SOLUTIONS FOR THE BUILT WORLD

Reducing the Carbon Footprint of Concrete Pavements Through Preservation

NPPC2023– September 19, 2023

www.wje.com

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.

Brief Personal Introduction

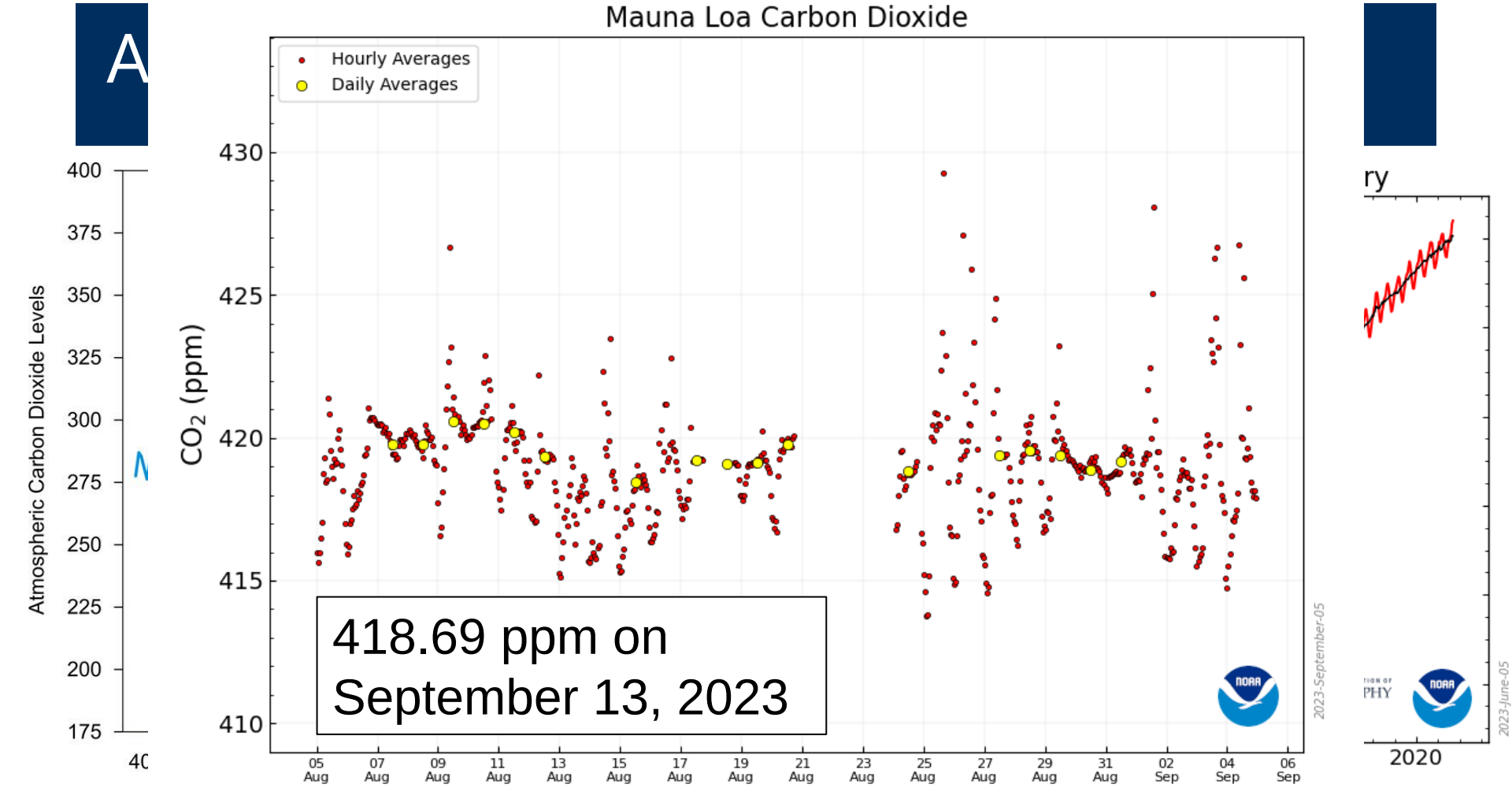
- I have 35+ years working with concrete materials, focused on durability and sustainability
  - A recovering academic who has worked as a consultant since 2008
  - Primary work is on concrete pavements and materials
    - Since 2010, working on sustainability and carbon reduction for FHWA, state DOTs, associations, and foundations
  - I recently became a grandfather, like to break other people's sailboats, and am a Black Rock Ranger at Burning Man

The Driver: Climate Change

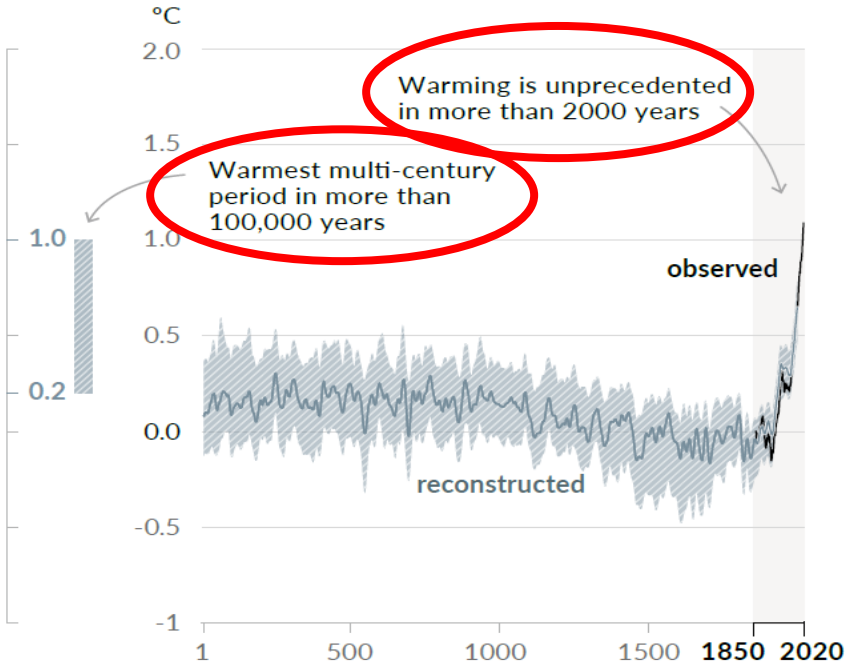
"Can you be more specific?"

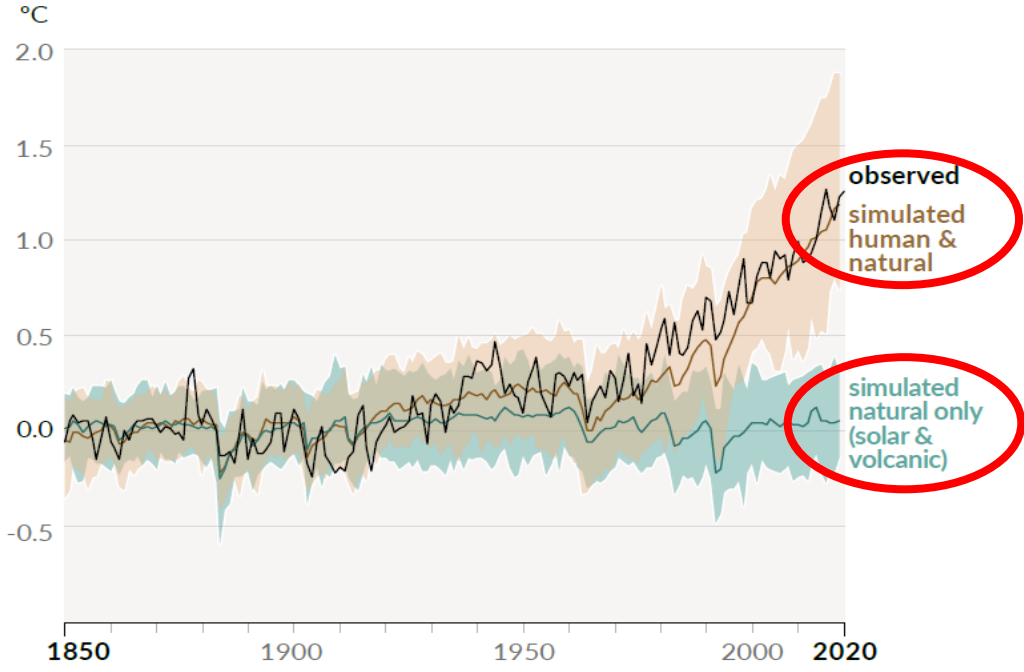
Climate Change at the Forefront

- Scientific observations confirm the climate is changing
  - The Arctic is melting, and sea levels are rising
  - Hurricanes and wildfires more severe
- Governmental policy is emphasizing climate change and carbon reduction
  - Infrastructure Investment and Jobs Act (IIJA) and Inflation Reduction Act (IRA)
- Low-carbon solutions are of increasing interest to governmental agencies and industry
- This is a world-wide effort


Mauna Loa Carbon Dioxide
Hourly Averages
Daily Averages
CO_2 (ppm)
430
425
420
415
410
05 Aug
07 Aug
09 Aug
11 Aug
13 Aug
15 Aug
17 Aug
19 Aug
21 Aug
23 Aug
25 Aug
27 Aug
29 Aug
31 Aug
02 Sep
04 Sep
06 Sep
418.69 ppm on
September 13, 2023
2023-September-05
Atmospheric Carbon Dioxide Levels
400
375
350
325
300
275
250
225
200
175
2020
2023-June-05

Changes in Global Surface Temperatures (IPCC 2021)

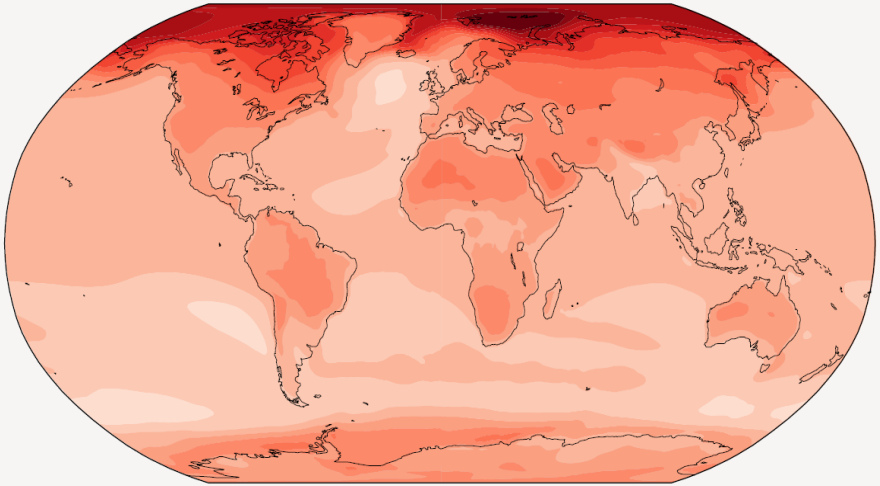


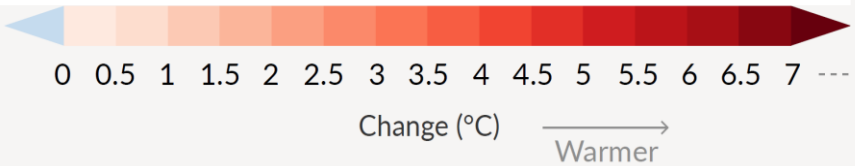


IPCC, 2021: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis*

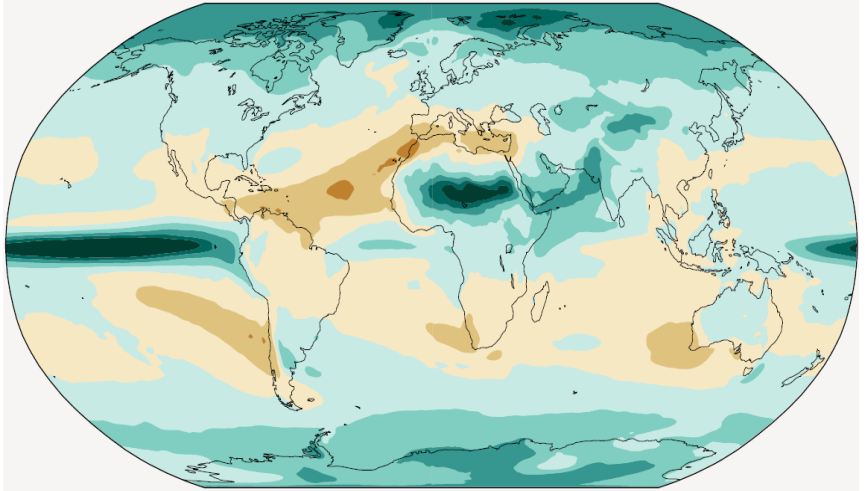
Regional Differences (IPCC 2021)

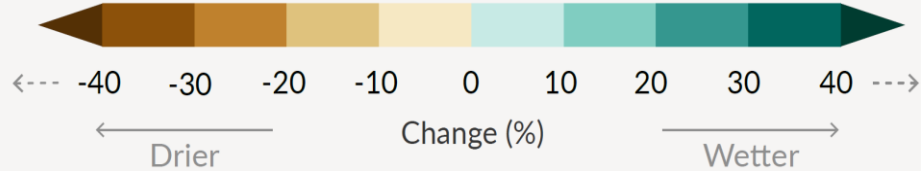
Simulated change at **2 °C** global warming





Simulated change at **2 °C** global warming

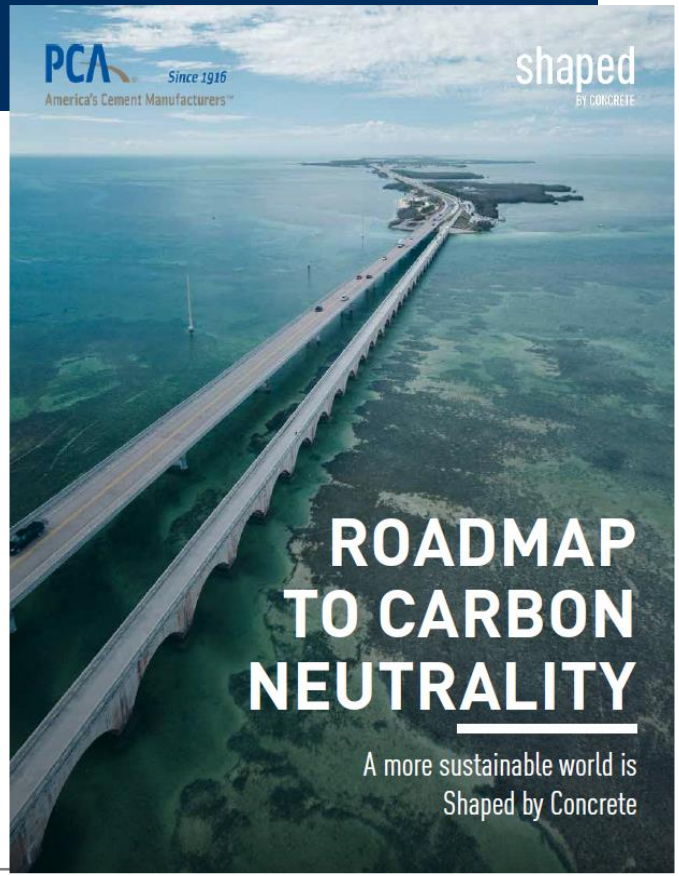




WJE

Challenges In Front of Us

- Change is difficult
  - Must end business as usual
- Traditional cement and concrete are carbon intensive
- Designs and materials are dictated by the past and “conservatism” in codes and specifications

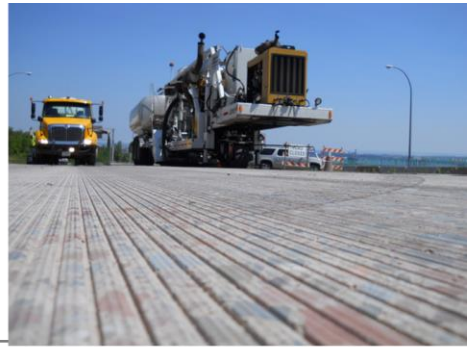


THIS IS AN OPPORTUNITY TO INNOVATE!

How Does Concrete Pavement Preservation Impact Climate Change?

- Extending the life of a concrete pavement reduces GHG emissions associated with construction over the life cycle
- Keeping smooth pavements smooth reduces vehicle GHG emissions and costs
- Grinding a carbonated concrete pavement surface will sequester additional CO_2

Diamond Grinding



Next Generation Concrete Surface
Or Grind and Groove

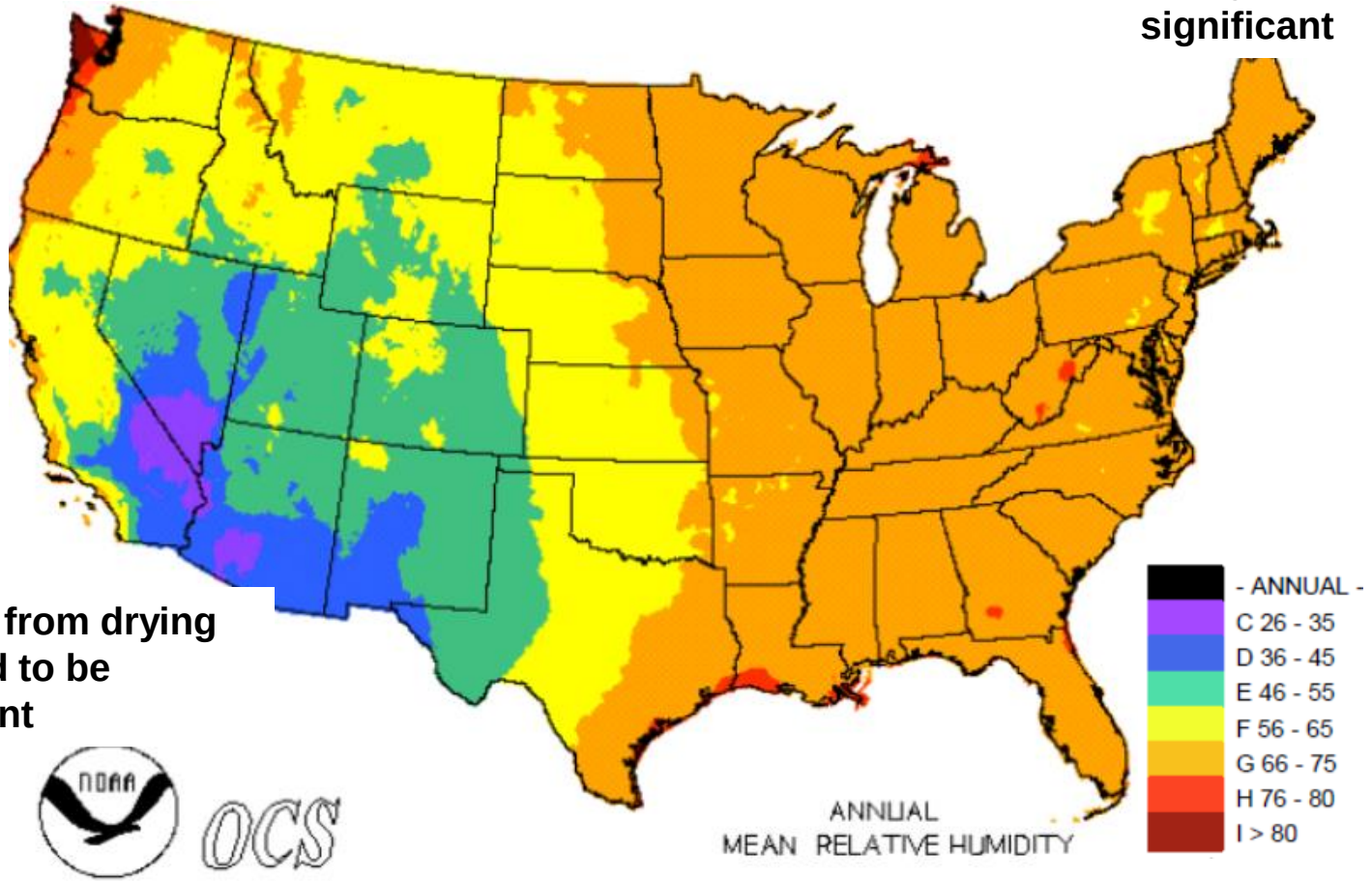
Benefits of Extended Pavement Life

- Reduction in material acquisition, processing, and construction
  - Concrete pavement preservation requires little to no new materials
- Reduction in congestion due to major reconstruction
  - Results in reduced GHG emissions
- These benefits are significant and quantifiable over the life cycle

Ride Quality and Concrete Pavements

- Concrete pavements are being constructed with improved ride quality
  - In some markets, initial IRI values of 40 in/mile are routinely achieved
- Over time, ride quality decreases for many reasons
  - Distress development (i.e., cracking, faulting, spalling)
  - Development of slab curvature due to temperature and moisture gradients
    - Trend is toward development of upward curvature

Warping from drying thought not to be as significant

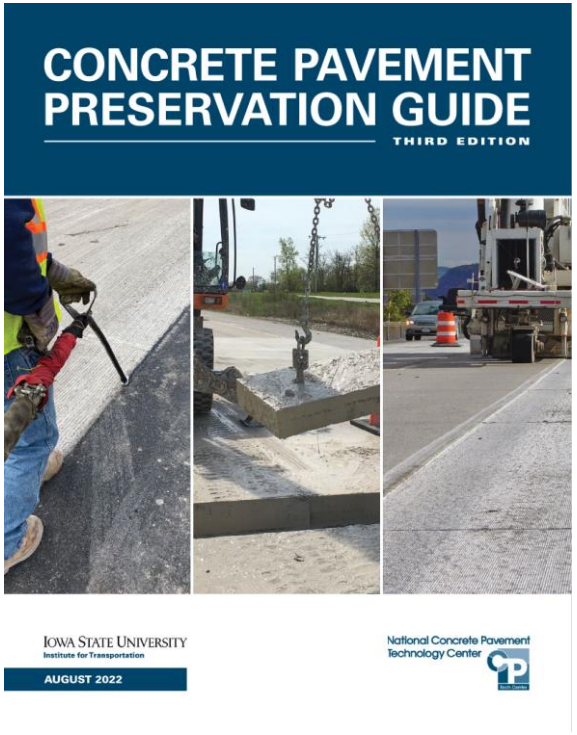


Warping from drying expected to be significant

WJE

Concrete Pavement Preservation Strategies

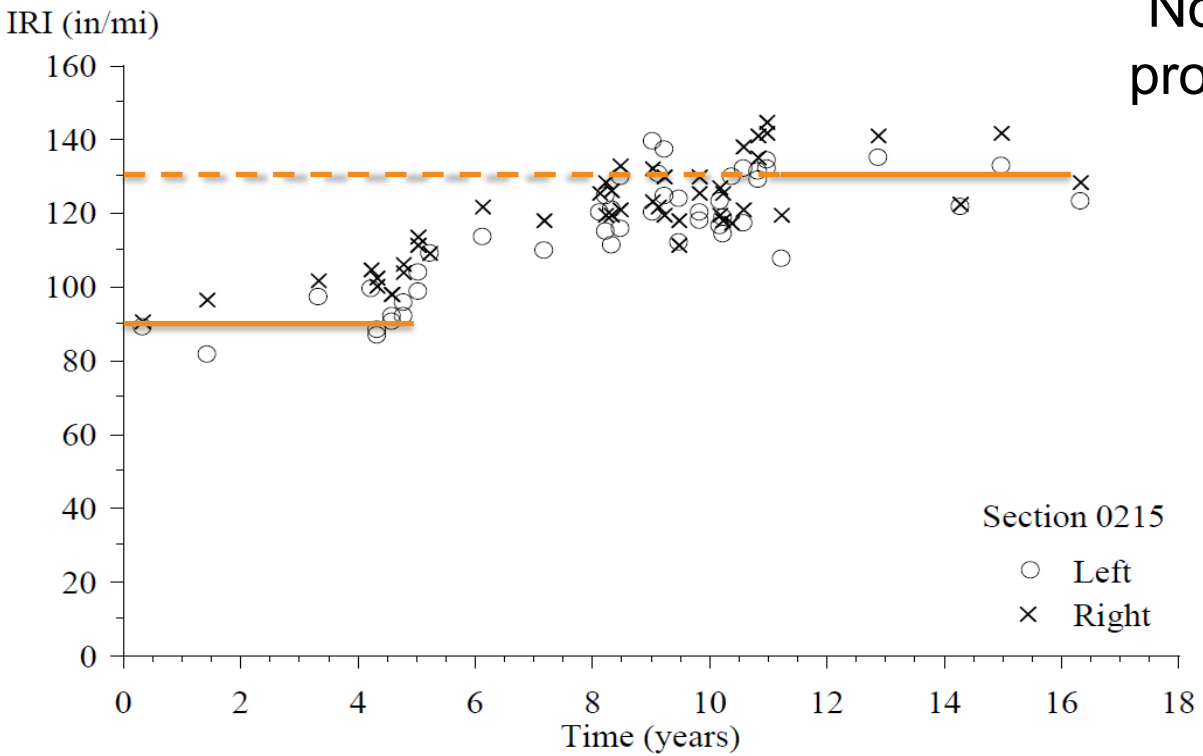
- Slab stabilization
- Partial-depth repair
- Full-depth repair
- Drainage restoration
- Dowel bar retrofit
- **Diamond grinding and grooving**
- Joint resealing



Diamond Grinding – Performance Benefits

- Significant noise reduction
- Improves friction
- Improves cross slope
- **Restores smoothness (by removing roughness due to curvature and joint/crack faulting)**
- Performance life (typical):
  - 14-17 years

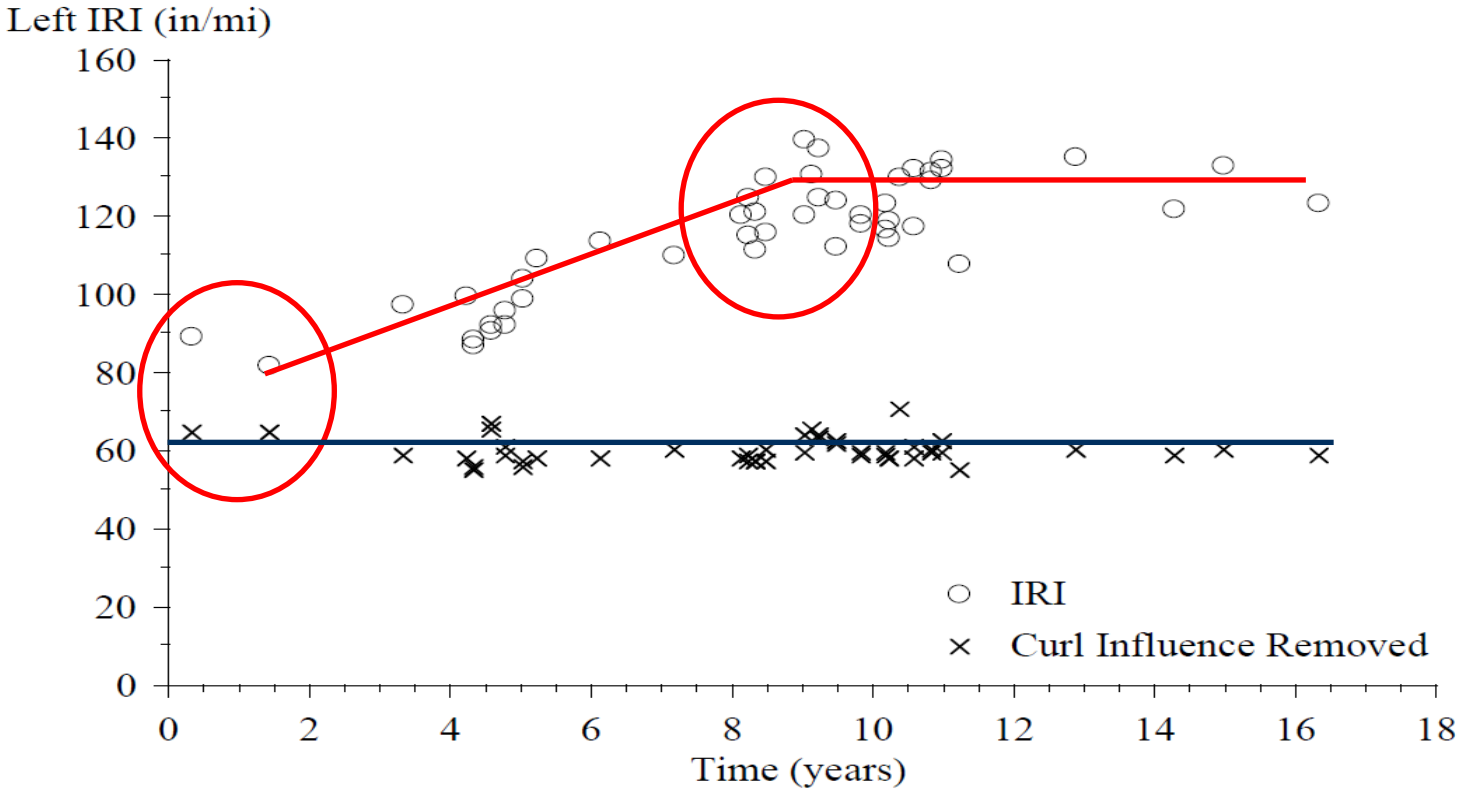
IRI Over Time - LTPP Section 040215 as Part of Arizona SPS-2



"Normal" roughness progression…

Except no cracking, faulting, or spalling

IRI Progression (Section 040215) Left Wheel Path



WJE

Pavement Smoothness and Fuel Consumption

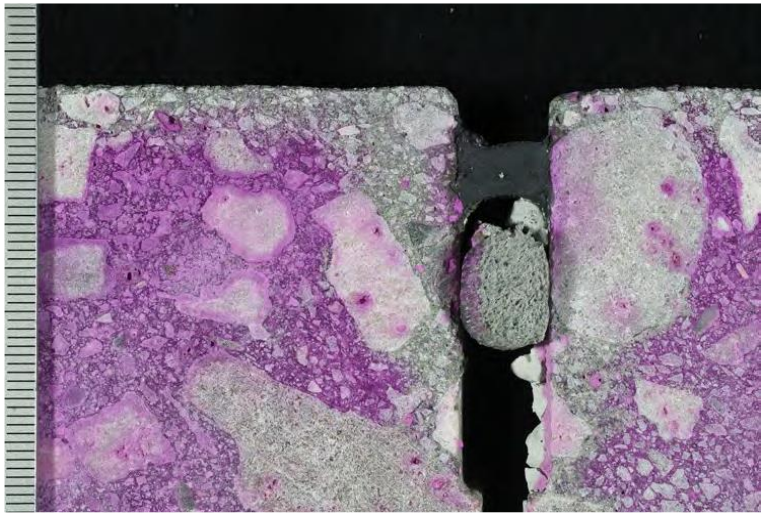
- It is well-documented that vehicle fuel efficiency is related to the smoothness of the pavement
  - Smoother pavements result in less fuel consumption and less GHG emissions
  - This is foundational to the World Bank HDM 4 model and has been validated by NCHRP, Caltrans, and in Europe
  - Work by UC-Davis and MIT have demonstrated this, and models have been developed to quantify it

IRI Trigger Values (Wang et al. 2012)

Traffic group	Daily PCE of lane-segments range	Total lane-miles	Percentile of lane-mile	Optimal IRI triggering value (m/km, inch/mile in parentheses)	Annualized CO_2-e reductions (MMT)	Modified total cost-effectiveness ($/t$CO_2$-e)
1	<2,517	12,068	<25	-----	0	N/A
2	2,517 to 11,704	12,068	25~50	2.8 (177)	0.141	1,169
3	11,704 to 19,108	4,827	50~60	2.0 (127)	0.096	857
4	19,108 to 33,908	4,827	60~70	2.0 (127)	0.128	503
5	33,908 to 64,656	4,827	70~80	1.6 (101)	0.264	516
6	64,656 to 95,184	4,827	80~90	1.6 (101)	0.297	259
7	>95,184	4,827	90~100	1.6 (101)	0.45	104
Total					**1.38**	**416**

What About CO_2 Sequestration Through Carbonation?

- It is a real thing
  - Anderson, et. al. (2019), "Carbonation as a method to improve climate performance for cement based materials." Cement and Concrete Research (2019)
- Paper quantifies uptake of CO_2 by concrete through carbonation
  - $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$
  - Calcium silicate hydrate also undergoes carbonation
  - Uses Fick's law



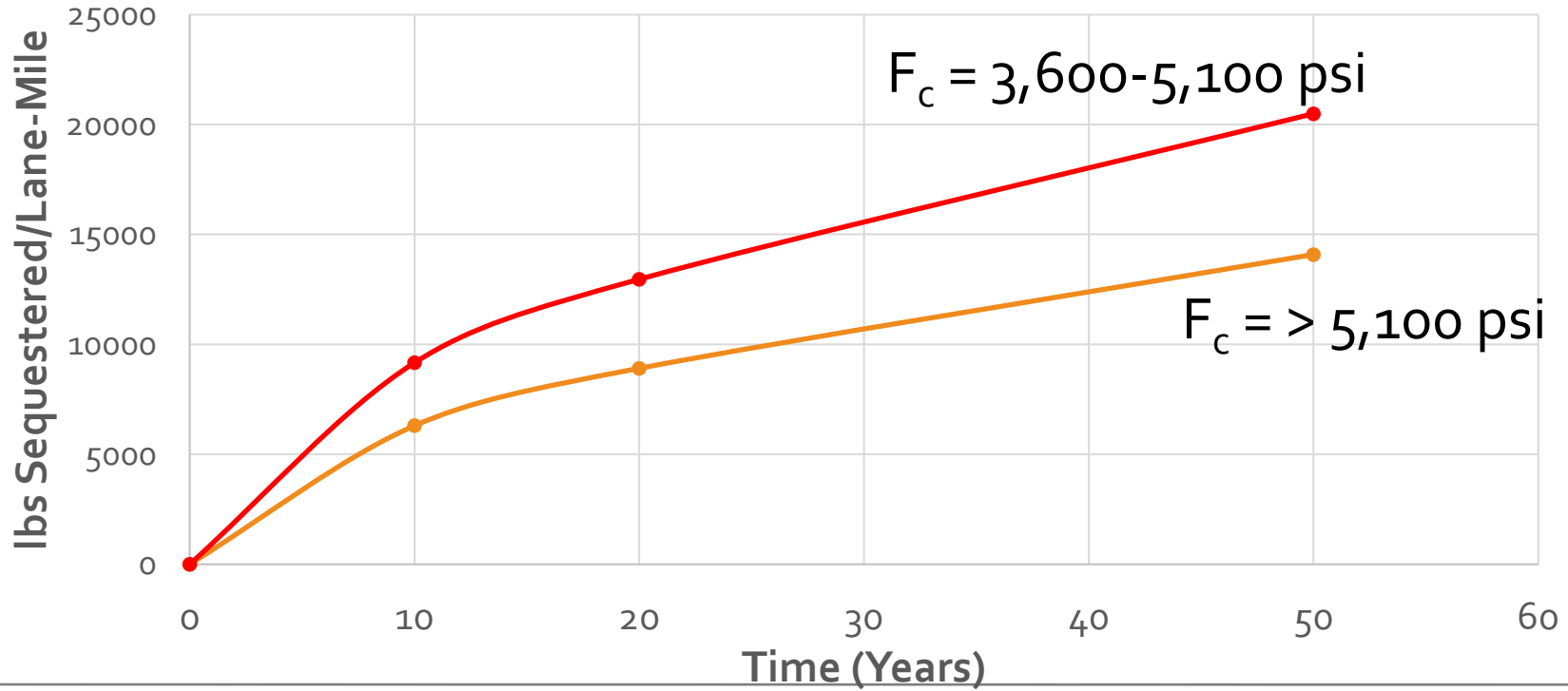
How Much Carbonation Occurs in Typical Concrete Pavement?

- Depends on exposure and quality of concrete
  - Is climate wet or dry? Is it exposed to rain?
- Quality of concrete
  - In Anderson et al. (2019), it is related to strength, but it is permeability that matters
- In general, dry concrete that is permeable (low strength) will have a higher degree of carbonation than wet concrete that has low permeability (high strength)

Applying This to a Typical U.S. Pavement

- Assume 564 lbs/yd^3 portland cement in concrete with a compressive strength of 4000 psi that is exposed to rain
- The amount of CO_2 sequestered through carbonation is calculated to be between 0.2-0.3 lbs/ft^2 of surface area in 50 years
  - Roughly 14,000-20,000 lbs CO_2 per lane-mile, or equivalent to 700 to 1000 gallons of fuel consumed
  - 1 to 1.5 cars off the road

Pounds CO_2 Sequestered Over Time per Lane-Mile

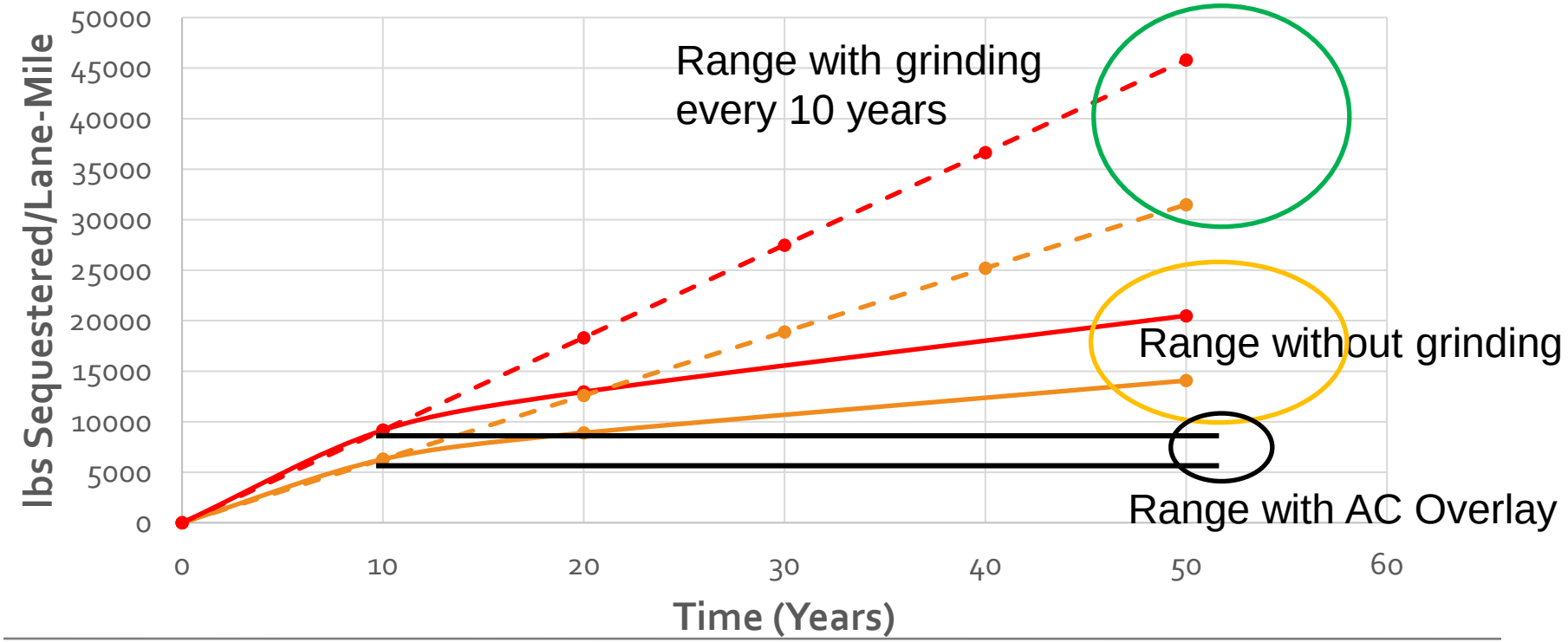


WJE

Diamond Grinding Increases Carbonation

- Rate of carbonation decreases with time
  - Roughly 45% of carbonation over 50 years occurs by Year 10
- Diamond grinding exposes “fresh”, uncarbonated concrete to the atmosphere
- Grinding every 10 years will more than double the amount of sequestered CO_2 over 50 years
- Overlaying concrete with asphalt will shut out atmospheric CO_2 and terminate sequestration

Pounds CO_2 Sequestered Over Time per Lane-Mile



WJE

Result - Diamond Grinding has Close to Net Zero GHG Emissions Due to Enhanced Carbonation

- Diamond grinding every 10 years results in 17,400 to 25,300 lbs of additional CO_2 being sequestered over 50 years per lane-mile
  - This is equivalent to 870 to 1,270 gallons of diesel fuel consumed over 50 years
- Diamond grinding four times over 50 years consumes between 1,000 and 1,600 gallons of diesel
  - 250-400 gallons per lane-mile of grinding

New Tool Being Released by IGGA/ACPA

- A new tool is being developed to estimate life cycle greenhouse gas emissions associated with pavement roughness and carbonation
- Can be used to thumbnail carbon savings incurred by keeping smooth pavements smooth
  - Important story for the pavement preservation industry to tell
- Contact Nick Davis at IGGA or Eric Ferrebee at ACPA for details

Current Funding Opportunities

- FHWA Climate Challenge
  - 27 projects awarded
- SHAs beginning to focus on quantifying and reducing carbon
- Buy Clean Initiatives (IIJA)
  - Federal, state, local agency and private interest
- IRA committed $2B through FHWA to facilitate adoption of low-carbon materials
  - Available to state and local agencies through federal-aid highway funding

FHWA IRA Funding

- The Inflation Reduction Act (IRA) Section 60506 provides for Low-Carbon Transportation Materials Grants
- Updates: https://www.fhwa.dot.gov/inflation-reduction-act/
- Fact sheets: https://www.fhwa.dot.gov/inflation-reduction-act/fact_sheets/lctm_grants.cfm
- EPA website: https://www.epa.gov/inflation-reduction-act/inflation-reduction-act-programs-fight-climate-change-reducing-embodied

We Are Looking For Willing Participants!

- Our team (NCE, WJE, Larry Sutter, Doug Hooton, and Al Innis) is funded by ClimateWorks Foundation and Breakthrough Energy Foundation to support SHAs, local agencies, and owners
  - Agency projects should be eligible for IRA funding
  - Pre-construction, construction, and post-construction assistance available
- Established a Reduced Carbon Concrete Consortium (RC^3) for agencies and industry partners
  - Looking for participants

Questions?

Thanks

Thomas Van Dam, Ph.D., P.E., FACI
Principal

Wiss, Janney, Elstner Associates, Inc.
Engineers | *Architects* | *Materials Scientists*
330 Pfingsten Road, Northbrook, Illinois 60062
tel 847.272.7400 | fax 847.291.9599
direct 847.753.6345 | mobile 775.527.2524
www.wje.com
tvandam@wje.com