NATIONAL ACADEMIES *Sciences Engineering Medicine*

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Sustainable, Resilient, and Durable Concrete Pavements

May 26, 2022

1:00 – 3:00 PM

Learning Objectives

- Identify key factors necessary to enhance the sustainability and resiliency of concrete pavements
- Implement adaptive practices to improve the performance and longevity of concrete pavements

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Beth Ewoldsen at Bewoldsen@nas.edu

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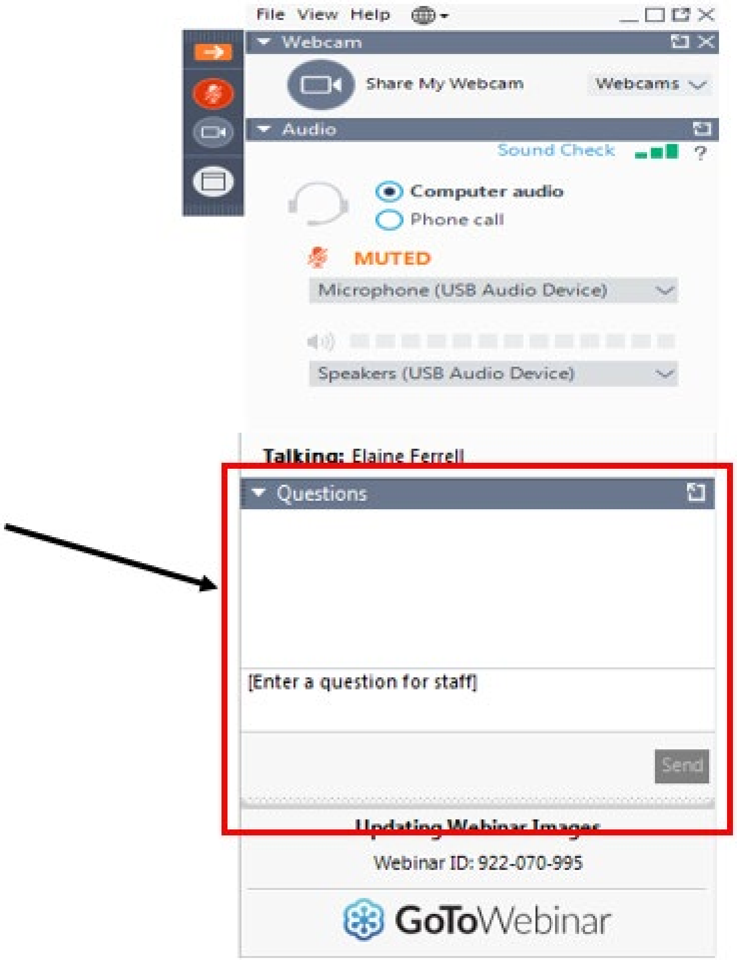
Questions and Answers

- Please type your questions into your webinar control panel

- We will read your questions out loud, and answer as many as time allows



Today's presenters

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Sustainability in New and Rehabilitated Concrete Pavements – Concepts

Thomas Van Dam, Ph.D., P.E.
Principal at NCE

TRB Webinar: Sustainable, Resilient, and Durable Concrete Pavements

Thursday, May 26, 2022

Today's Topics

- Climate change – driving the conversation
- What is sustainability?
- The role played by portland cement and concrete
- Importance of carbon footprint
- Considering the use phase
- Verification

And Just Like That, Sustainability is Important

- Politicians come and go, but scientific facts remain
  - Global temperatures continue to rise
  - The Arctic continues to melt
  - Sea levels are rising
- Current administration is emphasizing climate change
  - Climate change is a focal point in the new infrastructure bill (IIJA)
- Sustainability is of great interest to both agencies and industry
  - Implementing sustainability is less clear

Climate Change

- Changes in global climate from human activities are occurring
  - Supported by historical observations and climate modeling
- Optimistic models predict substantial climate change over the next century
  - Rate of change depends on what we do
  - Long life of emitted heat-trapping, greenhouse gases and slow feedback functions of atmospheric systems drive climate change

Certainty

"It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred"

IPCC, 2021: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis*

Uncertainty

The degree of change is uncertain as many variables are important and as yet, undefined

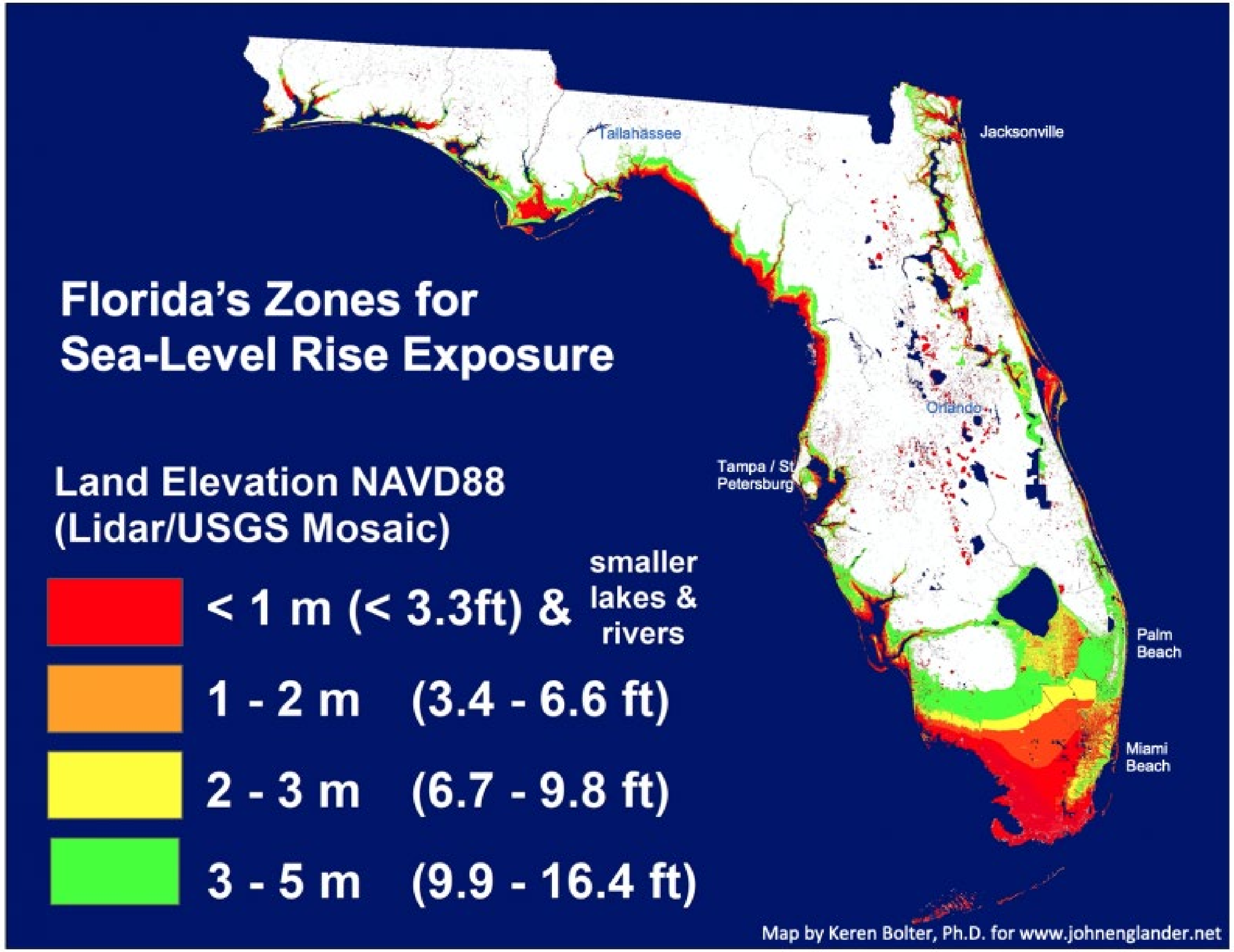
Let’s Start With Facts (IPCC 2021)

- The 1 °C rise in global temperature since 1850 is unprecedented in 2000 years of analyzed data
  - High temperatures in the Artic are resulting in melting of “permafrost”
  - There is a mass migration and extinction of species underway
- There has been a 0.2 m sea level rise since 1950
  - Superintendent of the U.S. Naval Academy (USNA) – “Sea level rise in Annapolis is putting the service academy’s buildings, historic infrastructure, and entire military mission at risk”
- Broad impacts on precipitation patterns have emerged
  - An example is the megadrought in the Western US is threatening water and energy supplies throughout the region

What Say The Models (IPCC 2021)

- Considering volcanism and solar activity alone, there would be no temperature rise since 1850
- Factoring in anthropogenic greenhouse gas (GHG) emissions
  - Current rise of 1 °C in global temperatures between 1850 and the present is predicted with great certainty
  - Future temperature increases will vary between 0.5 and 4.0 °C by 2100, depending on what we do
  - Sea level rise between 0.5 and 1.0 m by 2100
  - Temperature rise and precipitation patterns variable

Putting Sea-Level Rise Into Perspective

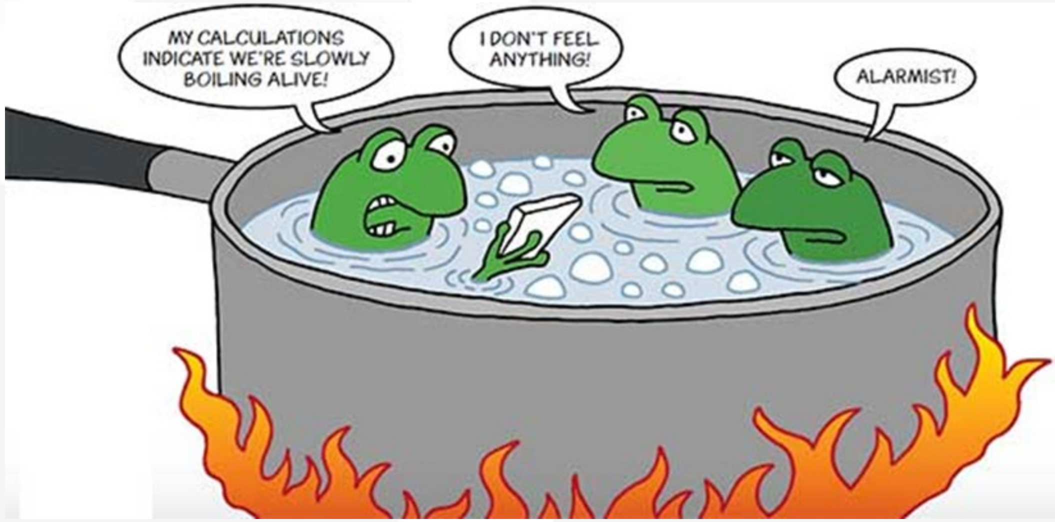


Why Is Acceptance of These Facts So Difficult?

- Although the science linking GHG emissions to climate change is sound, the current political environment lacks trust
- Agencies are worlds apart from each other when it comes to (1) how they conceptualize sustainability and (2) what they are willing to do

Why Is Acceptance of These Facts So Difficult?

- Sustainability and climate change are complicated
  - We want things to be simple
  - Requires education and acceptance of things we might not intuitively understand or accept
- There is not yet a business case for carbon reduction
  - Budgets remain limited, prices are skyrocketing, and infrastructure is failing
  - "Green" solutions that cost more will not be welcomed
  - Direction from above is to be more sustainable but it is unclear what this means

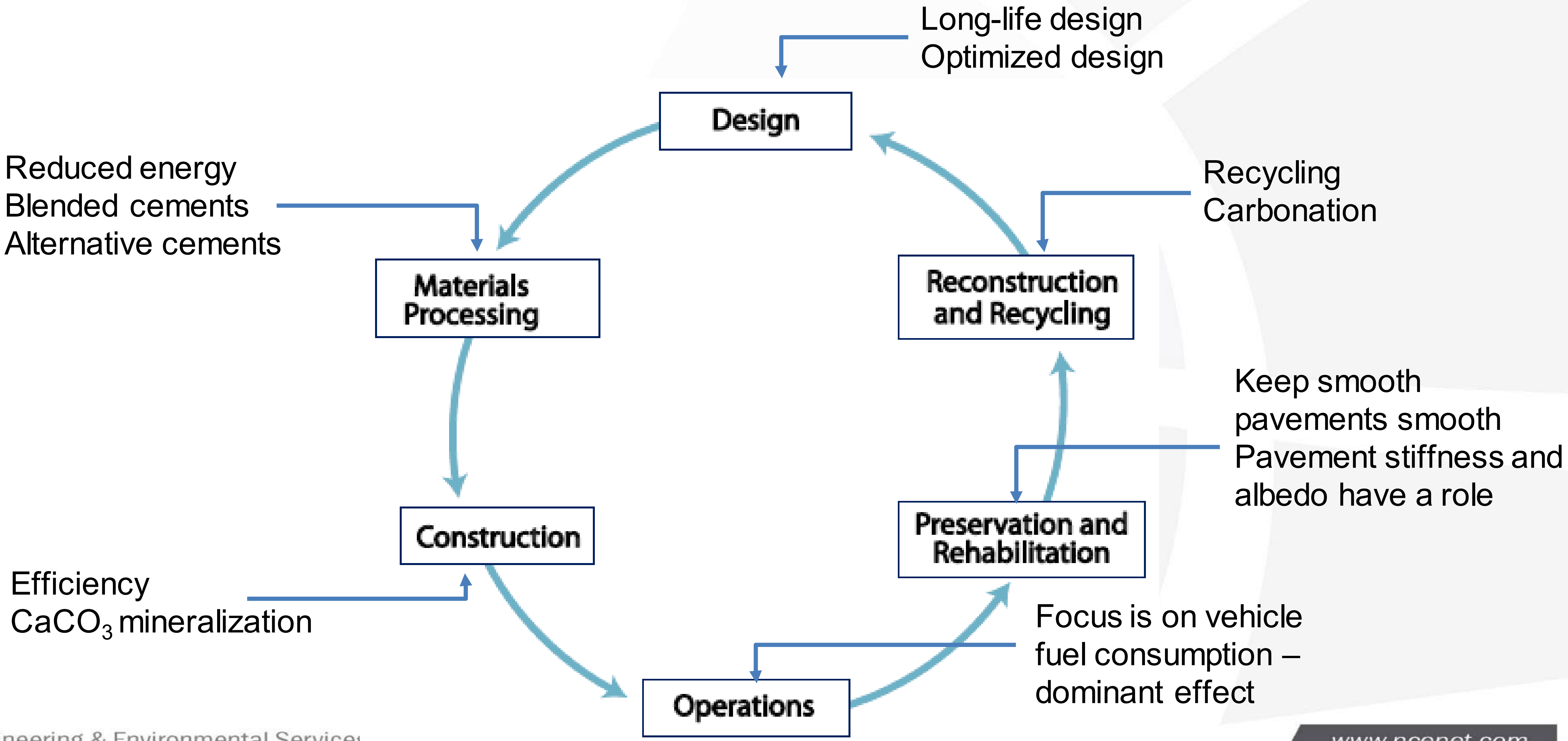


Sustainability: The Triple Bottom Line

Sustainable practices are simply good engineering

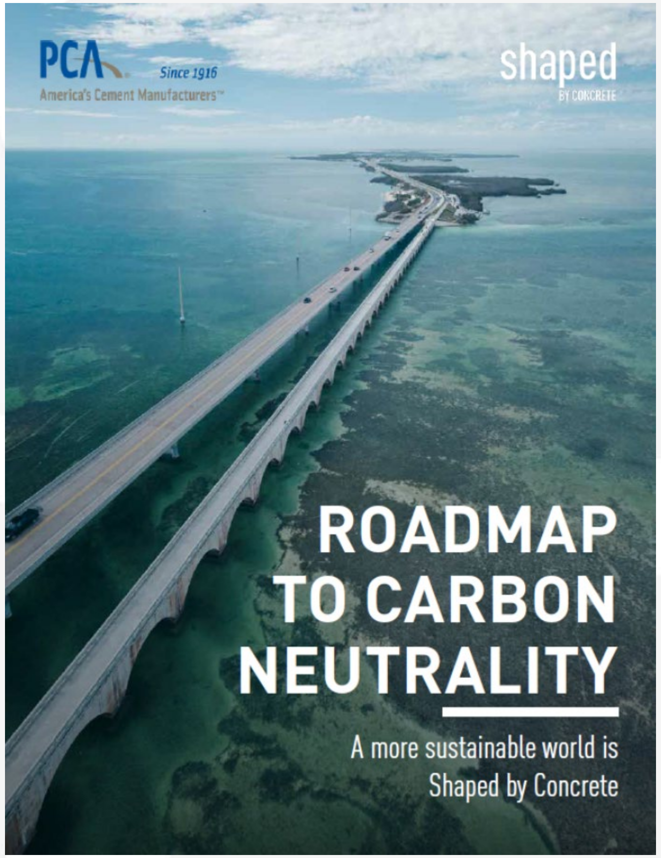
And not just GHG emissions or environmental impacts

Sustainable Solutions Require Life-Cycle Thinking

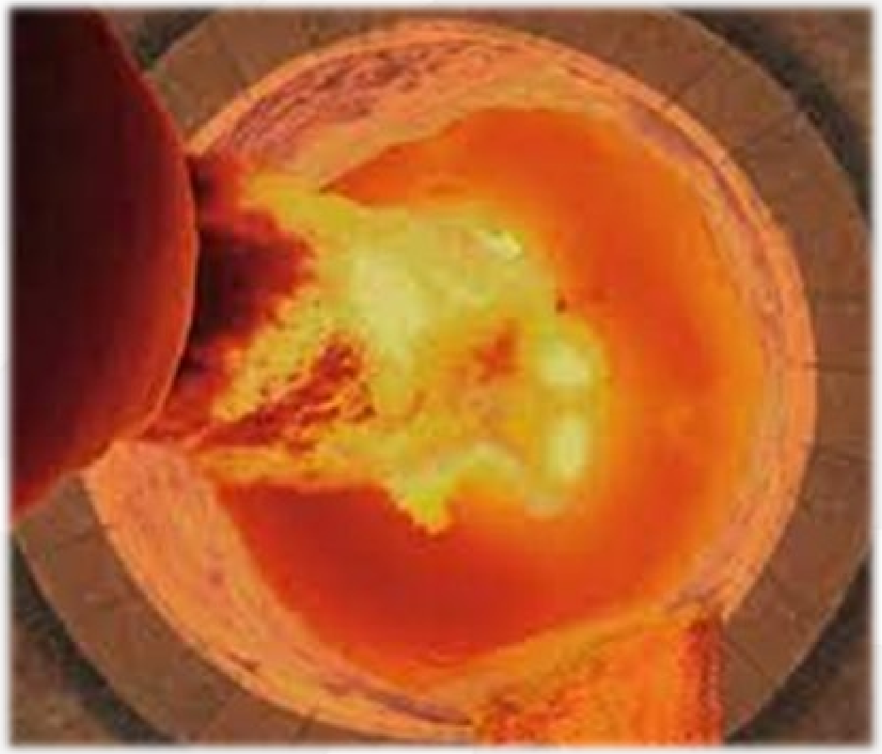


Role of Hydraulic Cement and Concrete Mixtures

- Hydraulic cement concrete is humankind's most used material after water
  - Approximately 2.2 yd^3/person/year
  - Civilization is built on it – no exaggeration
  - 5% to 8% of global GHG emissions
- Results in massive positive and negative economic, environmental, and social impacts
  - 90 million metric tons of cement manufactured in the U.S. in 2020 (4.1 billion worldwide)
  - In 2018, linked to 0.6% of US GHG emissions



GHG Emissions Associated With Concrete at the Gate



- ~1.5% from acquiring and processing raw materials
- **~89%** from cement manufacturing
  - ~37% from burning fuel
  - ~46% from calcination
- ~9.5% from making concrete

Net result: for every pound (kg, MT) of U.S. made ASTM C150 Type I cement, a little less than a pound (kg, MT) of GHG emissions are released

Keys to Reducing The Carbon Footprint of Concrete Through Construction Phase

- Use less concrete through the life cycle
  - Optimize design
  - Durability
- Use less portland cement clinker in cementitious materials
- Use less cementitious materials in concrete mixtures

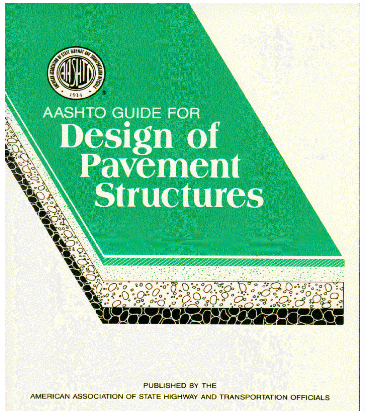
I will introduce these strategies, but they will be discussed in detail by other speakers

Key 1: Reduce Amount of Concrete Used

- Optimize conventional pavement design through use of mechanistic-empirical design
  - AASHTOWare Pavement ME software
- Consider alternative approach to design
  - Thin Concrete Pavement (TCP) design using OptiPave software
  - Can reduce required slab thickness by 40% or more for given situations
- Producing durable concrete that can be easily maintained in a smooth condition has added life cycle benefits

Concrete Pavement Design Methods

Outdated



THE 40 YEAR DIVIDE

StreetPave12

PavementDesigner.org

OptiPave 2 TCPavements

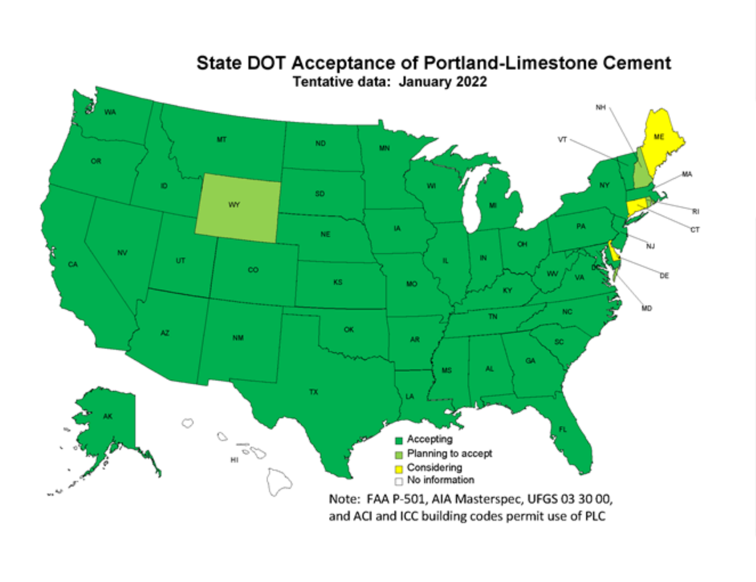
AASHTOWare Pavement

AASHTO 93	StreetPave	OptiPave	Pavement ME
1962-1998	2005-2014	2009-2016	2009-2020
10 inputs	12 inputs	≈ 50 inputs	≈ 1,000 inputs
"Performance"	Crack & Fault	Crack, Fault, IRI	Crack, Fault, IRI
Field Data	**FEA** + Field Data	**FEA** + Field Data	**FEA** + Field Data

Increasing Complexity = More Accurate Models & More *Optimization* Options

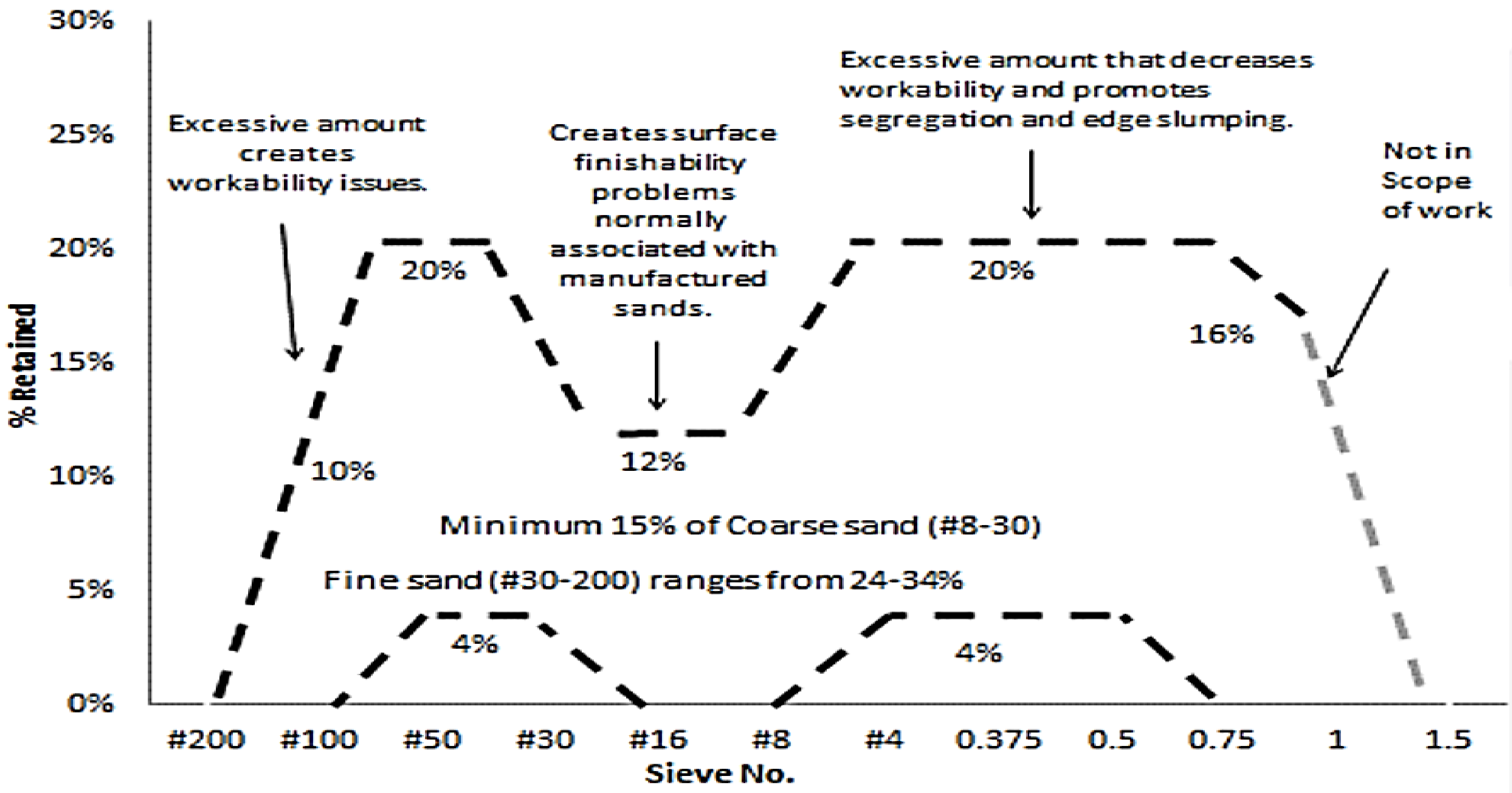
Key 2: Reduce Clinker in Cement SCMs and Blended Cements

- Increased amounts of fly ash, slag cement, and natural pozzolans
- ASTM C595 Type IP(X), Type IS(X), and Type IT (X)(Y)
  - Blended with pozzolan, slag cement, limestone or ternary blend
- ASTM C595 Type IL will reduce carbon footprint by 8 to 10 percent with little impact on behavior



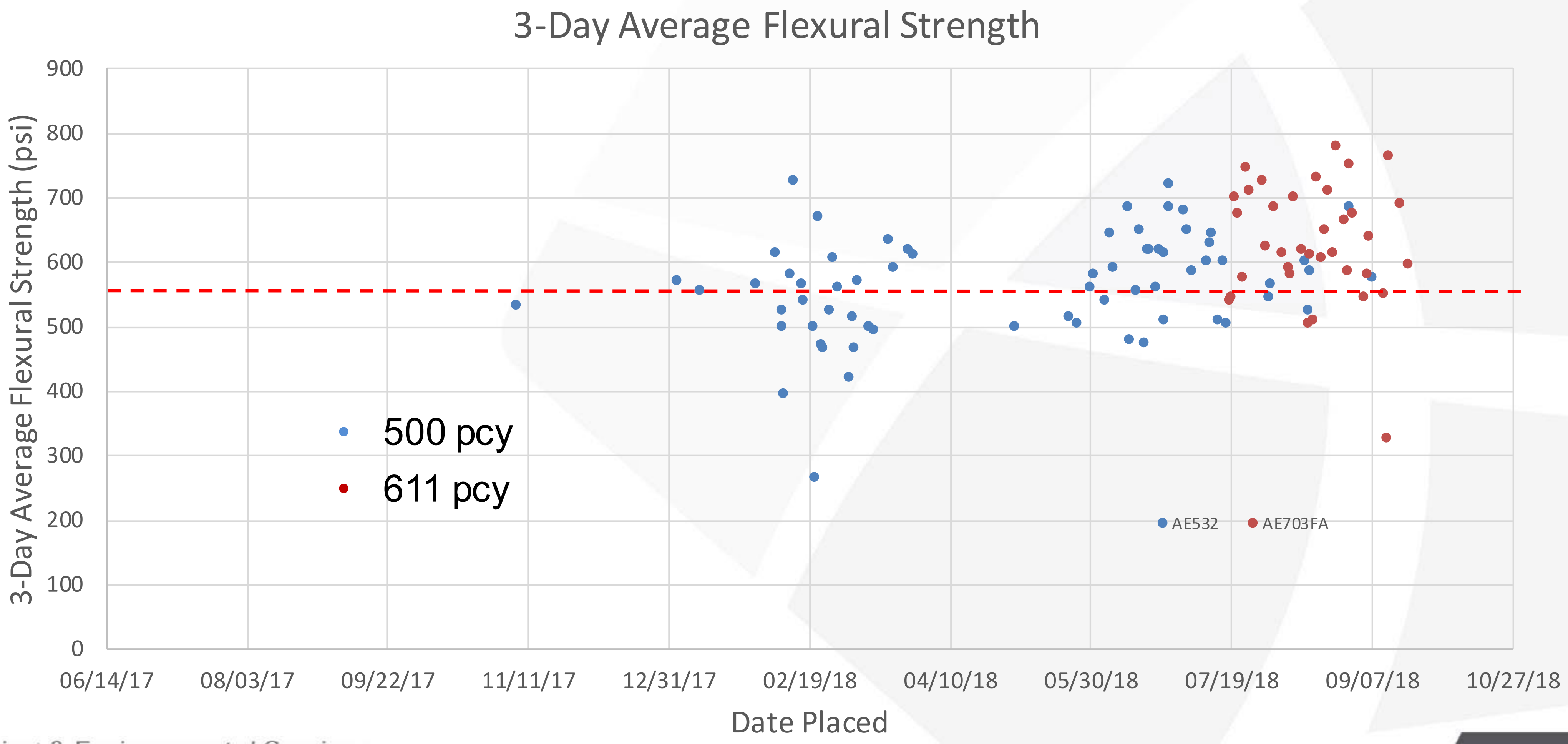
Key 3: Reduce Cementitious Content in Concrete

- Maximize aggregate content through use of optimized aggregate grading

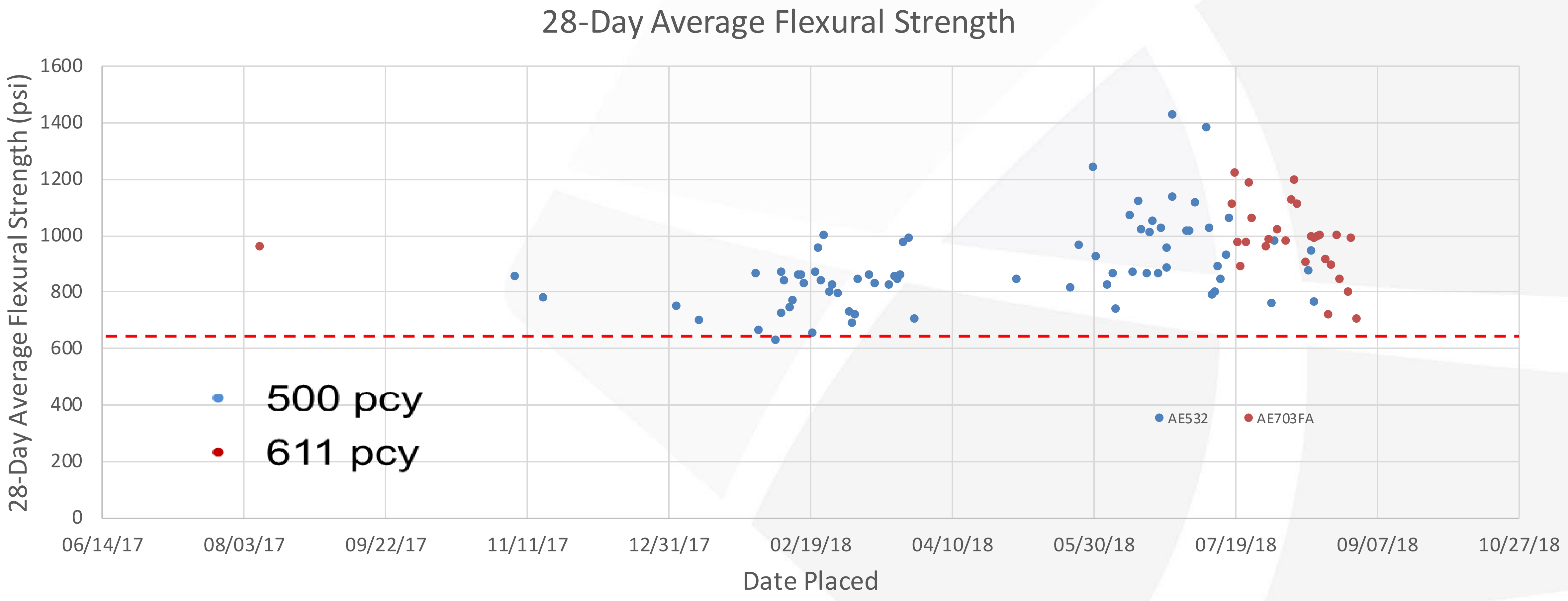


Tarantula curved based on Tyler Ley et al.

Reducing Cement Content in Mixture - Real Data from Project NEON in Las Vegas

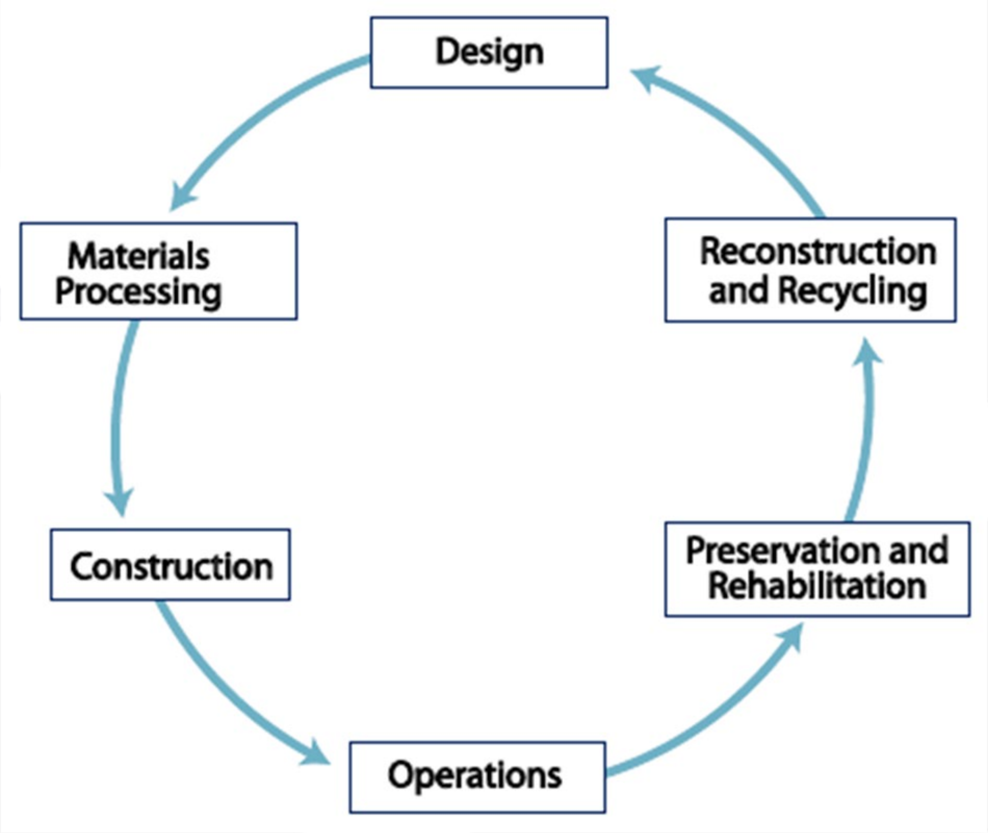


Reducing Cement Content in Mixture - Real Data from Project NEON in Las Vegas



Reducing Carbon Footprint Over the Life Cycle

- This is critically important to the concrete pavement industry
  - Far less important to most of our clients
- Important elements include:
  - Long-lasting, durable concrete pavements
  - Maintaining ride quality through design, durability, and diamond grinding to reduce vehicle-pavement interaction (VPI)
  - Carbonation - GHG emissions associated with diamond grinding are largely offset by increased carbonation



Diamond Grinding Increases Carbonation

- Rate of carbonation decreases with time
  - Roughly 45% of 50 years of carbonation occurs by year 10
- Diamond grinding exposes “fresh”, uncarbonated surface to the atmosphere
- Grinding every 10 years will more than double the amount of sequestered CO_2
  - About equal to GHG emissions incurred due to diamond grinding

Assessing Sustainability

- Use unbiased, factually-based tools/resources to assess life cycle impacts
  - There is A LOT of greenwashing going on
- A life cycle assessment (LCA) meeting ISO standards is the best way to assess environmental impact
  - Request environmental product declarations (EPDs) based on approved product category rules (PCR)
  - Stay informed
  - Seek help as needed

Example: Concrete EPD

Summary of Environmental Product Declaration	
Central Concrete	
Mix 340PG9Q1	
San Jose Service Area	
EF V2 Gen Use P4000 3" Line 50% SCM	
Performance Metrics	
28-day compressive strength	4,000 psi
Slump	4.0 in

Environmental Impacts

Impact name	Unit	Impact per m3	Impact per cyd
Total primary energy consumption	MJ	2,491	1,906
Concrete water use (batch)	m3	6.66E-2	5.10E-2
Concrete water use (wash)	m3	8.56E-3	6.55E-3
Global warming potential	kg CO2-eq	271	207
Ozone depletion	kg CFC-11-eq	5.40E-6	4.14E-6
Acidification	kg SO2-eq	2.26	1.73
Eutrophication	kg N-eq	1.31E-1	1.00E-1
Photochemical ozone creation	kg O3-eq	46.6	35.7

A sample EPD for a concrete mix design by Central Concrete Supply Co.

Credit: Central Concrete Supply

https://www.fhwa.dot.gov/pavement/sustainability/articles/environmental.cfm

Summary

- Sustainable concrete pavement practices are available for all phases of life
- Sustainable solutions require a life cycle perspective
  - Evaluating cradle to construction only will result in short-sighted decisions
  - Unfortunately, this is where most clients presently reside
- Strive to optimize your cement and concrete
- Use rigorous verification to avoid “greenwashing”

Questions?

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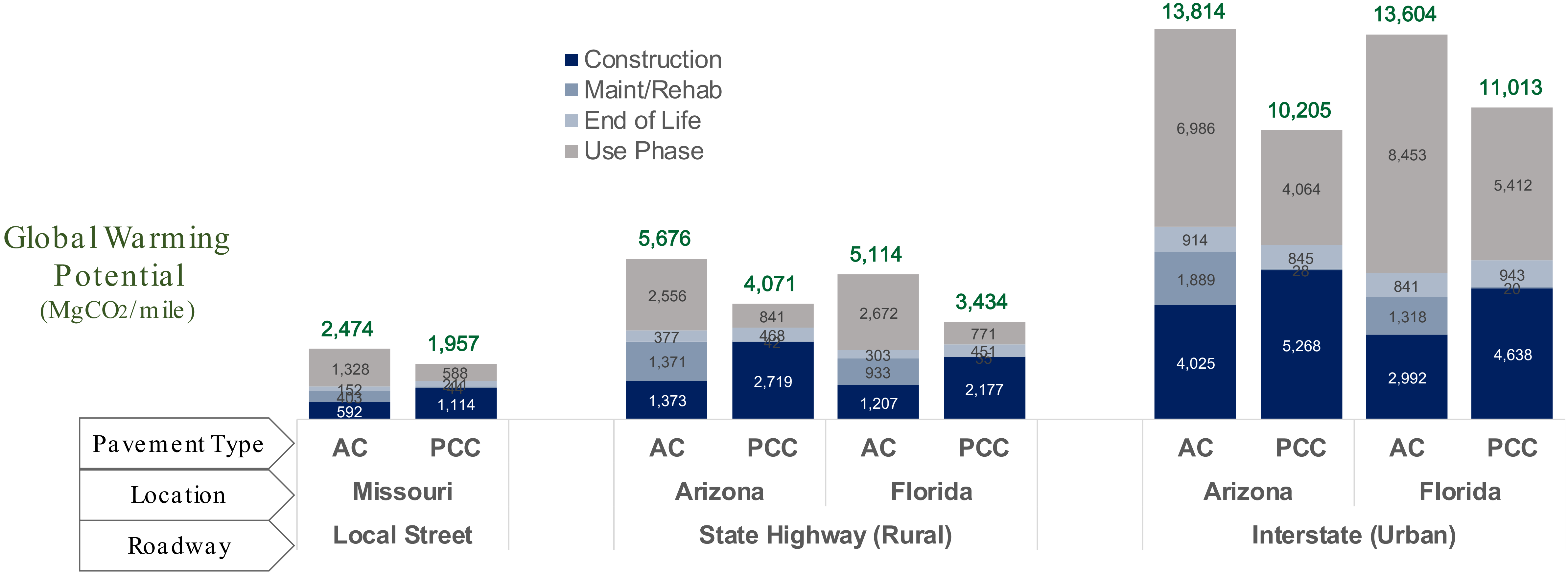
Climate Change Impacts and Resiliency in New and Rehabilitated Concrete Pavements

TRB Webinar Series:
Sustainable, Resilient, and Durable Concrete Pavements

May 26, 2022

Most CO2 improvement discussion are about reducing the "Embodied Emissions" of the Pavement

A Pavement's environmental impacts are dominated by rehabilitation activities & the "Use Phase"



Meaningful CO2 reductions can come from optimizing Pavement Designs and managing them to reduce the Use Phase Emission.

- MIT Concrete Sustainability Hub. *Scenario Analysis of Comparative Pavement Life Cycle Assessment Using a Probabilistic Approach* and *Supplementary Information for Comparative Pavement Life Cycle Assessment and Life Cycle Cost Analysis*
- Total GWP by phases for 1 mile of pavement with Design life = 30 years and analysis period = 50 years.
- Use phase includes Pavement Vehicle interaction (Fuel efficiency) and Albedo

Strategies to Lower a (Concrete) Pavement's Life Cycle CO_2

- **Optimizing Designs**
  Concrete's durability reduces future rehabilitation and reconstruction activities.
  Concrete's strength and resiliency allows it to withstand storms, fires and other natural disasters.

- **Improving Resilience and Durability**
  Concrete's strength and resiliency allows it to withstand storms, fires and other natural disasters.
  Concrete's durability reduces future rehabilitation and reconstruction activities.

- **Improving Fuel Efficiency**
  Fuel consumption of trucks on concrete is improved because concrete pavements are stiffer and stay smoother longer.

- **Increase the Pavement's Albedo**
  Concrete's light color and higher albedo increases Radiative Forcing Impacts & lowers Urban heat Island impacts

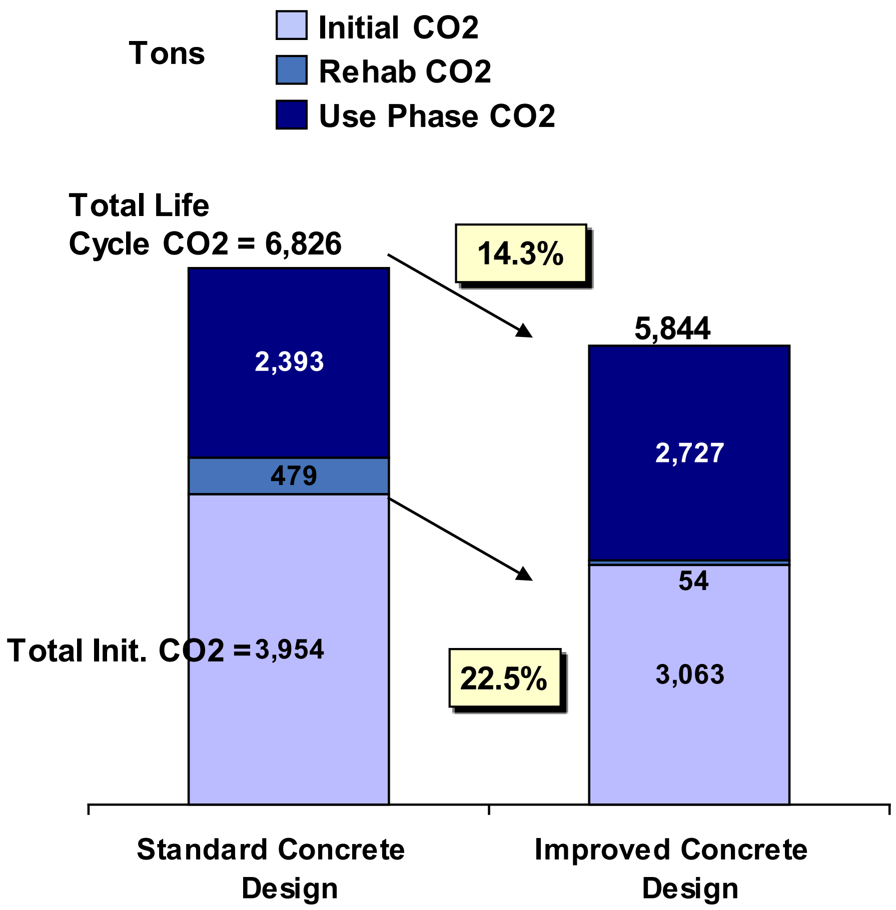
- **Take advantage of Carbonation**
  Carbonation is the reabsorption CO2 into concrete. Once absorbed, CO2 cannot be re-released, which reduce Concrete's overall CO2

Optimizing Pavement Designs

Concrete pavements have historically been “over - designed”

Optimizing can remove “over design” to lowers the Environmental Impact of the Pavement System

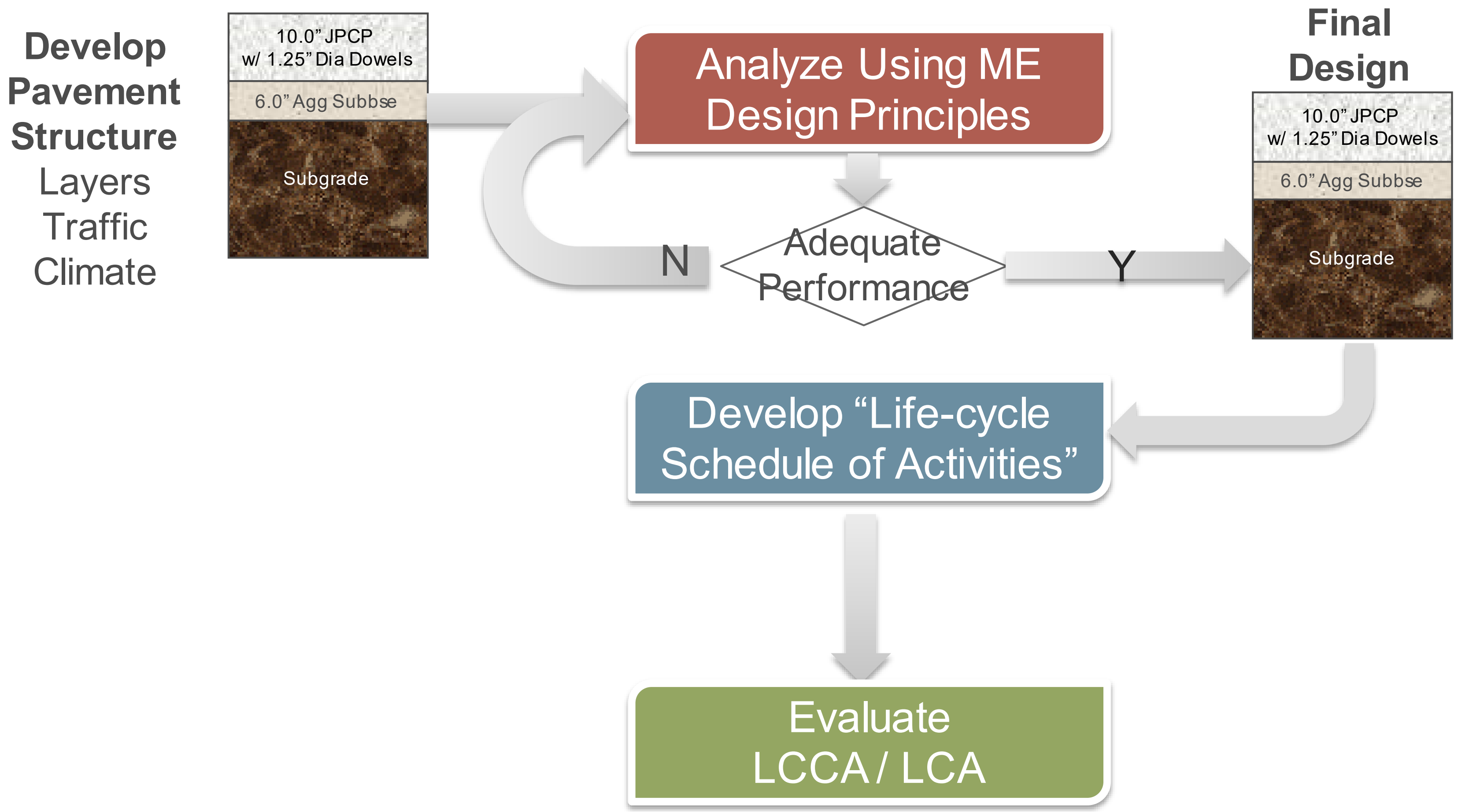
Lower Initial and Long Term CO_2 Emissions



Optimizing designs brings value to the project

Currently LCA is Used in a Comparative Mode

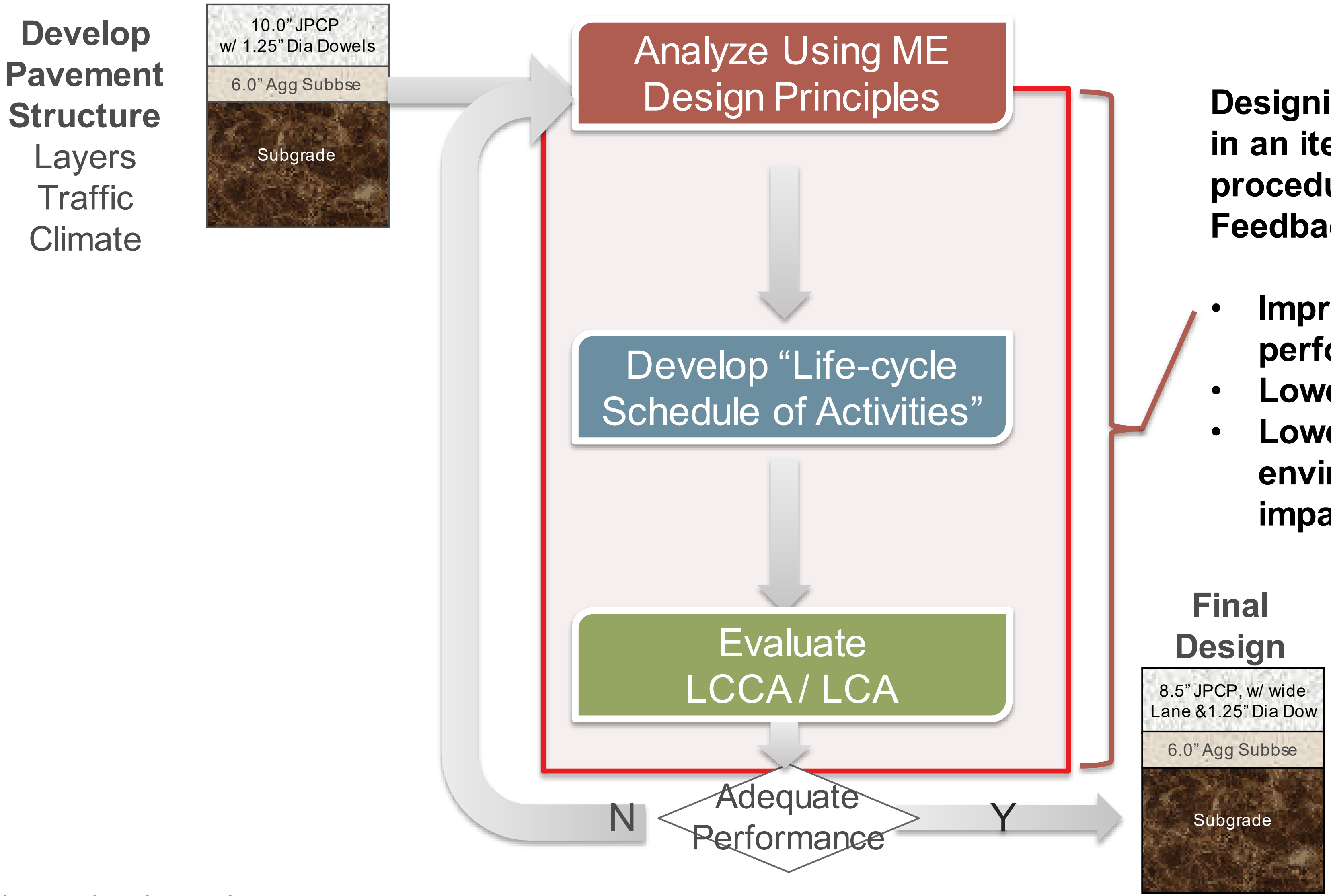
Concrete and asphalt designs are developed, the final pavement design selected, then evaluated



Doing a LCA at the end of the process means it is too costly to make design changes

Incorporating LCA into the Design Process Allows Changes to be Made

Creates a link between design and life cycle evaluation in an iterative process to lower CO2



Designing pavements in an iterative procedure provides a Feedback Loop

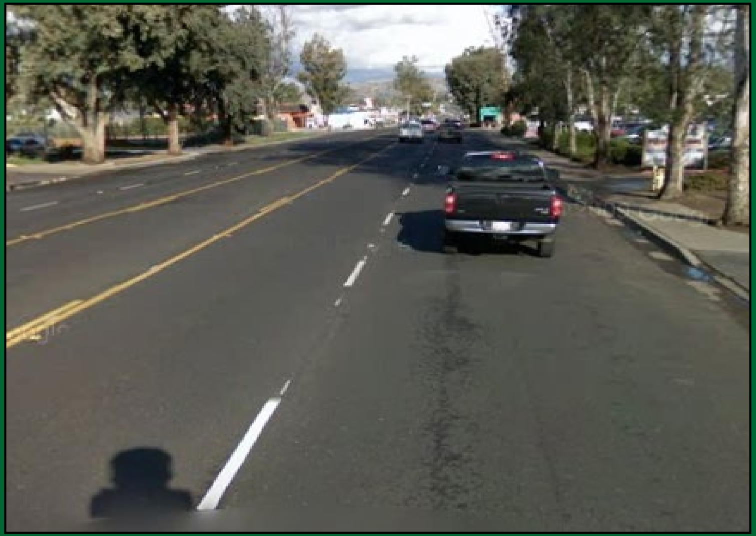
- **Improves performance**
- **Lowers cost**
- **Lowers environmental impacts**

Slide: Courtesy of MIT Concrete Sustainability Hub

Example:

Route 67 in Ramona, CA

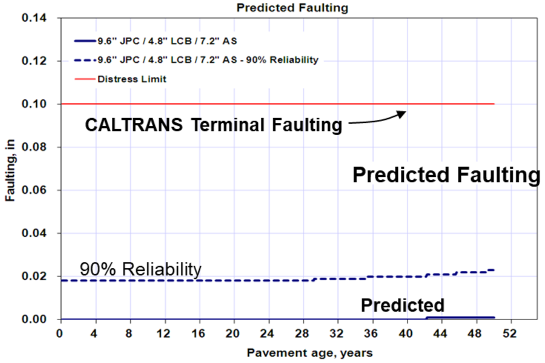
- Moderate volume road:
- 35 mph urban road
- Daily traffic: 23,400 (ADTT = 1,357)
- Initial ESAL = 335,000 / year



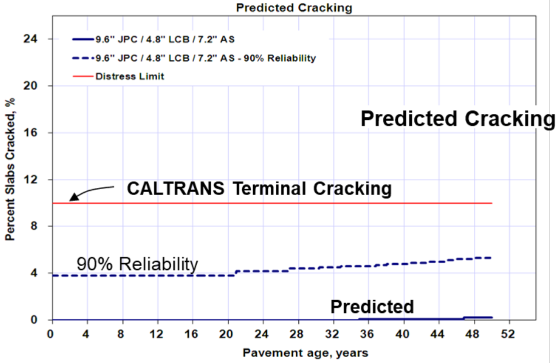
CALTRANS Concrete Design

	LCA (tons CO2e/mile)
Initial Const.	**3,954**
Pavement	*2,860*
LCB	*781*
Agg Subbase	*313*
Rehabilitation	**479**
Carbonation	**(123)**
PVI-Deflection	**604**
PVI-Roughness	**1,912**
Total	**6,826**

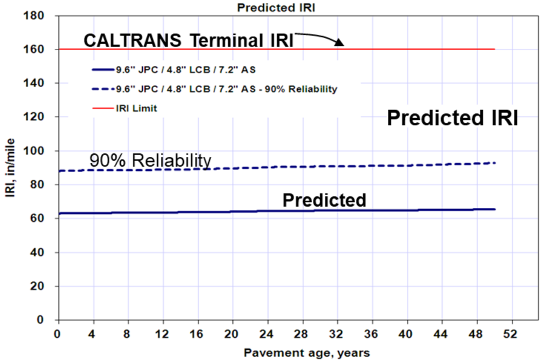
Faulting



Cracking



IRI

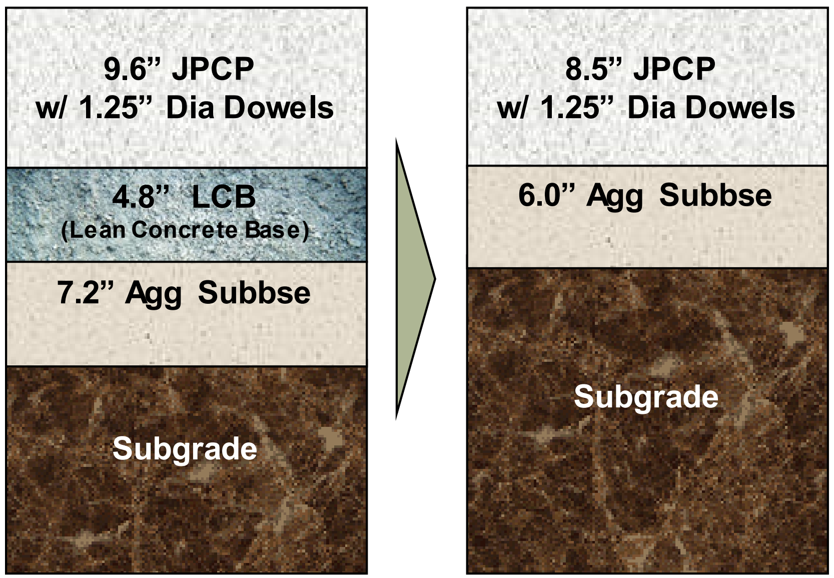


Highw ay Design Manual 6th Ed. Sacramento: California Department of Transportation, CALTRANS, 2010.
Life-Cycle Cost Analysis Procedures Manual. Sacramento, CA: California Department of Transportation, CALTRANS, 2010.

Optimizing Opportunities to Lower Environmental Impact

Each design feature needs need to balance performance, cost & environmental impact

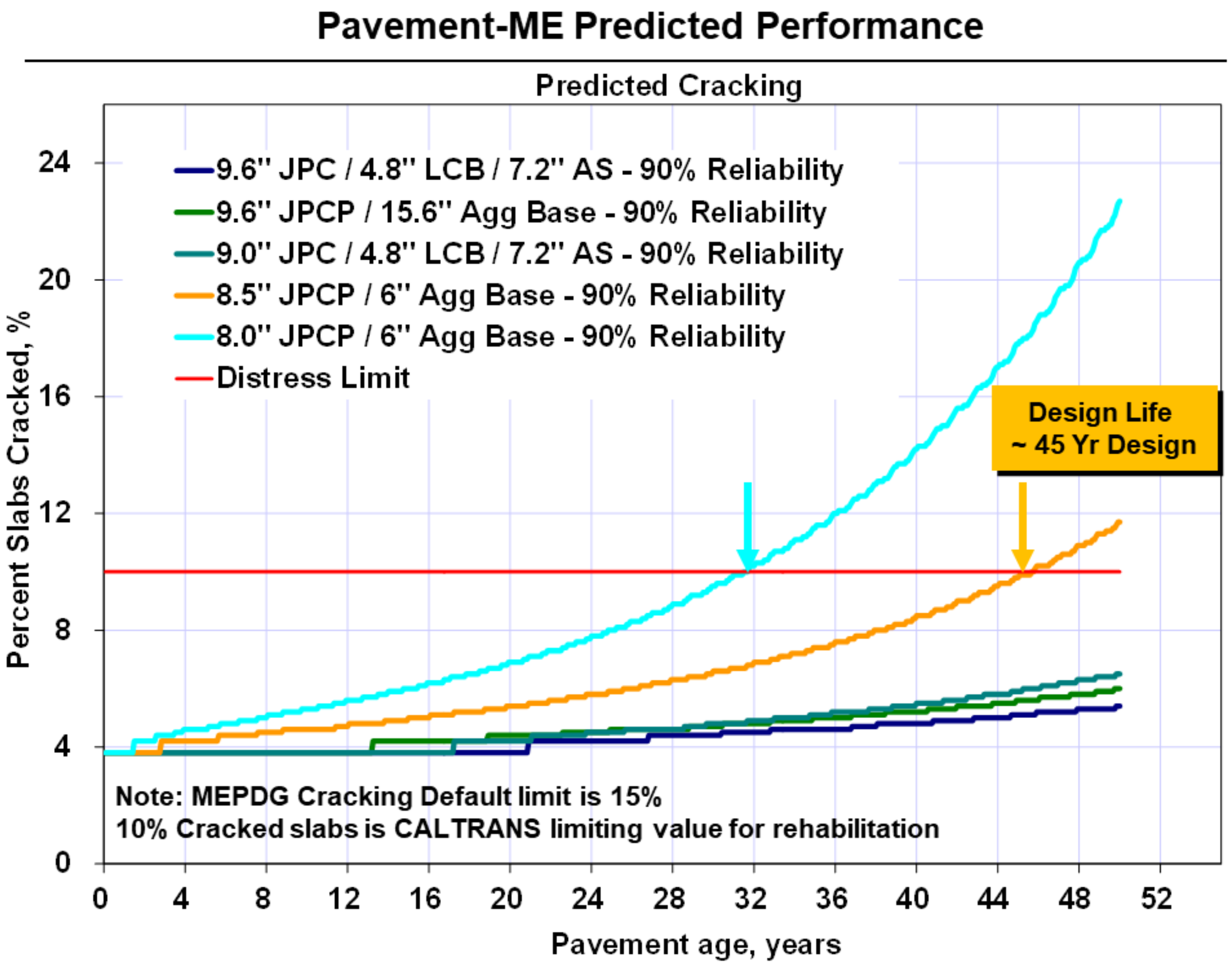
CALTRANS Concrete Design | **Optimized Concrete Design**



Iterated Concrete Thickness
- 9.0”
- 8.5”
- 8.0

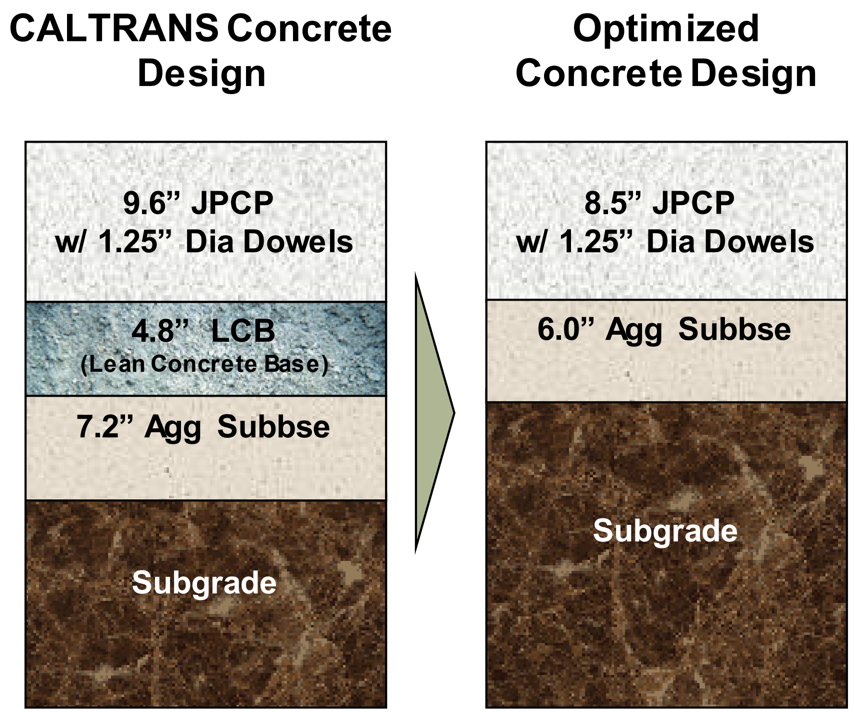
Removed 4.8” Lean Concrete Base
- Accounts for 20% of the initial CO_2

Iterated Aggregate base thickness



Optimizing Opportunities to Lower Environmental Impact

Each design feature needs need to balance performance, cost & environmental impact



	Original CALTRANS Design LCA (tons CO2e)	Optimized Design LCA (tons CO2e)
Initial Const.	**3,954**	**3,063**
Pavement	*2,860*	*2,803*
LCB	*781*	*--*
Agg Subbase	*313*	*260*
Rehabilitation	**479**	**54**
Carbonation	**(123)**	**(87)**
PVI-Deflection	**604**	**704**
PVI-Roughness	**1,912**	**2,110**
Total	**6,826**	**5,844**

Optimization reduced the initial construction GWP by 890 tons (22.5%) and the life cycle GWP by 980 tons (14.3%)

Resilience

The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions [1]

Deals with extraordinary events that have low probabilities but high impacts (loss due to flood, earthquake, etc) [2]

Flood

Fire

Storms

Source:
1. FHWA Order 5520: Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events
2. Adapted from Rodrigues and Perez, 2014

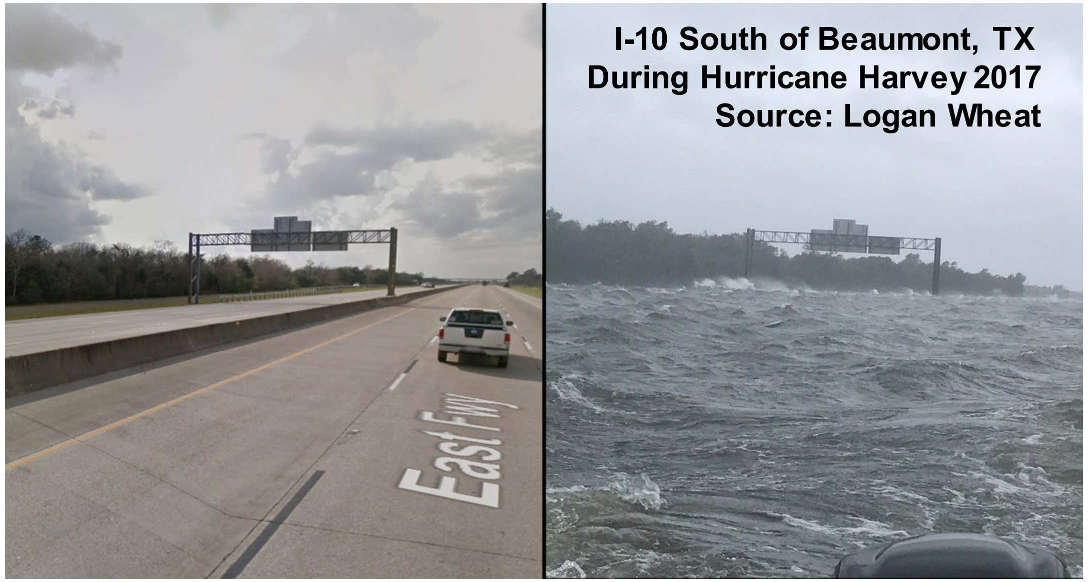
While Sustainability & Resilience Are Different ,

They are Related

A Resilient system is usually a Sustainable system

- Reduces future rehabilitation and reconstruction activities
  - Environmental savings
    - Reduced waste
  - Economic savings
    - Reduced reconstruction
  - Societal savings
    - Continued use

Concrete Pavements Stiffness & Resistance to Fire make It a More Resilient Pavement



Pavement Damage due to Car Fires

Not having to rebuild after storms & disasters saves CO2

Similarly, Increased Durability means Less Rehabilitation Activities, Less Traffic Congestion and Reduced CO2

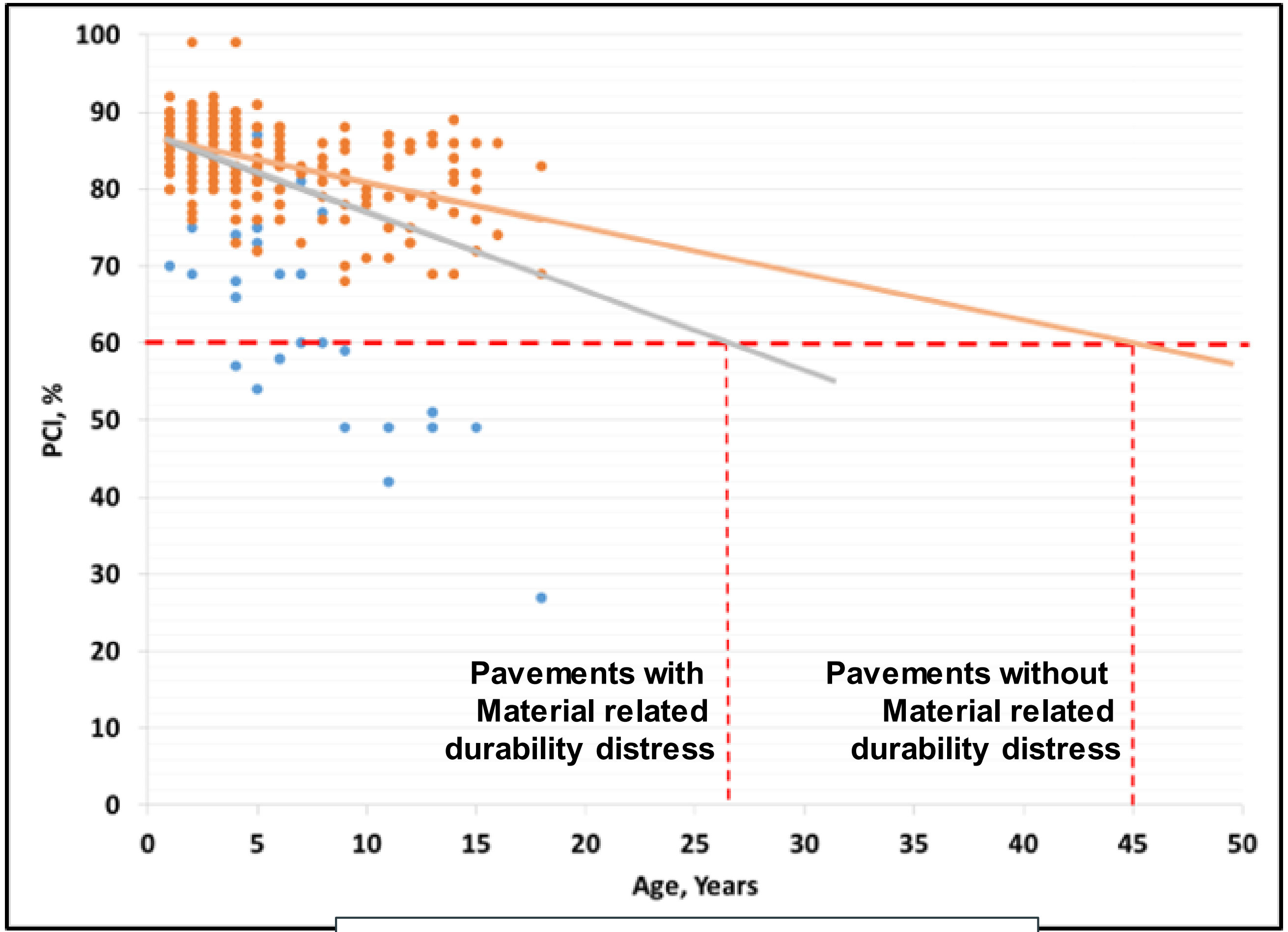
Concrete Overlay performance in Iowa has been excellent

- As a whole: approximately 35 years to PCI = 60
- Approximately 40 years to IRI = 170 in/mi

Poor performing outliers & early failure causes:

- Materials-related distresses (most common) (approximately 27 years to PCI = 60)
- Load-related/under-design
- Rough ride

Bonded Concrete Overlay of Asphalt

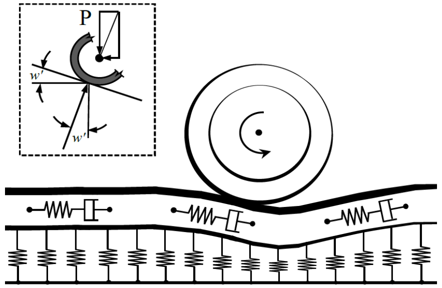


12 ft Joint Spacing, less than 20 years old

Pavement Vehicle Interaction Impacts the Excess Fuel Usage (EFC)

- **Pavement texture:**
  - **The micro-surface of the pavement “grabs” the tire, which increases friction and lowers fuel efficiency.**
  - **Tire industry. Critical for safety. Tire-pavement contact area**

- **Roughness/smoothness*:**
  - **Higher roughness “bounces” the cars and increases fuel usage**
  - **Absolute value = vehicle dependent.**
  - **Changes / evolves over time: material specific**



- **Deflection/dissipation induced PVI**:**
  - **Vehicle deflects the pavement and vehicle drives up a hill**
  - **Pavement Design Parameters (materials, stiffness & thickness) matter**
  - **Speed and temperature dependent, especially for inter-city pavement systems**

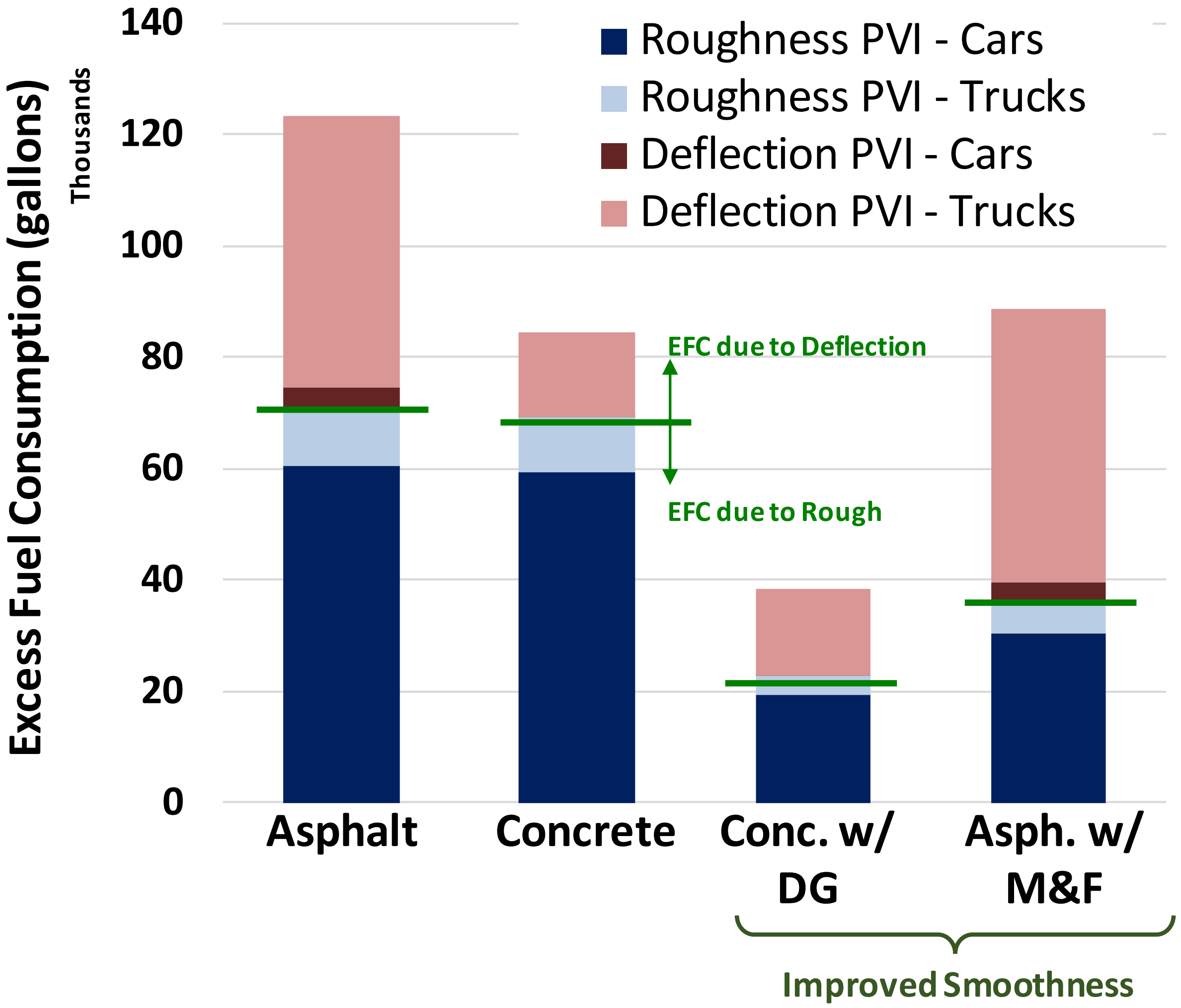
*Zaabar, I., Chatti, K. 2010. Calibration of HDM-4 Models for Estimating the Effect of Pavement Roughness on Fuel Consumption for U.S. Conditions. Transportation Research Record: **Journal of the Transportation Research Board**, No. 2155. Pages 105-116.

** Akbarian M., Moeini S.S., Ulm F-J, Nazzal M. 2012. Mechanistic Approach to Pavement-Vehicle Interaction and Its Impact on Life-Cycle Assessment. Transportation Research Record: **Journal of the Transportation Research Board**, No. 2306. Pages 171-179.

Strategies to lower PVI / EFC of a pavement system

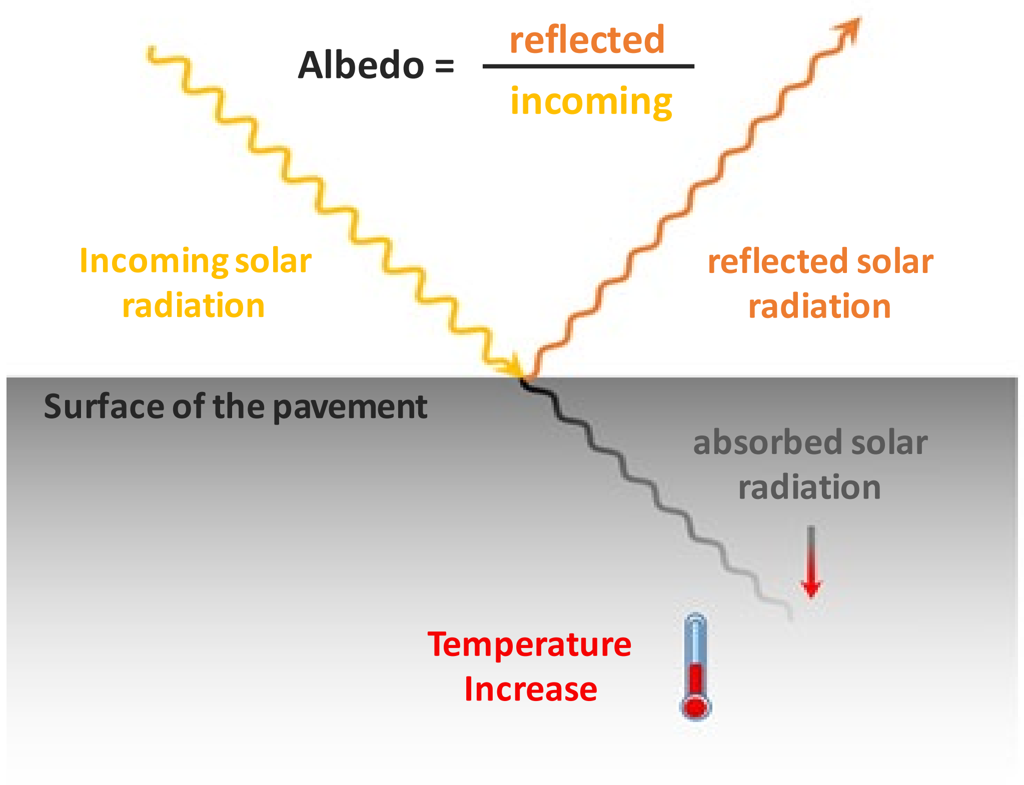
Strategies

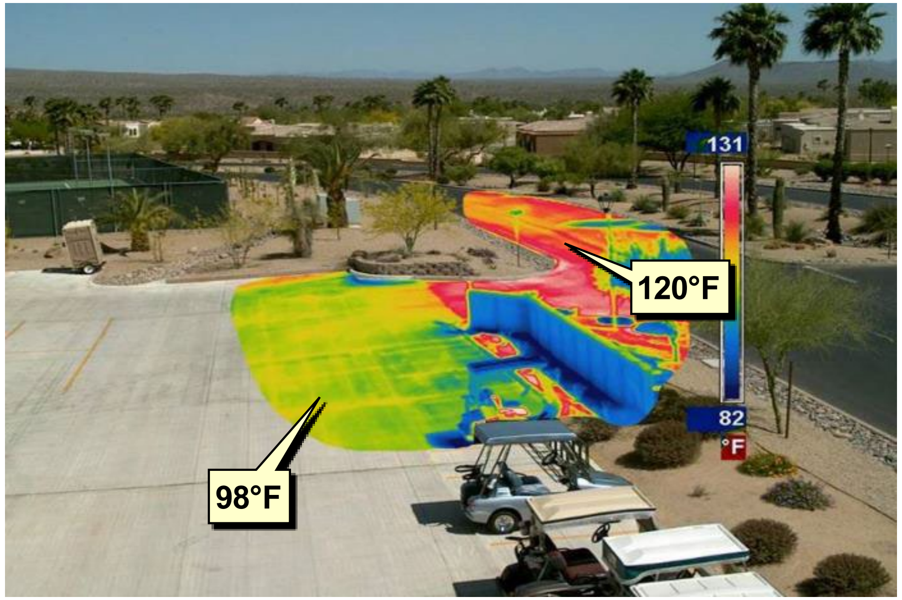
1. Build & Maintain Smoother Pavements
   - Improved Maintenance activities that keep a Pavement smooth over its lifetime
   - Build Pavements that stay smoother longer
2. Build "Stiffer" Pavements
   - Concrete's inherent higher stiffness means it lower structural PVI impacts



Albedo – the measure of solar energy reflected by surface

Albedo is the measure of the fraction of solar energy reflected by surface.



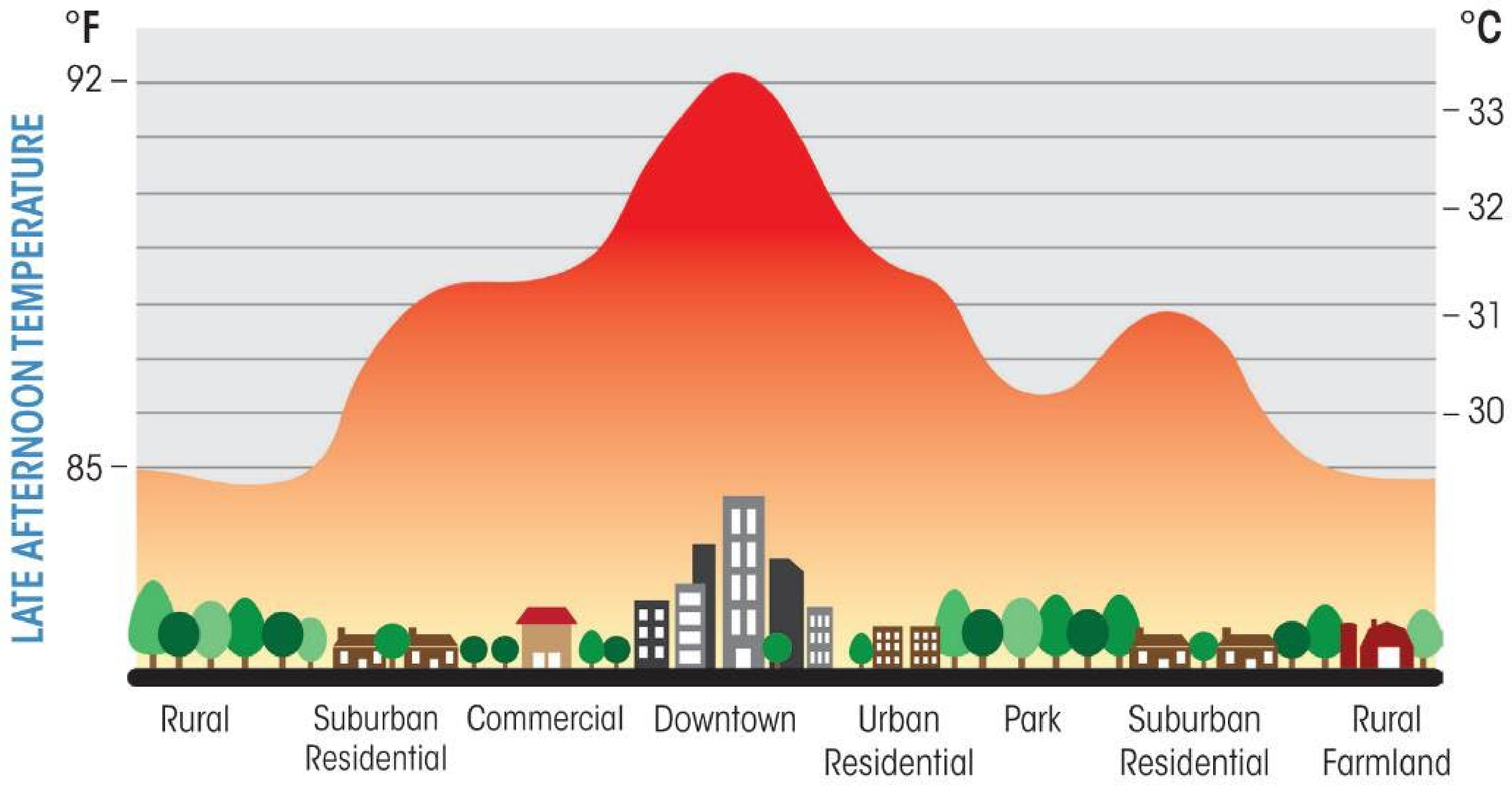


Albedo Values

- Concrete ≈ 0.40 (new) to 0.2 (old)
  Concrete with PLC &/or Slag ≈ 0.45 to 0.55
- Asphalt ≈ 0.05 (new) to 0.15 (old)
- Earth Avg ≈ 0.3 to 0.35

Concrete's high albedo reduces Urban Heat Island impacts

Example of Heat Island effect



Increasing pavement albedo by 0.20 (asphalt to concrete) can reduce city temperatures by :

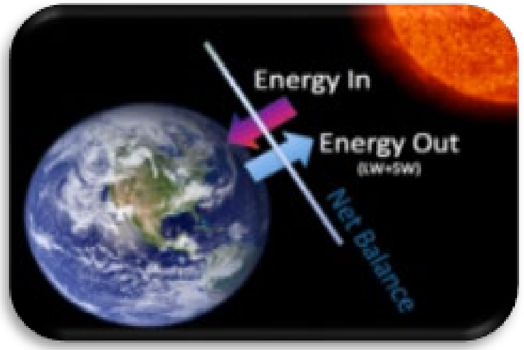
- 0.3° C (Boston)
- 2.1° C (Phx)

Sources:
http://www.cleanairpartnership.org/files/urbanheatisland.jpg
http://cshub.mit.edu/pavements/albedo

Increasing pavement albedo is meaningful and low -cost and low risk endeavor to address climate change

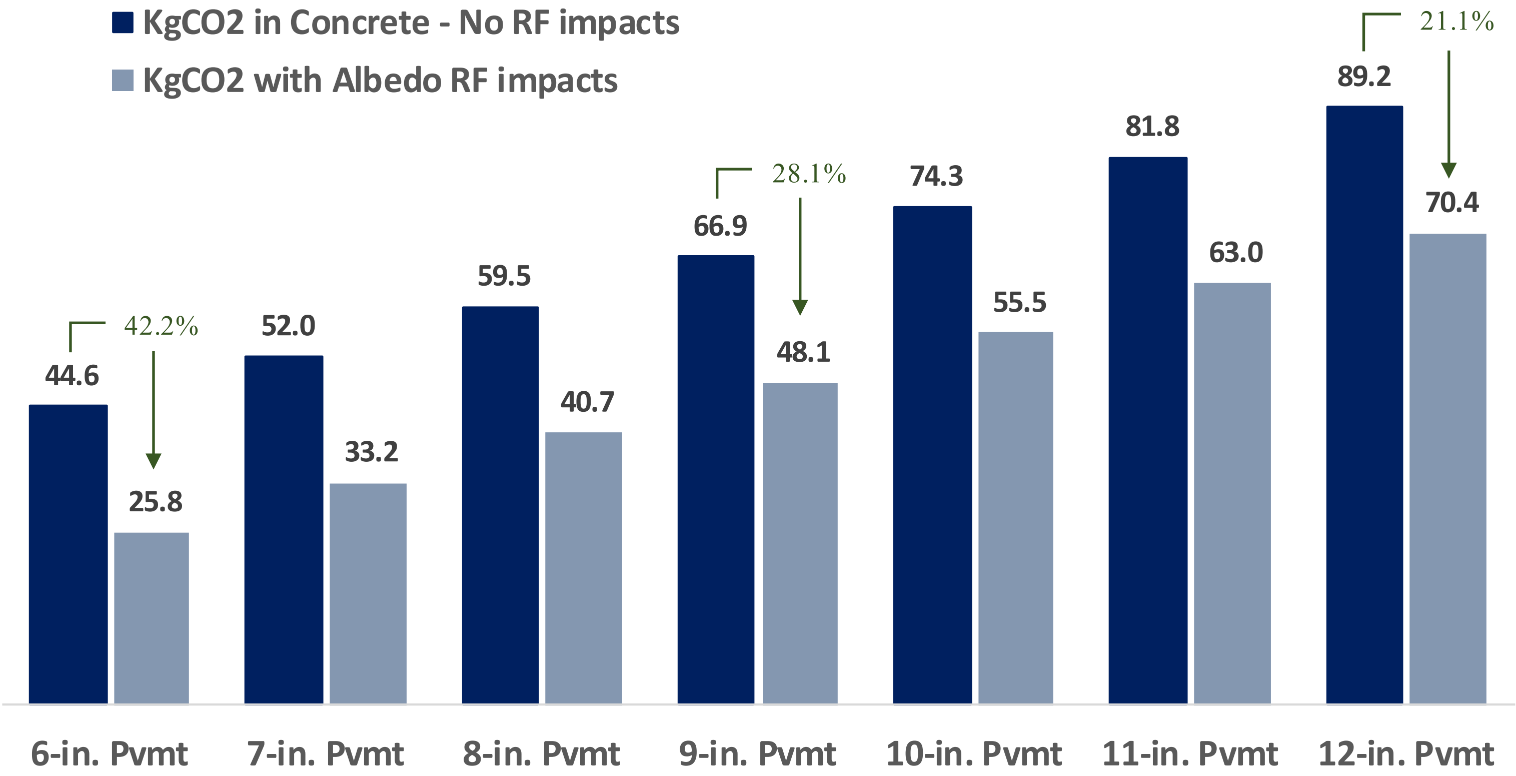
KgCO2 /SY of Pavement with & without RF Impacts

Earth's Energy Balance



Radiative forcing

Albedo improves the Earth's Energy Balance to create **Cooling Benefits**



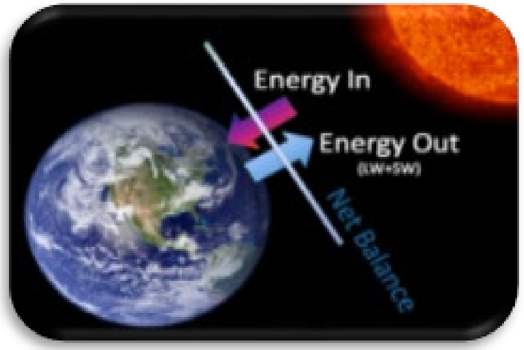
Over a 50-year period, albedo offsets 20% to 40% of the production CO2 for the cement used in pavements (depends on thickness)

Sources:
http://www.cleanairpartnership.org/files/urbanheatisland.jpg
http://cshub.mit.edu/pavements/albedo

Assumes 350 kgCo2 / 1 CM of concrete – NRMCA industry Average

Increasing pavement albedo is meaningful and low-cost and low risk endeavor to address climate change

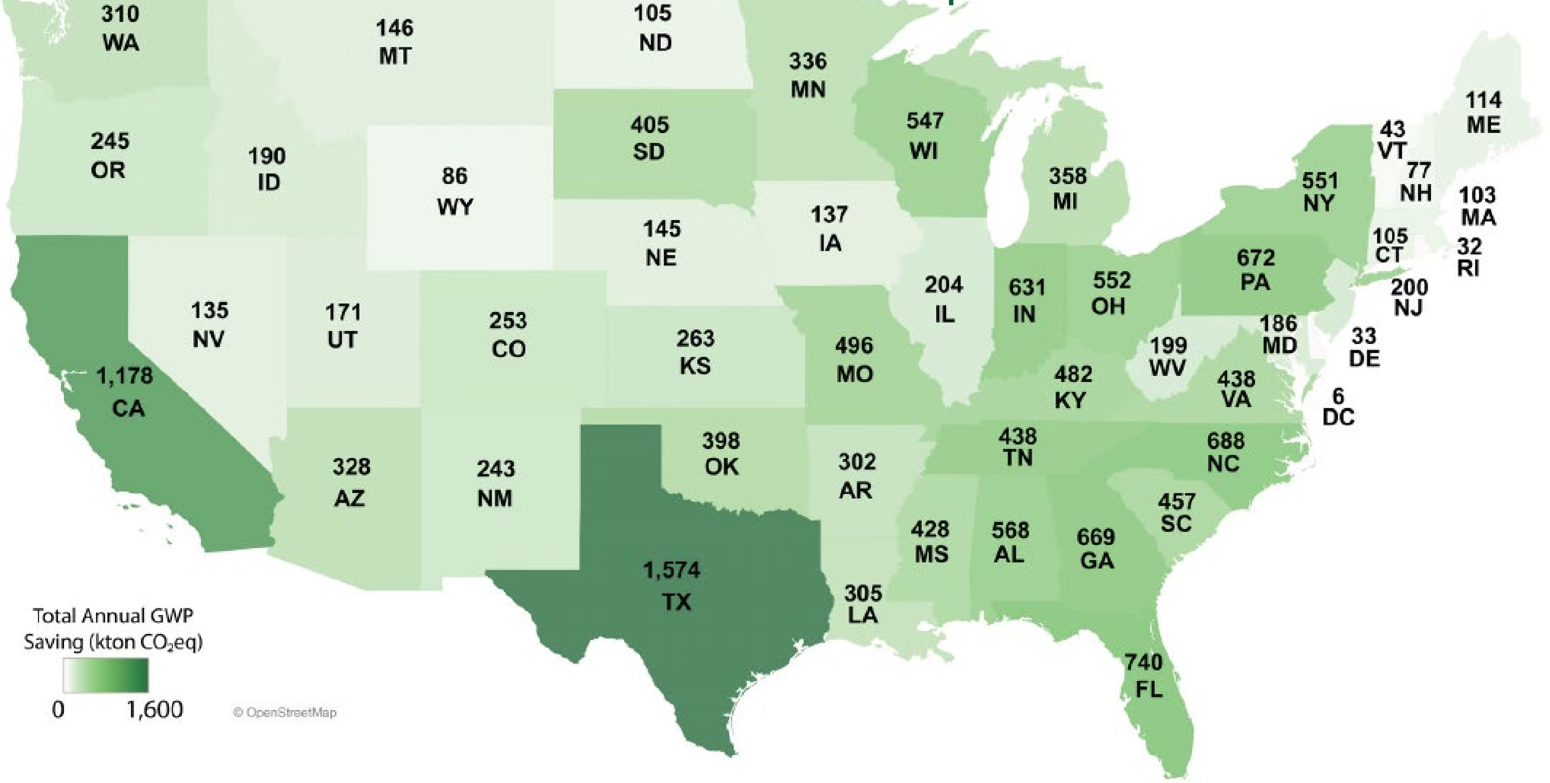
Earth's Energy Balance



Radiative forcing

Albedo improves the Earth's Energy Balance to create **Cooling Benefits**

Annual GWP savings due to increasing the surface reflectivity of all pavements across the continental U.S. (kton CO_{2eq})



An increase in pavement albedo on all U.S. roads would reduce CO2eq by 17.45 Mton per year due to radiative forcing—equivalent to ~ 4 million cars

Sources:
http://www.cleanairpartnership.org/files/urbanheatisland.jpg
http://cshub.mit.edu/pavements/albedo

Carbonation of Concrete

Carbonation is the reabsorption CO_2.

Calcium hydroxide in the concrete reacts with CO2 in the atmosphere and creates calcium carbonate and water

Once absorbed, CO_2 cannot be re-released

- Reduce Concrete's initial and overall CO_2

Concrete carbon uptake depends on:

- Concrete mix design
- Concrete exposure (surface area)
- Environmental conditions / climate

Rate of carbonation decreases with time

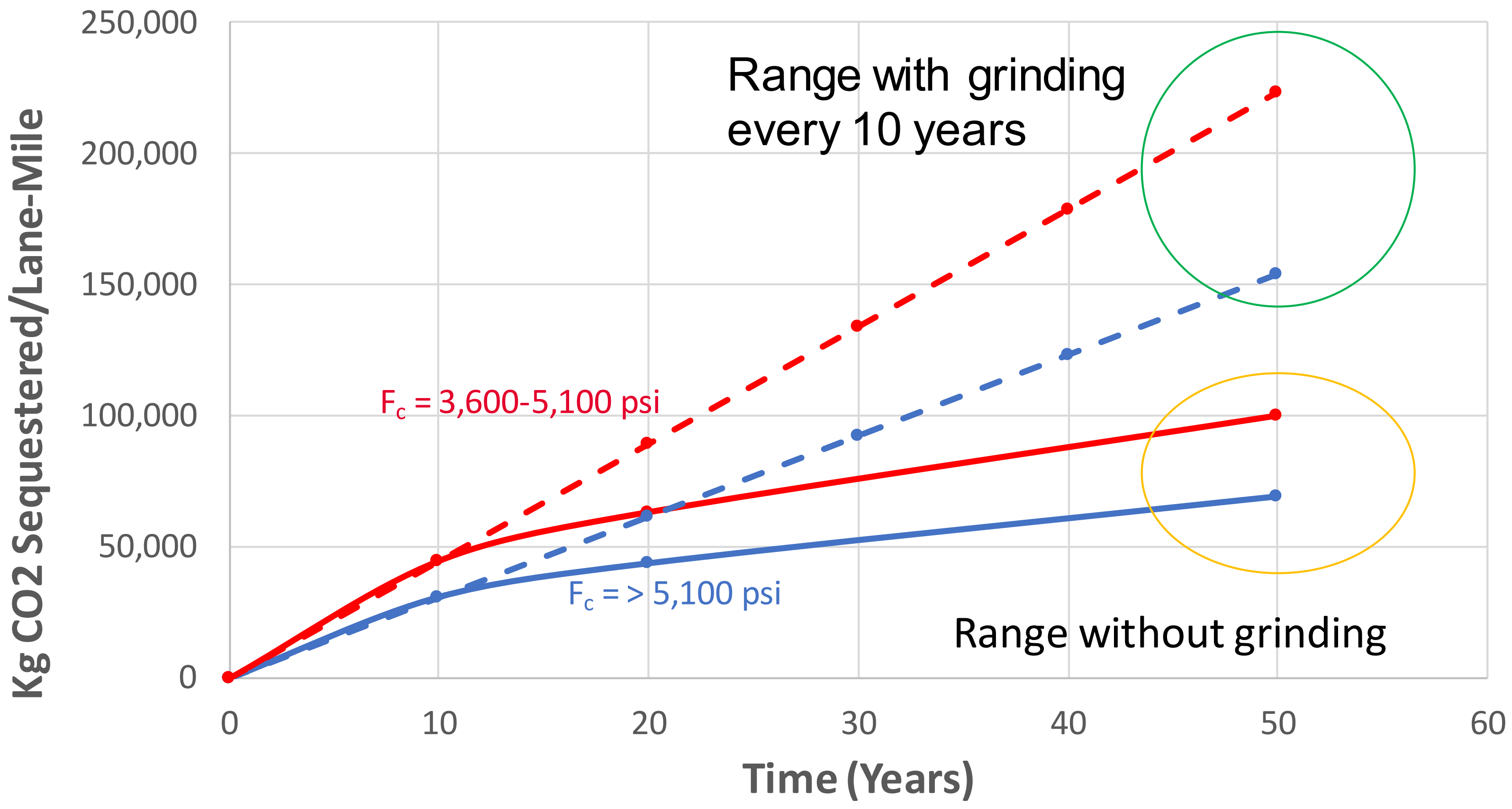
- Roughly 45% of 50 year of carbonation for concrete pavement occurs by Year 10

Punta Gorda Airport Apron Expansion

Source: Information courtesy of Tom Van Dam, NCE

Diamond Grinding exposes a “fresh” uncarbonated surface to the atmosphere

CO_2 Sequestered Over Time per Lane-Mile with Diamond Grinding



Source: Information courtesy of Tom Van Dam, NCE

Additional Diamond Grinding also improves vehicle fuel efficiency due to improved smoothness and increases Albedo resulting in even greater GHG reductions

Summary & Key Take-aways

1. **The cement and concrete industries worldwide are committed to combat climate change, but we cannot do it ourselves**
   - We need support from government, agencies, designers, engineers and all groups throughout the value chain

2. **There are a variety of levers already available to lower concrete's CO_2 emissions**
   - Portland Limestone Cement (Type 1L), Supplementary Cementitious Materials (SCMs), Alternative & Blended Cements / Clinkers, and Aggregate Optimization are just some examples

3. **In the built environment, we need to design the structures from a Life Cycle Perspective**
   - Cement & Concrete are not the end products.
   - Meaningful CO_2 reductions can come from optimizing Pavement Designs and minimizing the Use Phase Emission.
     - Concrete's strength, durability and resilience allow it to withstand storms, floods, and other natural disasters
     - These same properties also lower the operational and use phase impacts

Q&A

jamesw.mack@cemex.com

Example of New Concrete Pavement Construction Specifications to Meet Future Needs

May 26, 2022

TRB Webinar: Sustainable, Resilient, and Durable Concrete Pavements

Melissa Titherington, M.A.Sc., P.Eng.

Senior Concrete Engineer, Concrete Section

Engineering Materials Office (EMO)

Ontario Ministry of Transportation (MTO)

Presentation Overview

- Premature concrete pavement joint deterioration issue.
- Changes to concrete pavement specification to improve performance and longevity.
- Contract results using new specification.

Premature Joint Deterioration

Premature Joint Deterioration

- Premature joint deterioration 8 years after construction on Hwy 417.
- Many joints visibly deteriorated at the pavement surface.
- Cores revealed that many joints that appear to be intact, actually have signification levels of deterioration below the sealant.


CM 2 4 6 8
0 INCH 1 2 3


Core 9

Core 9


18


18

Are other MTO highways affected?

- Investigation to assess joint performance on other provincial highways.
- Cores taken from two other highways.
- The sections examined are not showing any signs of deterioration at the surface, but cores show that some freeze-thaw damage is occurring in the joint, although damage is less severe than Hwy 417.

Hwy 410 (Constructed in 2007) – Core 2A

Hwy 410 – Core 2A

Hwy 410 – Core 2A

Findings of Investigation

- Deterioration mechanism: freeze-thaw damage of critically saturated joints.
- Level of deterioration varies between contracts, and between stages of the same contract.

Contributing Factors

Marginal Quality of Concrete

- strength
- permeability
- air void system

Saturated Joints

- drainage, water not draining through the joint
- joint design

Changes to Concrete Pavement Specification to Improve Performance and Longevity

Changes to Concrete Pavement Specification

- Improved concrete properties
- New joint design for durability
- Smoother pavement
- Longitudinal grooving – less noise
- Better friction properties

Changes to Address Premature Joint Deterioration

- Concrete properties
- Joint design

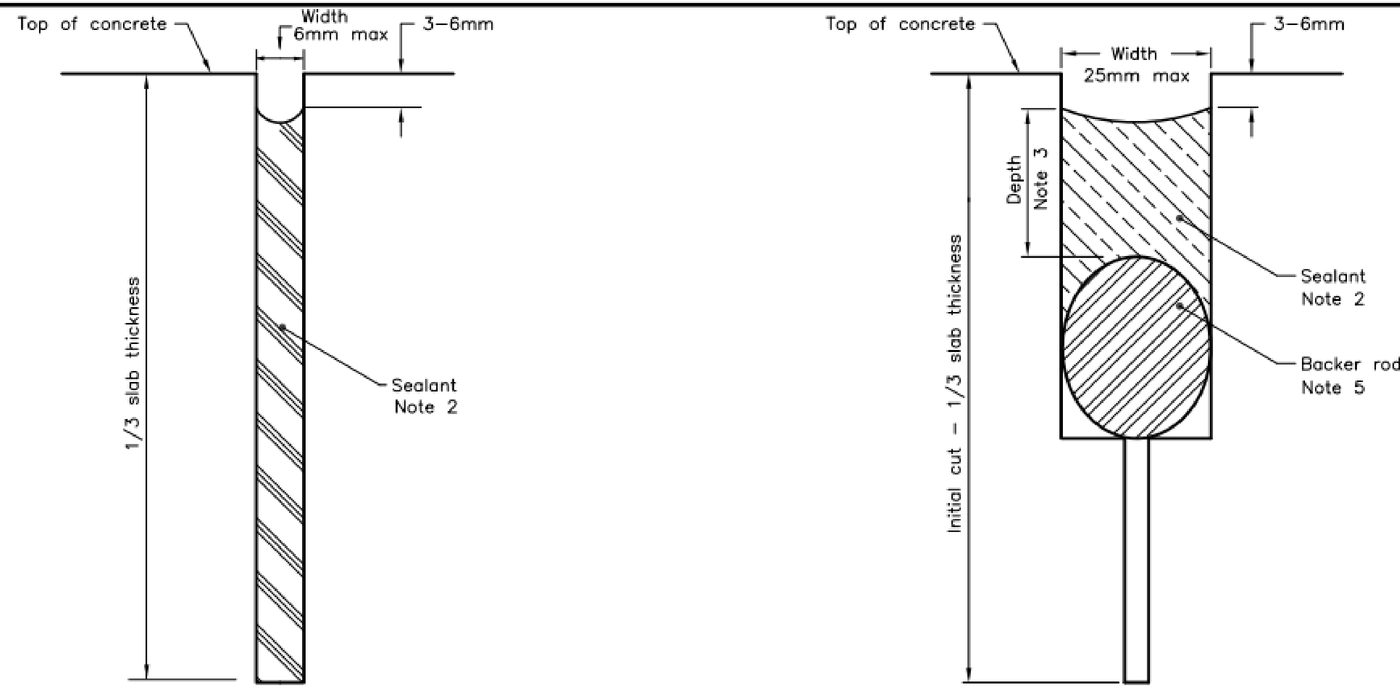
Changes to Concrete Properties

- **Compressive Strength** (28 day)
  30 MPa → 35 MPa

- **Rapid Chloride Permeability** (28 day)
  2500 coulombs (max)

- **Hardened Air Void System**
  - 3.0 % air content (min)
  - 0.230 mm spacing factor (max)

Changes to Joint Design



HOT POURED RUBBERIZED SEALANT –FULL DEPTH JOINT FILLING WITHOUT RESERVOIR CUT

NOTE 1

HOT POURED RUBBERIZED SEALANT – WITH RESERVOIR CUT

NOTE 4

NOTES:

1 Joint shall be completely filled to the bottom of the sawcut with sealant.
2 Sealant shall be hot poured rubberized joint sealing compound according to the Contract Documents.
3 Shape factor has a width to depth ratio of – 1H:1V for hot poured rubberized sealant.
4 Use for resealing existing joints with reservoir cut.
5 Backer rod according to the Contract Documents.

A Reservoir width design to accommodate anticipated slab movement.
B All dimensions are in millimetres unless otherwise shown.

MINISTRY OF TRANSPORTATION ONTARIO	Feb 2019	Rev	0
SEALING OR RESEALING OF JOINTS AND CRACKS IN CONCRETE PAVEMENT AND CONCRETE BASE	----------- -----------		
	MTOD 508.020		

QC → QA

- Owner Quality Assurance testing replaces Contractor Quality Control testing for acceptance, and referee processes added for measurement of:
  - Pavement Smoothness
  - Dowel Alignment (using MIT Scan)

Smoothness Measurement Equipment

- High Speed Inertial Profiler Replaces California Profilograph

- MTO Correlation Programme for Inertial Profilers to Measure Concrete Pavement

Smoother Pavement

MRI (m/km)	Sublot Payment Factors
≤ 0.500	1.200 (subject to Note 1 & 2 given below)
> 0.500 to 0.650	1.867 - (1.333 x MRI) (subject to Note 1 & 2 given below)
> 0.650 to 1.000	1.000
> 1.000 to 1.250	2.200 - (1.200 x MRI)

Notes:

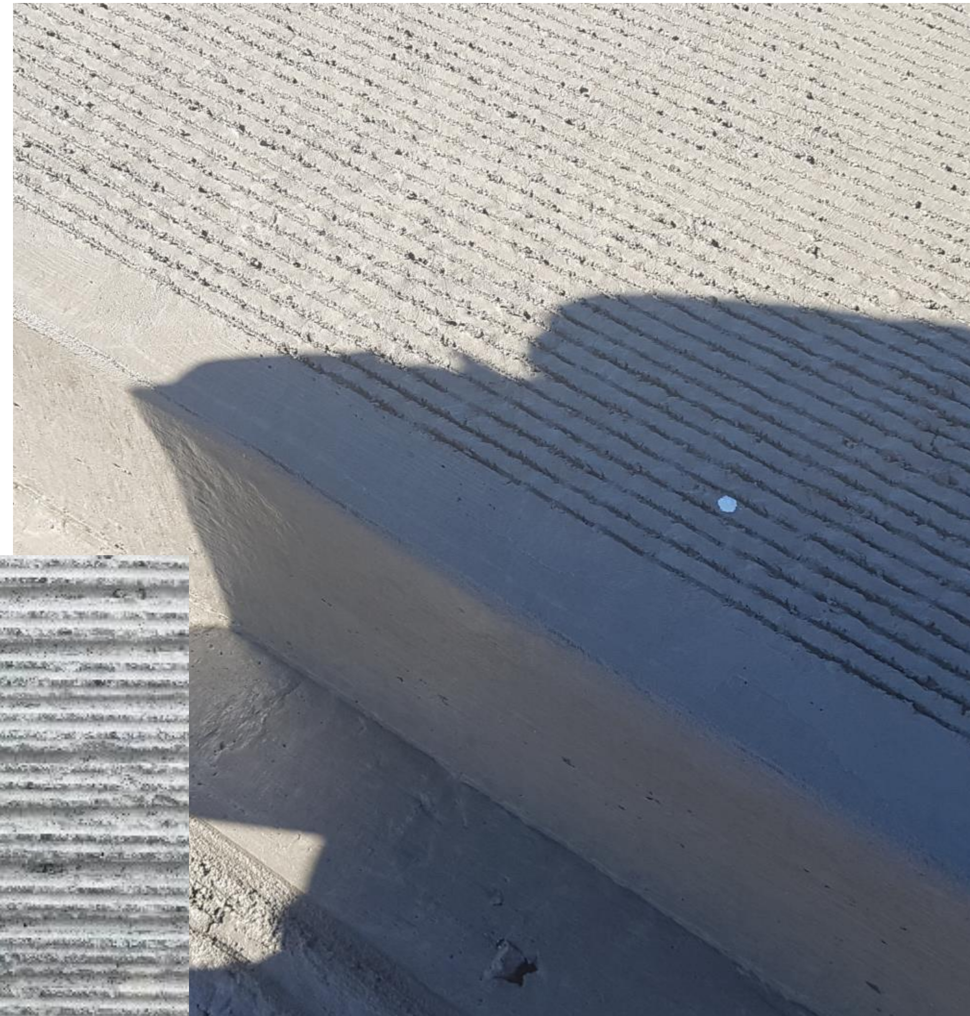
1. The payment factor shall not exceed 1.000 for subsequent MRI measurements which are taken after repairs regardless of the reason for the repairs.
2. The payment factor for concrete base shall not exceed 1.000.

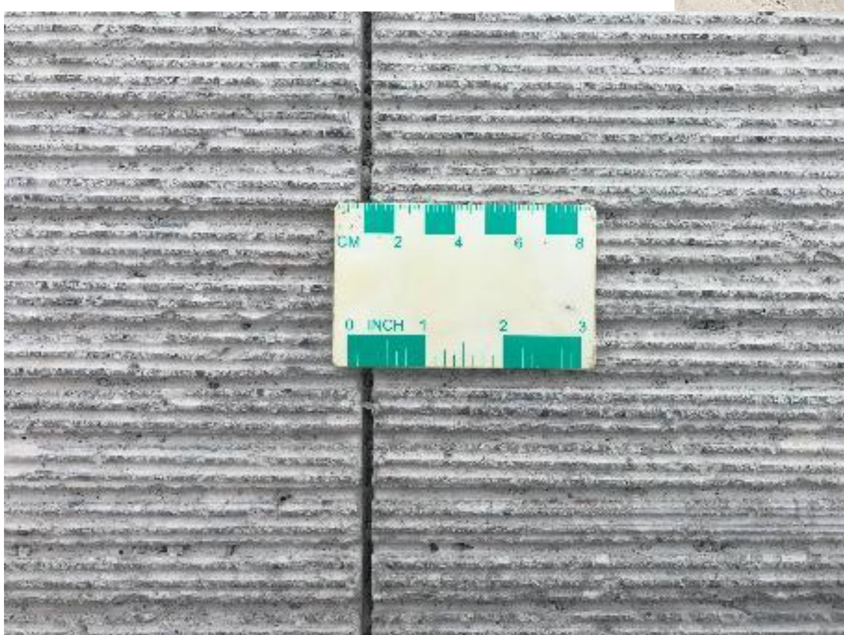
Better Friction

- Fine aggregate shall have a minimum insoluble residue content of 60%.
- Acid insoluble residue testing that restricts the carbonate content of fine aggregate is used by many transportation agencies as an indicator of aggregate suitability for pavement frictional performance.

Quieter Pavement → Grooving

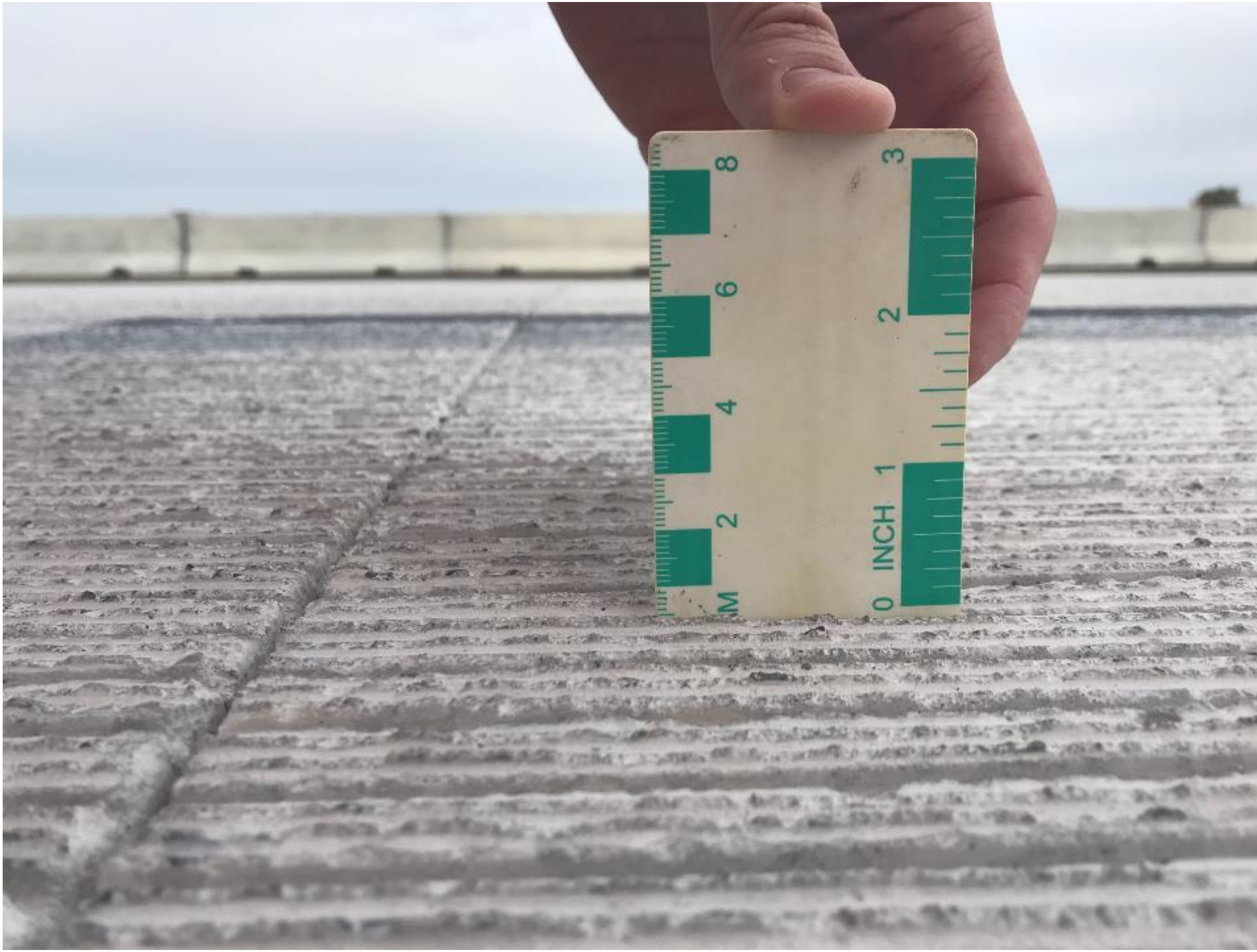
- Longitudinal grooving of hardened concrete replaces transverse tining of plastic concrete.



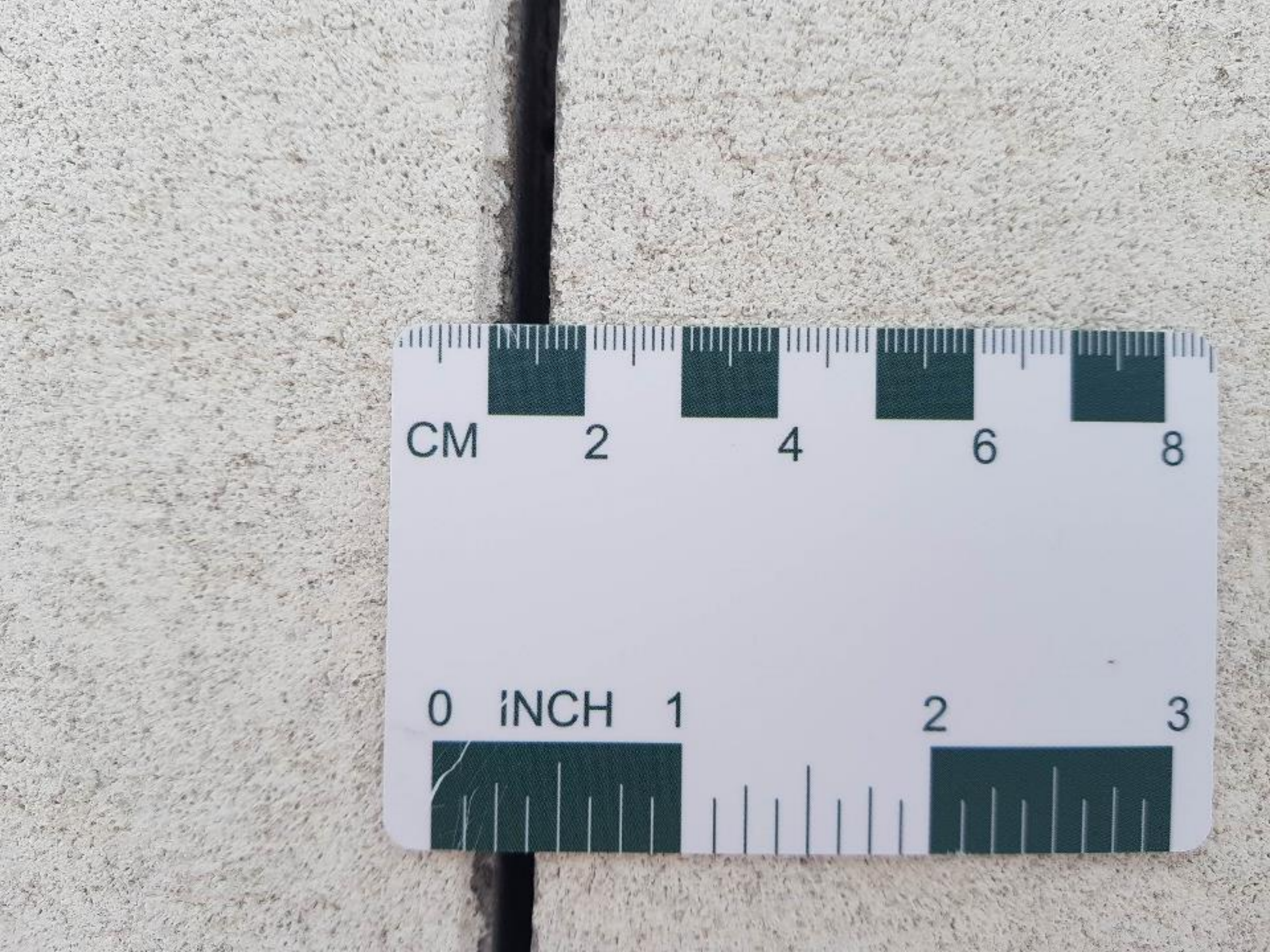


Contract Results With New Concrete Pavement Specification


CHESTER


INCH


8
6
4
3
2
1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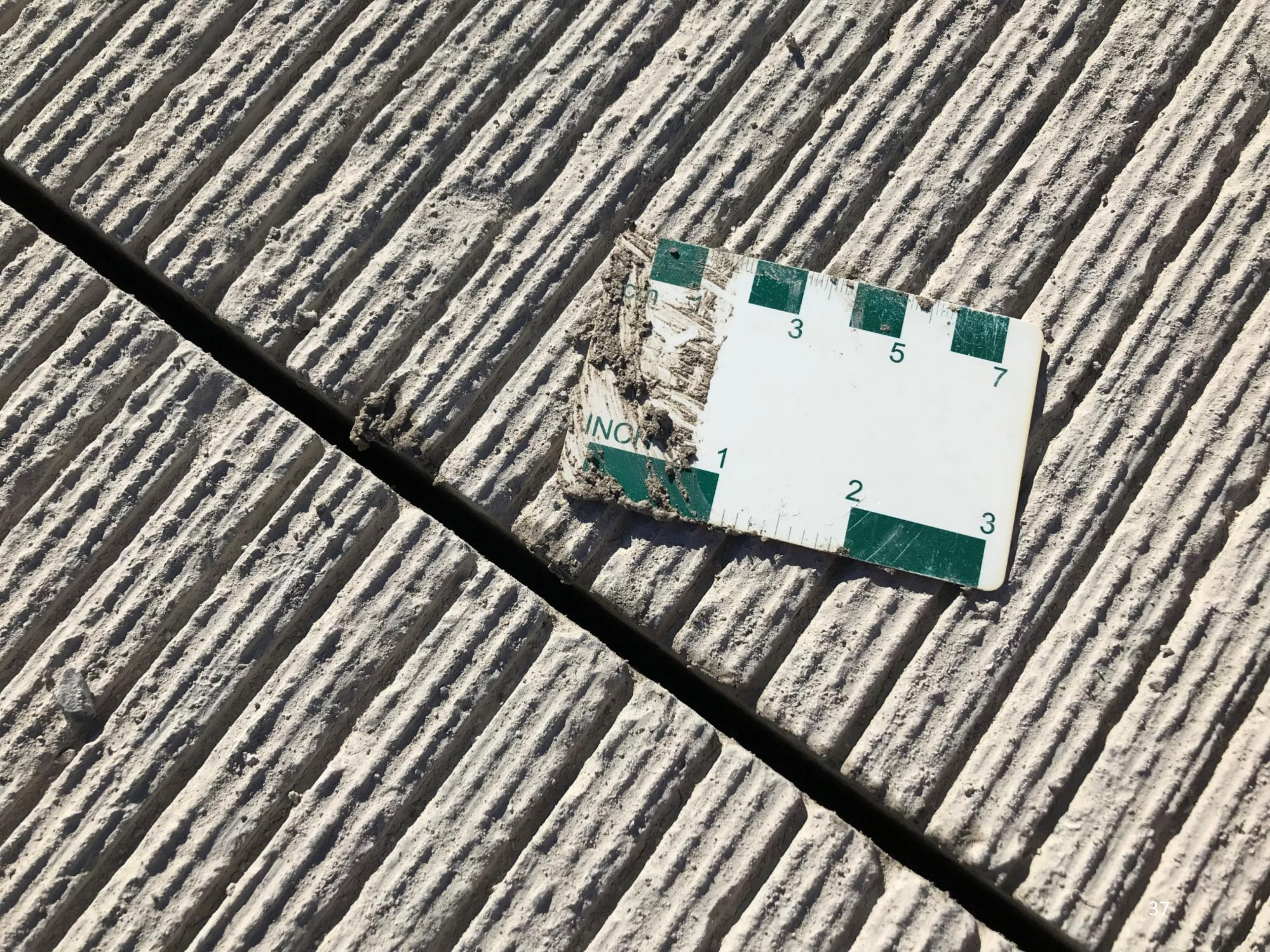
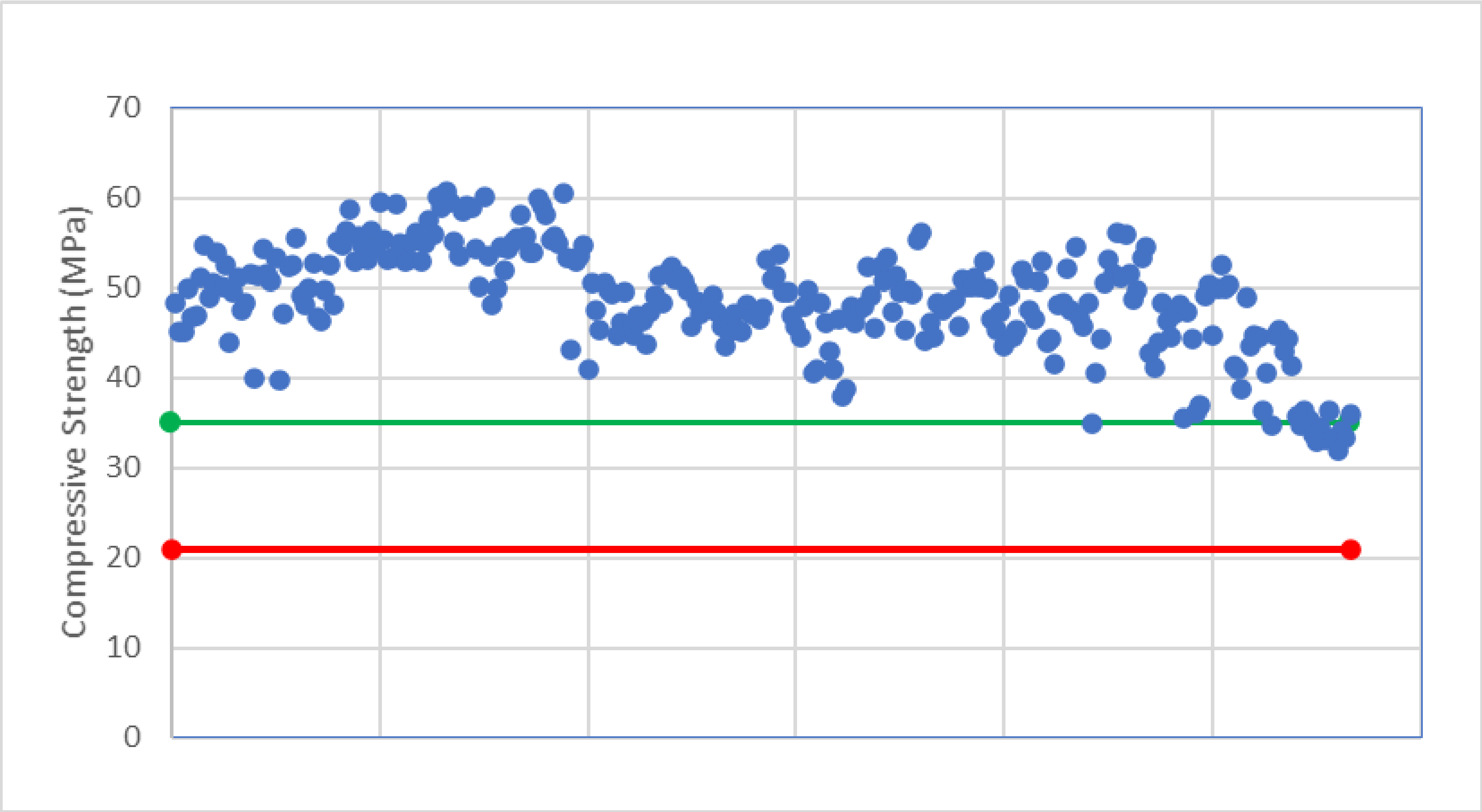

3
5
7
1
2
3

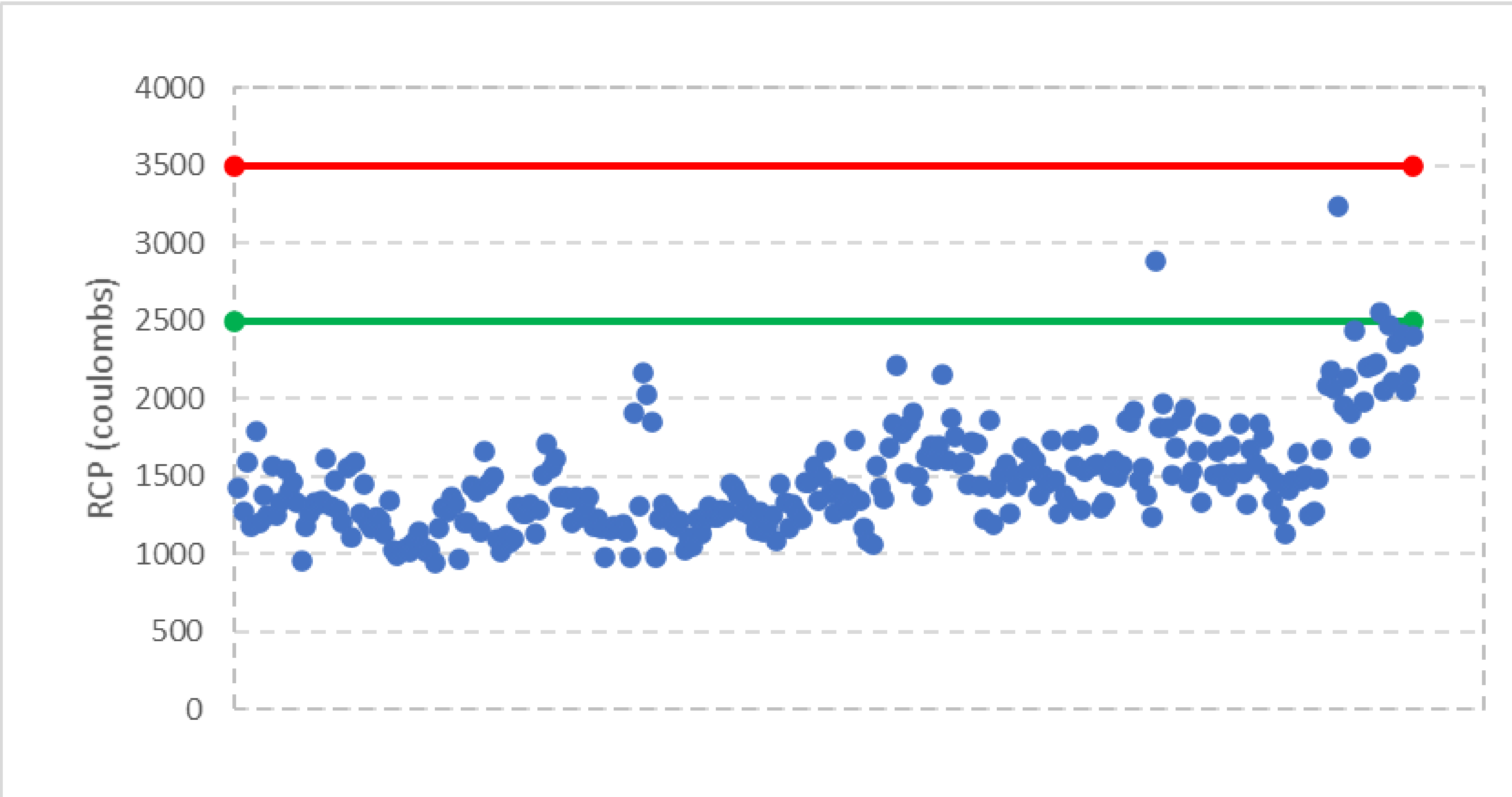
Summary of Contract Results – Hardened Concrete Properties

Property	Average Result	Requirement
28-Day Compressive Strength	48.6 MPa	35.0 MPa (minimum)
RCP	1476 coulombs	2500 coulombs (maximum)
Hardened Air Content	4.6 %	3.0 % (minimum)
Spacing Factor	0.148 mm	0.230 mm (maximum)

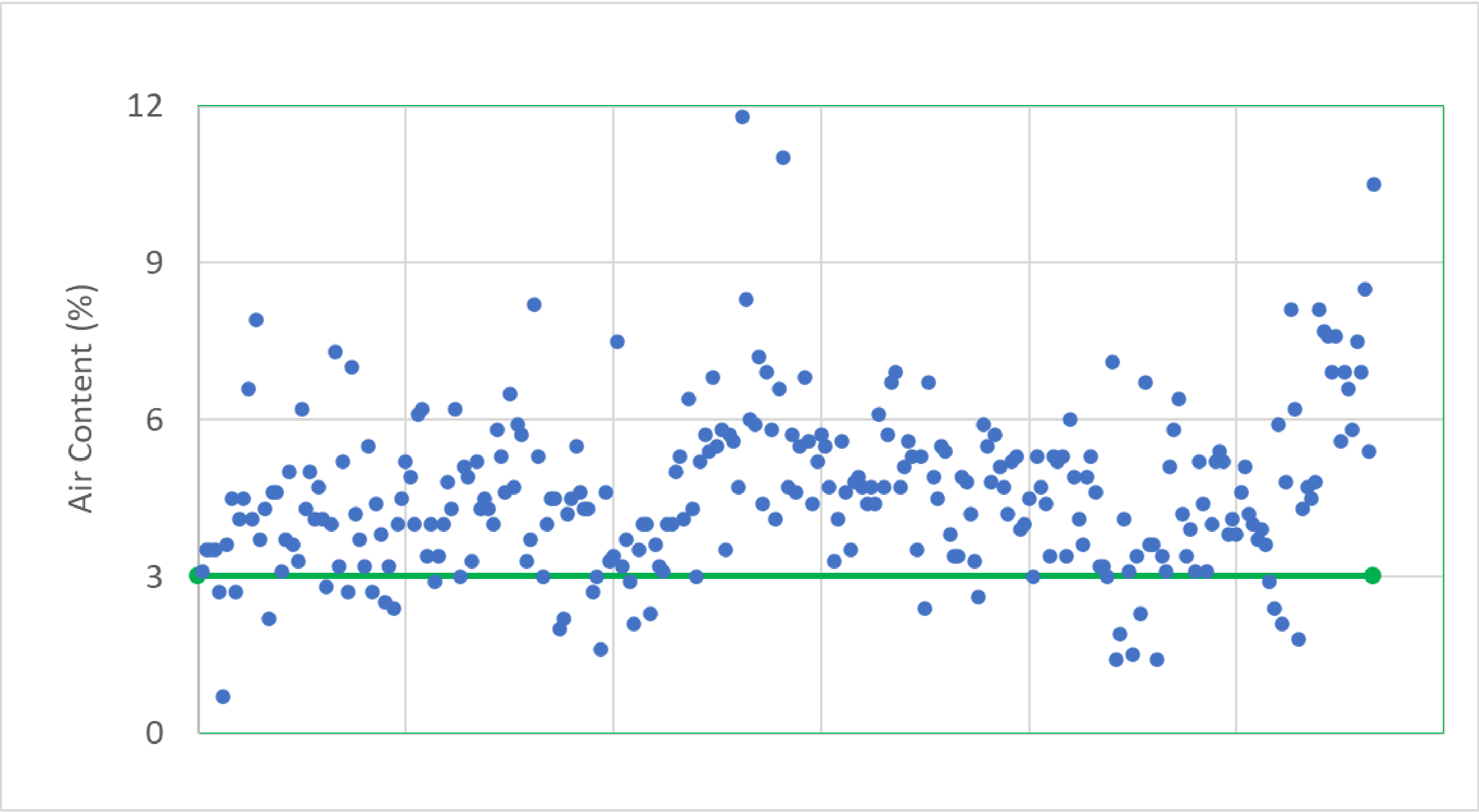
28-Day Compressive Strength of Cores



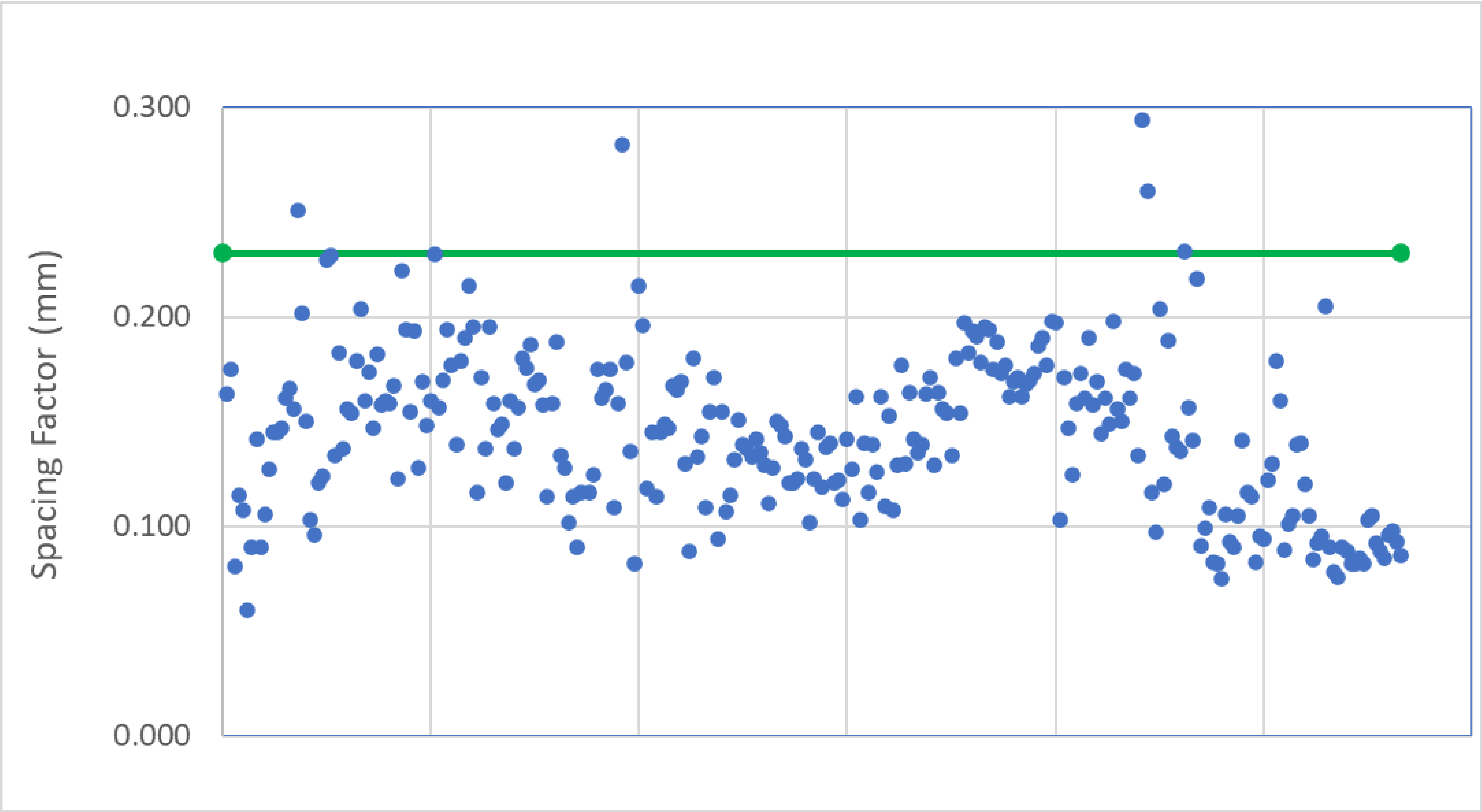
Rapid Chloride Permeability of Cores



Hardened Air Void System
Air Content of Cores



Hardened Air Void System
Spacing Factor of Cores



Thank You!

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Long Life and Sustainability

Peter Taylor

Setting the Stage

What do humans need:

- Sustenance
- Shelter
- Help
- Hope

Setting the Stage

Imagine a world without infrastructure:

- Transportation
- Energy
- Expertise

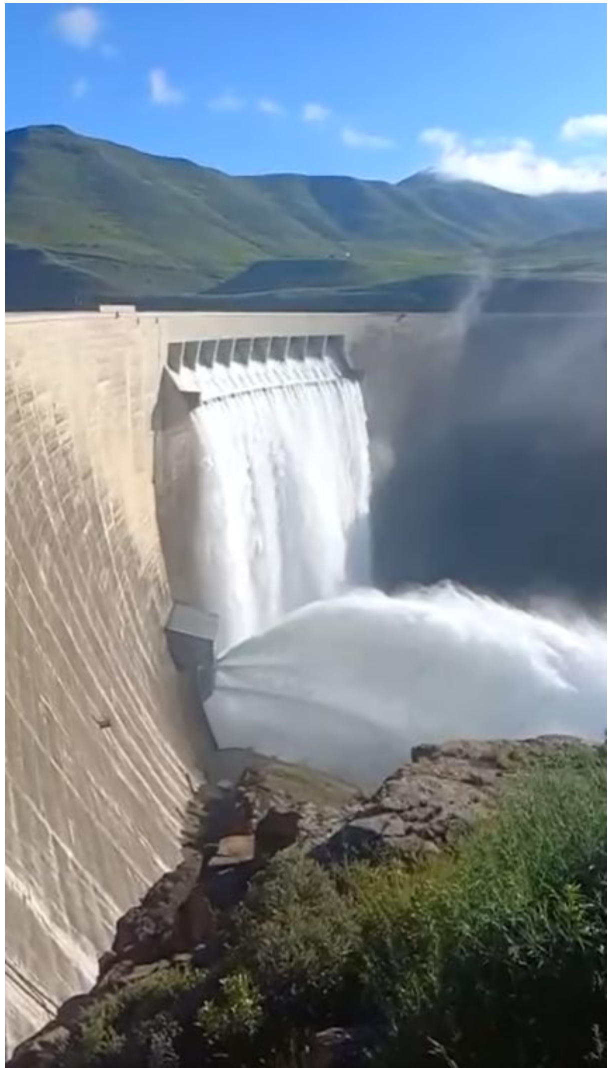
Setting the Stage

- Imagine infrastructure without concrete
  - Buildings
  - Services
  - Transportation

Setting the Stage

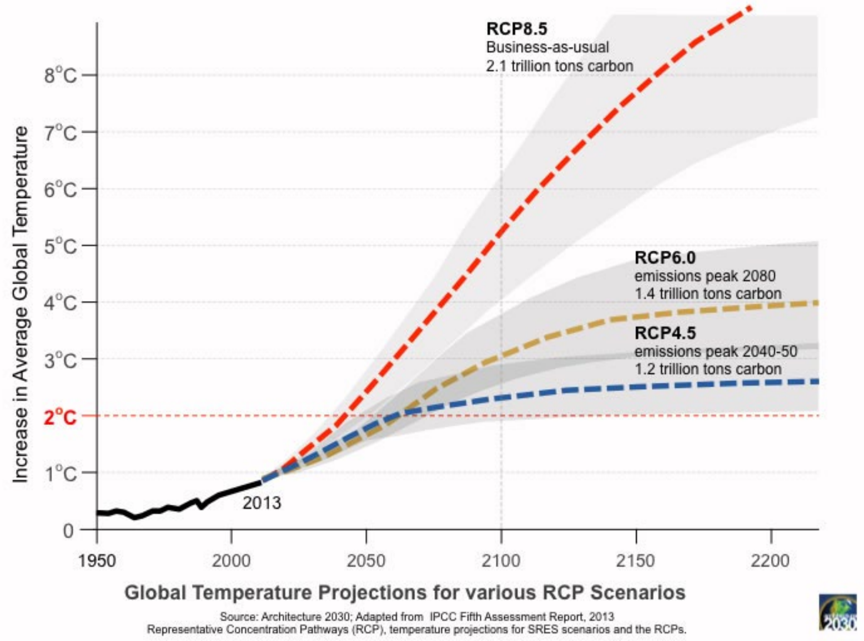
We use a lot of concrete

- Concrete impacts the environment
- Changes in environment affect infrastructure needs



Setting the Stage

The conundrum then is: how do we deliver/maintain the infrastructure without hurting the planet?



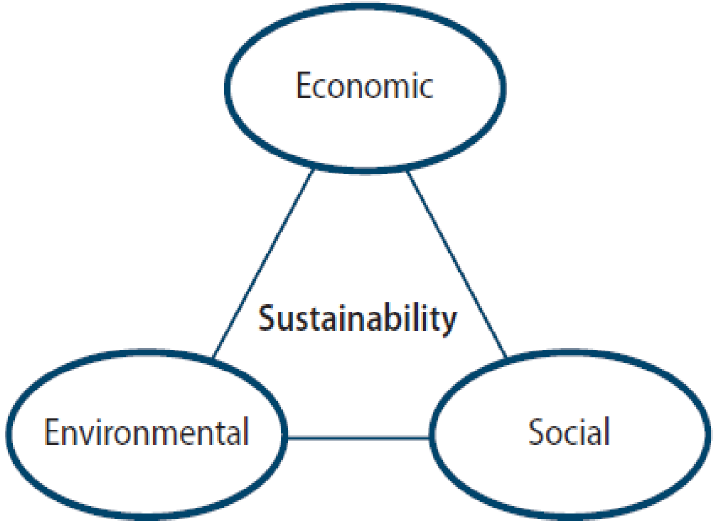
https://architecture2030.org/ipcc_analysis/

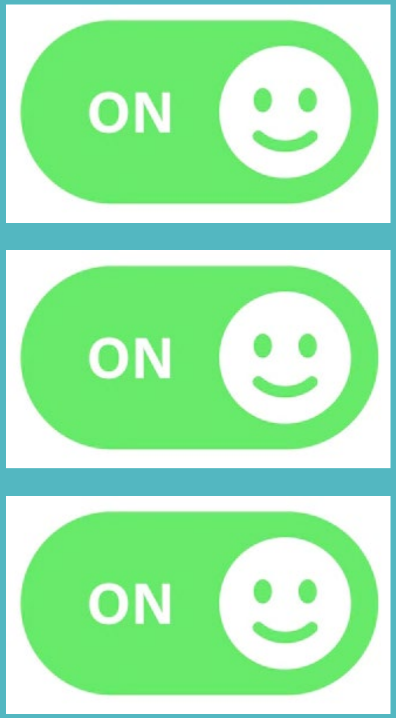
Setting the Stage

- Pick 2

Setting the Stage

- Pick ~~2~~ 3





Durable

Sustainable

Cost effective

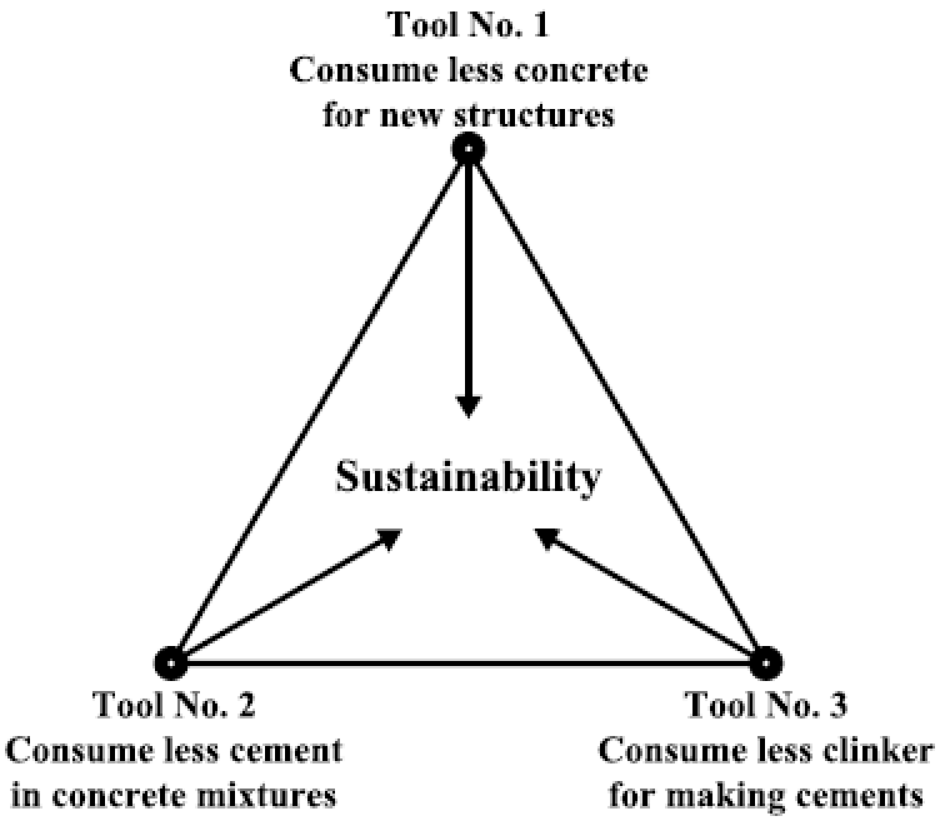
Which one was cheaper?

- To buy
- To own

Materials

What can we do?

- Use less concrete
- Use less binder in the concrete
- Use less clinker in the binder



Mehta, CI Feb. 2009

What do we need for long life?

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

- Workability

Transport properties (permeability)

- Keep the fluids out
- Controlled by w/cm and SCMs
- Measure using resistivity

Cold Weather

- Freeze-thaw
  - Saturation
  - Entrained air
- De-icing salts
  - Sufficient SCM
- Measure using SAM

Aggregate Stability

- If aggregates expand = damage
  - ASR
  - (ACR)
  - D-Cracking

- Careful aggregate selection
- SCMs help ASR

Strength

- Strong enough to carry loads
- Controlled by cementitious system and w/cm

Shrinkage

- Influences cracking risk
- Controls warping
- Takes time

- Controlled by paste content

Workability

- Controlled by
  - Water content
  - Aggregate gradation
  - Properties of fine materials
  - Admixtures

- Should be tied to equipment in use
- Measure using VKelly or Box

Paste Content

- Need a minimum paste for workability
- Excess has a:
  - Small negative effect on strength
  - Negative effect on permeability, shrinkage, cost

		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	✓	-	-	-	✓✓	-

Summary

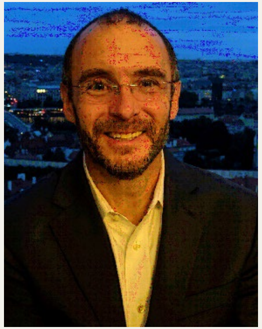
	Sustainability	Longevity
Paste Content	✓	✓
w/cm	~	✓
SCM type and dose	✓	✓
Air void system	~	✓

But wait there's more

- Don't forget about
  - Design
  - Detailing
  - Construction practices
  - Recycling
  - Resilience
  - …


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

Today's presenters



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Update Events for you

May 31, 2022

[TRB Webinar: Pavement Performance—Fundamentals and New Technologies]

July 13, 2022

[TRB Webinar: Geotechnical Asset Performance in a Changing Climate]

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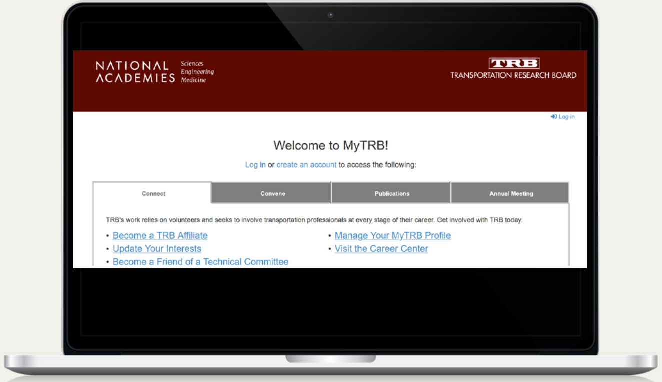

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