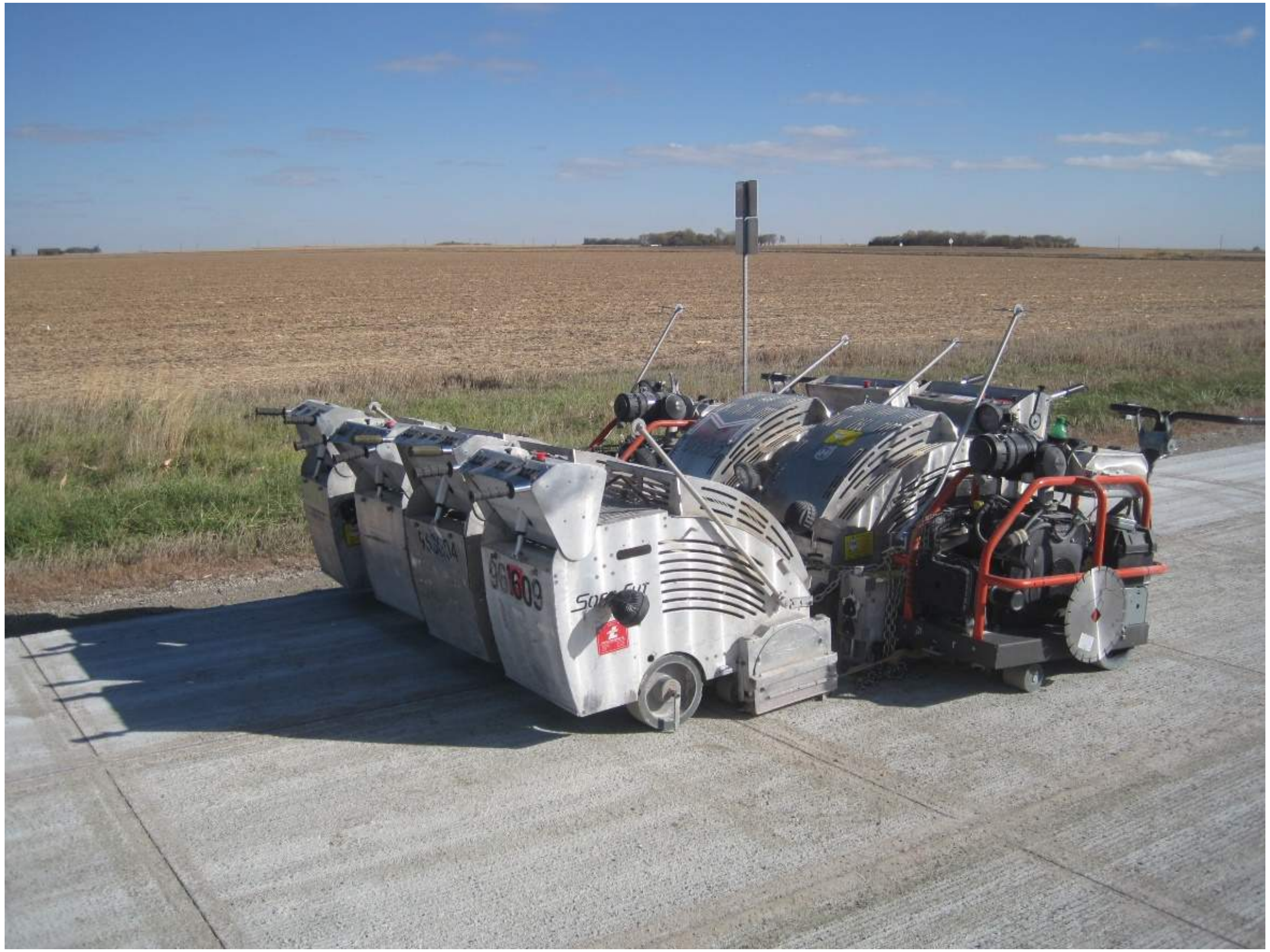


Sawing Equipment

- Conventional sawing
  - A little later
  - Deeper
- The right blade for the aggregate

Sawing Equipment

- Early entry sawing
  - A little earlier
  - Shallower
  - Blade spins up in front
- The right blade for the aggregate
- The shoe must be replaced regularly



What happened?

Sawcut too shallow

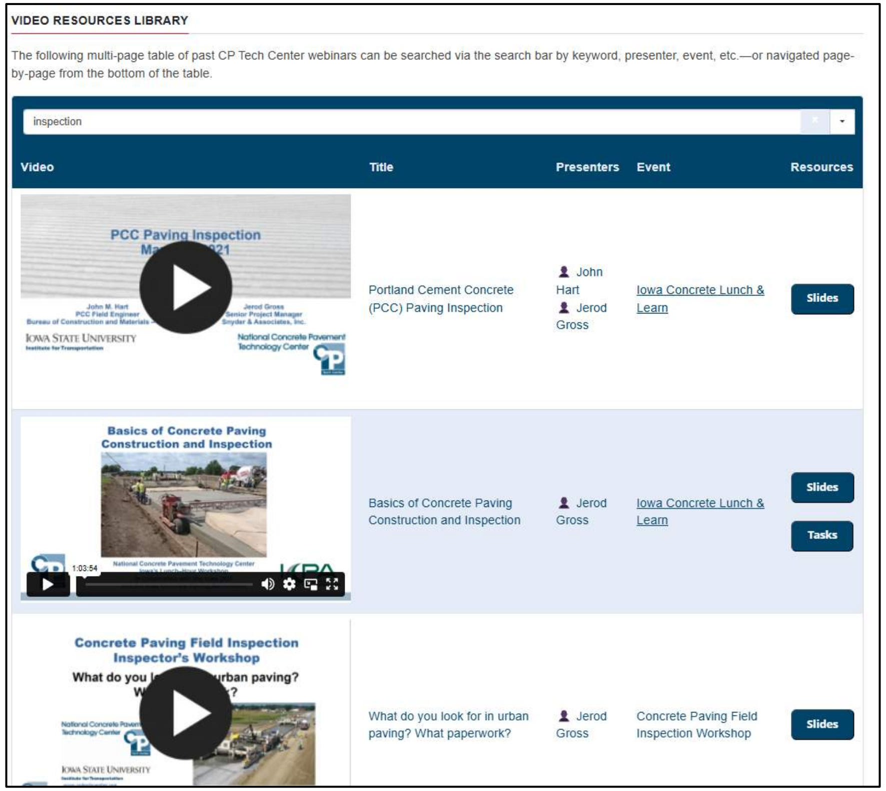
Edge blowout with early entry saw

Joint Sealing

- Clean and dry joint faces
  - Sandblast, and dry compressed air
- Backer rod installation
  - Not recommended in F-T environments
- Sealant installation

Summary

- Resources are available!
- https://www.cptechcenter.org/webinars-and-videos/


VIDEO RESOURCES LIBRARY

The following multi-page table of past CP Tech Center webinars can be searched via the search bar by keyword, presenter, event, etc.—or navigated page-by-page from the bottom of the table.

inspection

Video	Title	Presenters	Event	Resources
PCC Paving Inspection	Portland Cement Concrete (PCC) Paving Inspection	John Hart, Jerod Gross	Iowa Concrete Lunch & Learn	Slides
Basics of Concrete Paving Construction and Inspection	Basics of Concrete Paving Construction and Inspection	Jerod Gross	Iowa Concrete Lunch & Learn	Slides, Tasks
Concrete Paving Field Inspection Inspector's Workshop	What do you look for in urban paving? What paperwork?	Jerod Gross	Concrete Paving Field Inspection Workshop	Slides

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Institute for Transportation