Carbon Reduction Strategies for Concrete Airfield Pavements

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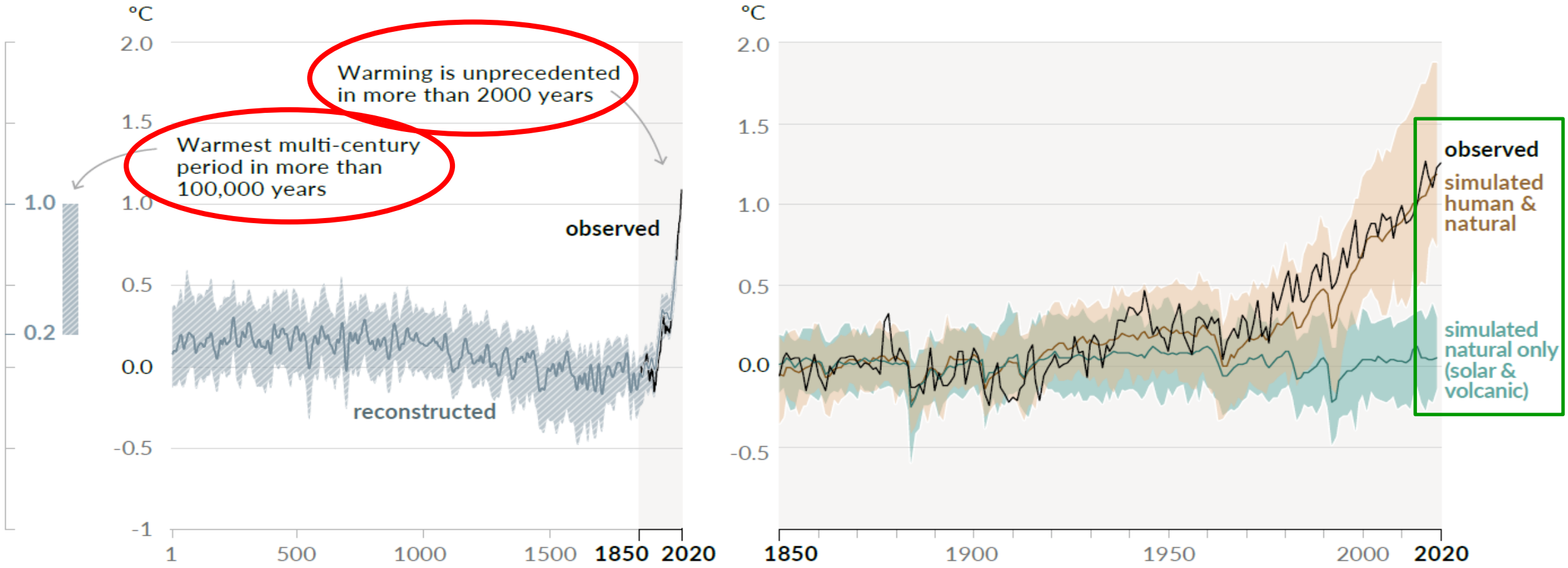
American Concrete Institute
Always advancing

Background: Climate Change

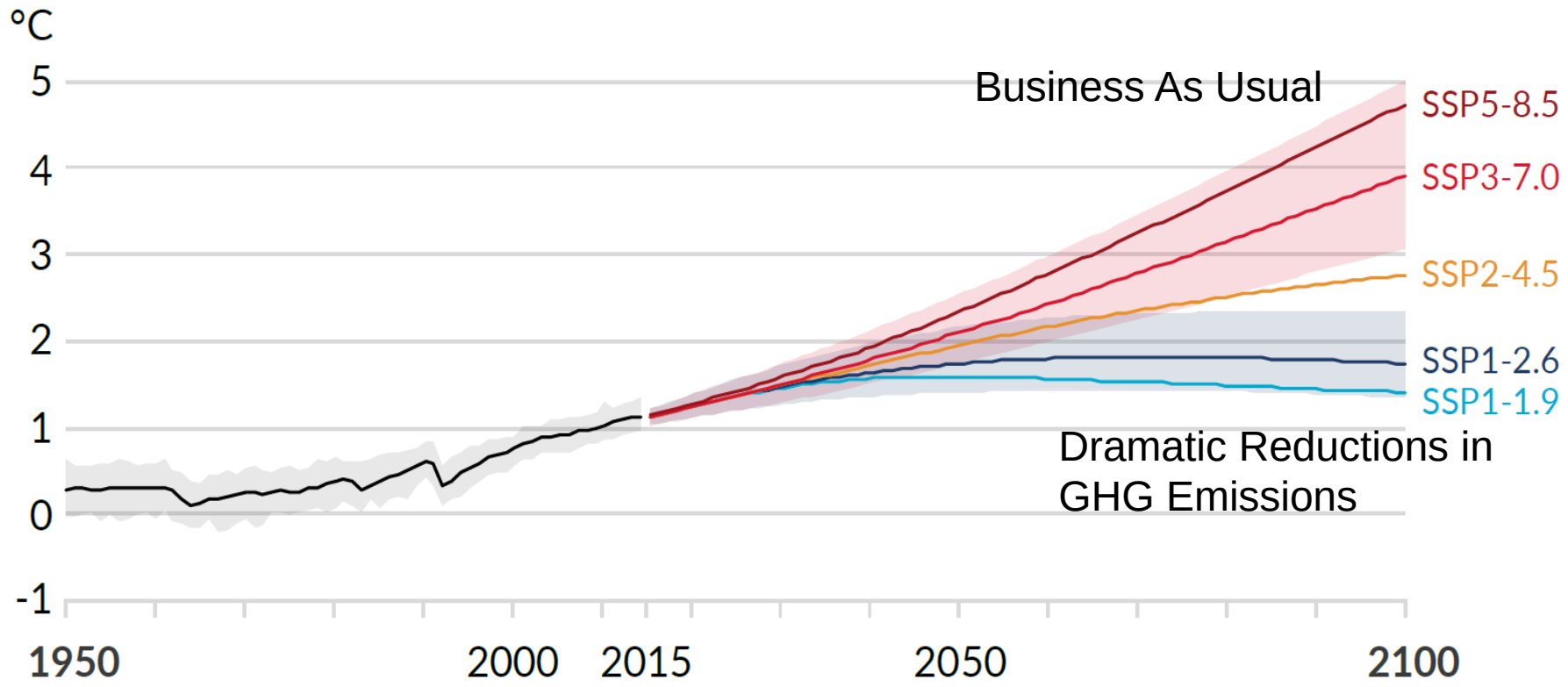
- Changes in global climate from human activities are occurring
  - Supported by historical observations and climate modeling
- Optimistic models predict substantial climate change over the next century
  - Rate of change depends on what we do
  - Long life of emitted heat-trapping, greenhouse gases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

Changes in Global Surface Temperatures Relative to 1850-1900 (IPCC 2021)



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

Global Surface Temperature Increases Compared to 1850-1900 Average



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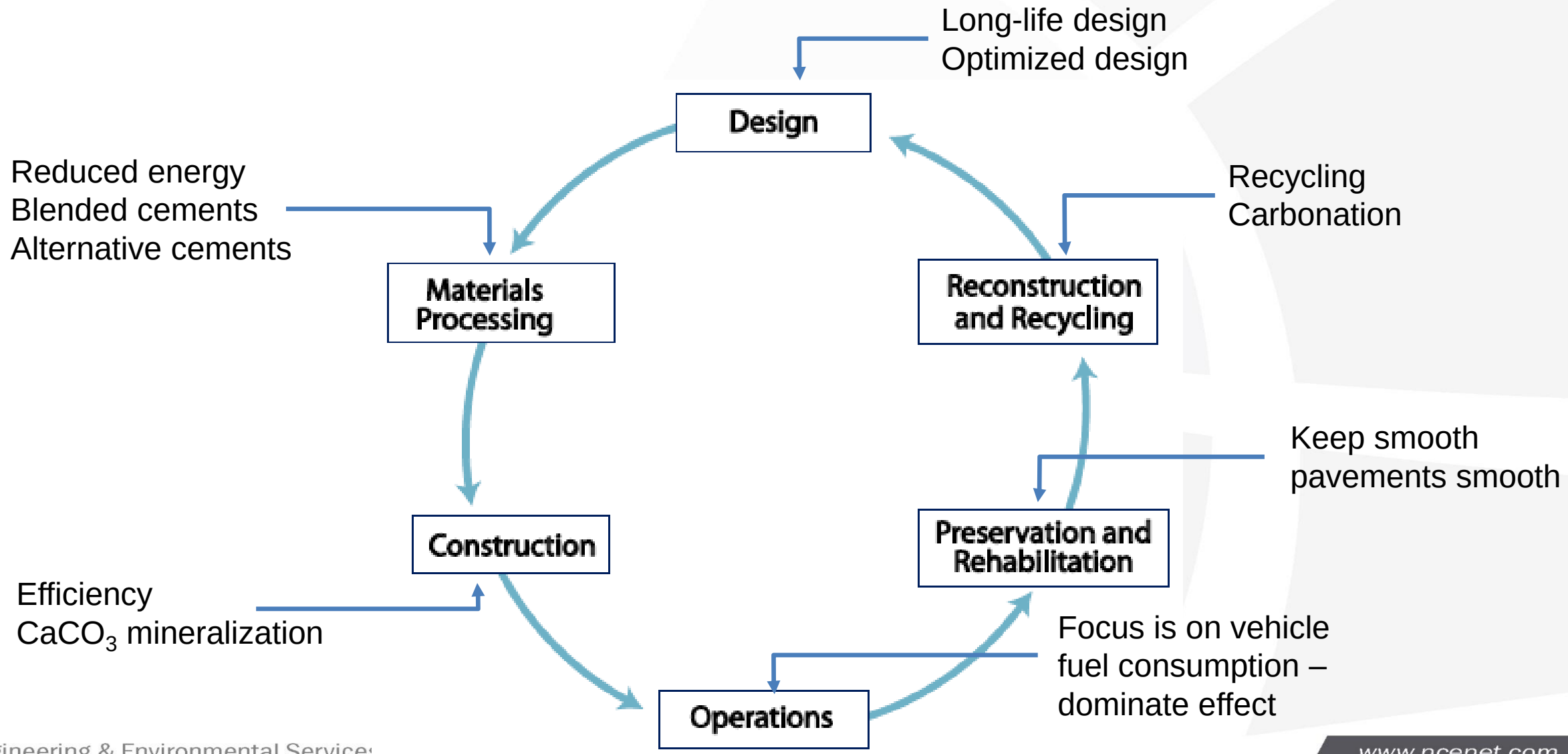
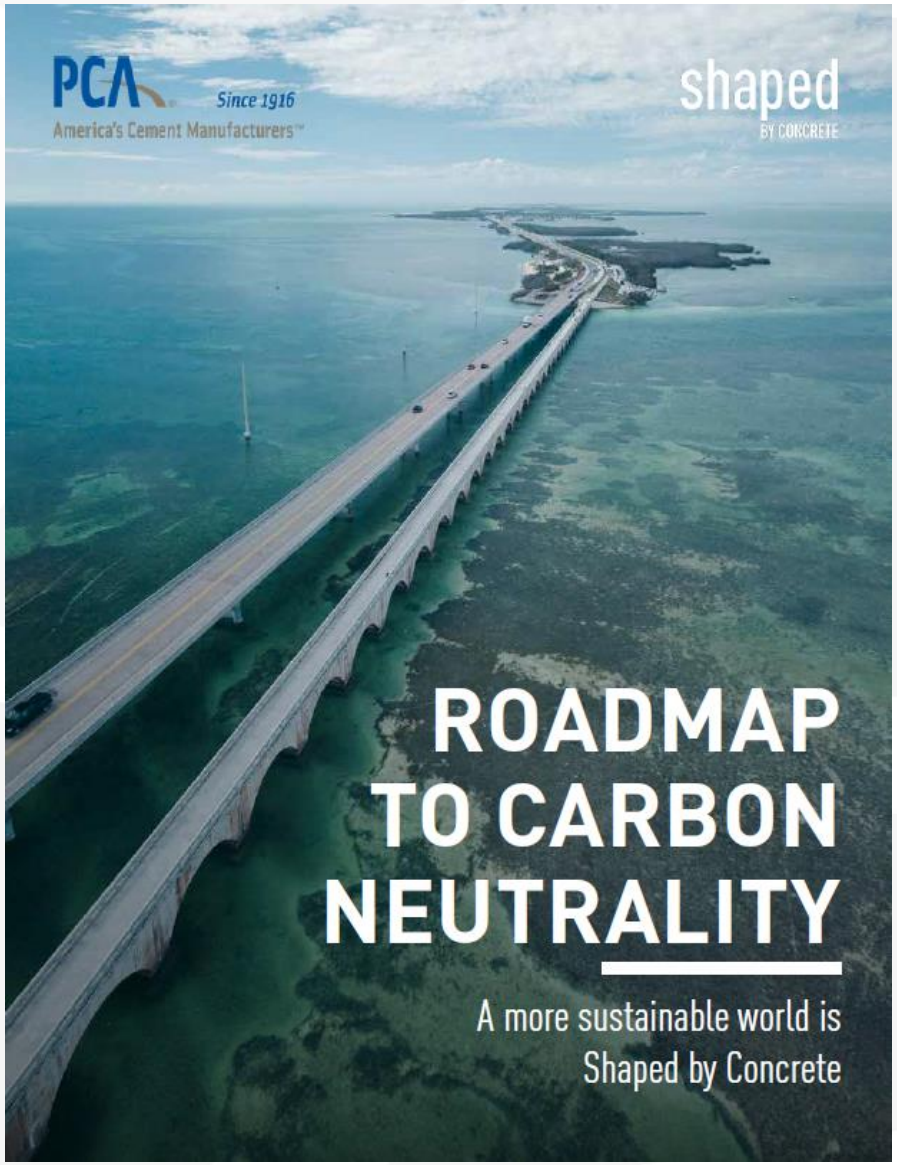
Sustainable Solutions Require Life-Cycle Thinking



Challenges In Front of Us

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

DON’T BE SAD – INNOVATE!

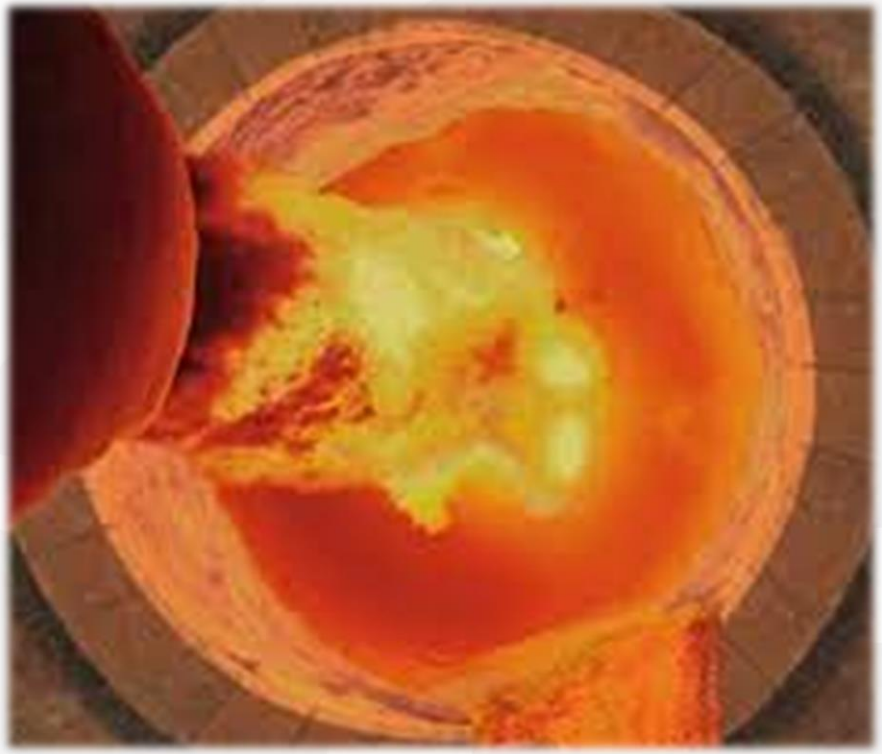


Hydraulic Cement and Concrete Mixtures

- 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
- Massive economic, environmental, and social impacts
  - 90 million metric tons of cement manufactured in the U.S. in 2020 (4.1 billion MT 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, roughly 0.922 lbs (kg,MT) of GHG emissions are released

Total GHG Emissions Embodied in Concrete

Cement

Gravel
Sand
Water

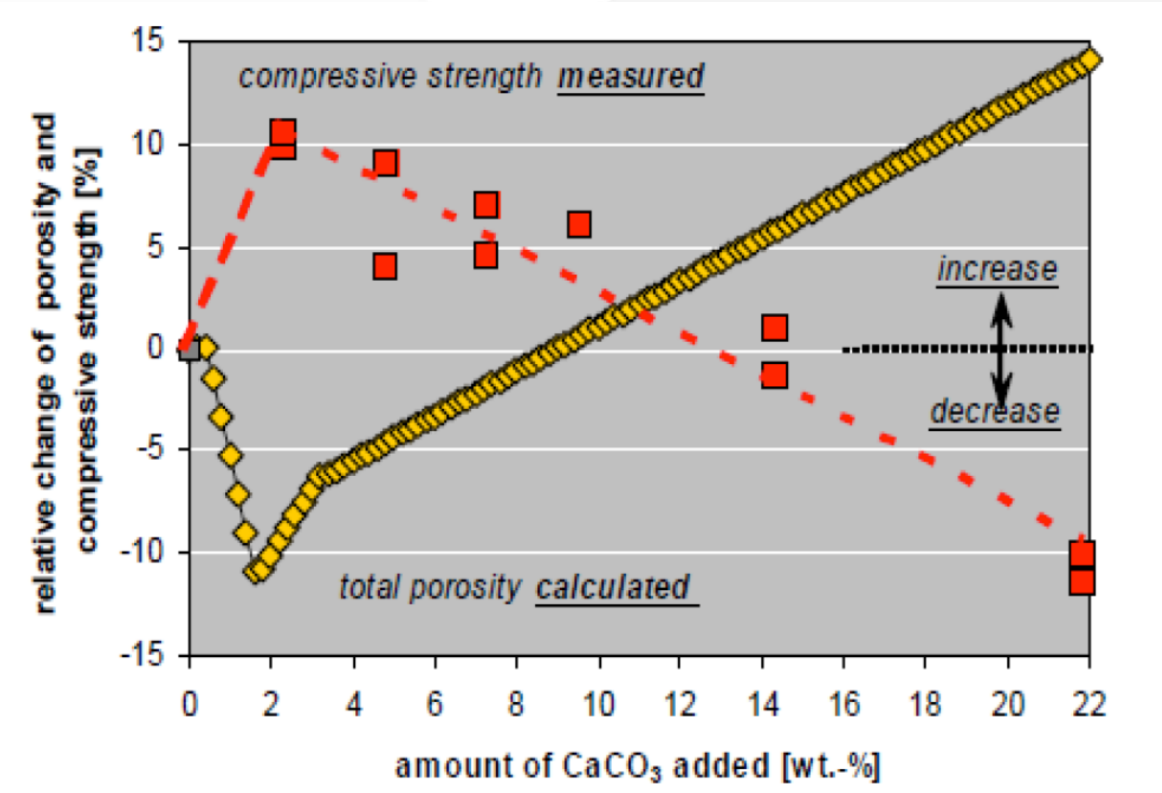
Typical concrete at the gate:
~0.26 tons CO_2 /yd^3 concrete
~0.23 tons CO_2 from portland cement

PCA's Commitment: Net Zero by 2050

- Clinker optimization
  - Production enhancements
  - Sequestration
- Cement optimization
  - Blended portland cements
  - Alternative cements
- Concrete optimization
  - Reduced cementitious materials content
  - Longevity
- In-service and end-of-life carbonation
  - For structural concrete, small but still significant

What Can You Do Now? Cement Optimization

- Replace clinker with supplementary cementitious materials (SCMs)
  - Blend at concrete plant
  - Obtained as blended cement (ASTM C595)
- Replace clinker with ground limestone
  - ASTM C595 Type IL blended cement can have up to 15% limestone
    - Widespread acceptance
  - On-going work to look at higher limestone content
    - 25% or more w/ SCM

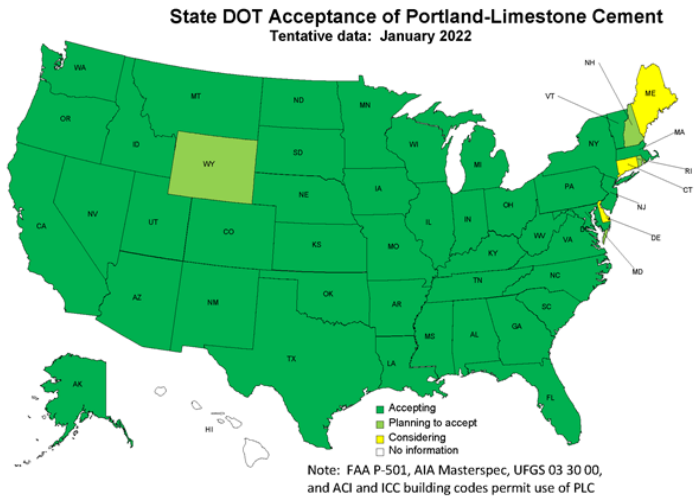


Traditional Supplementary Cementitious Materials (SCMs)

- Fly ash
  - Collected from flue gases of coal burning power plant
- Slag cement
  - From iron blast furnace
- Natural pozzolan
  - Calcined clay, volcanic ash, ground pumice, etc.

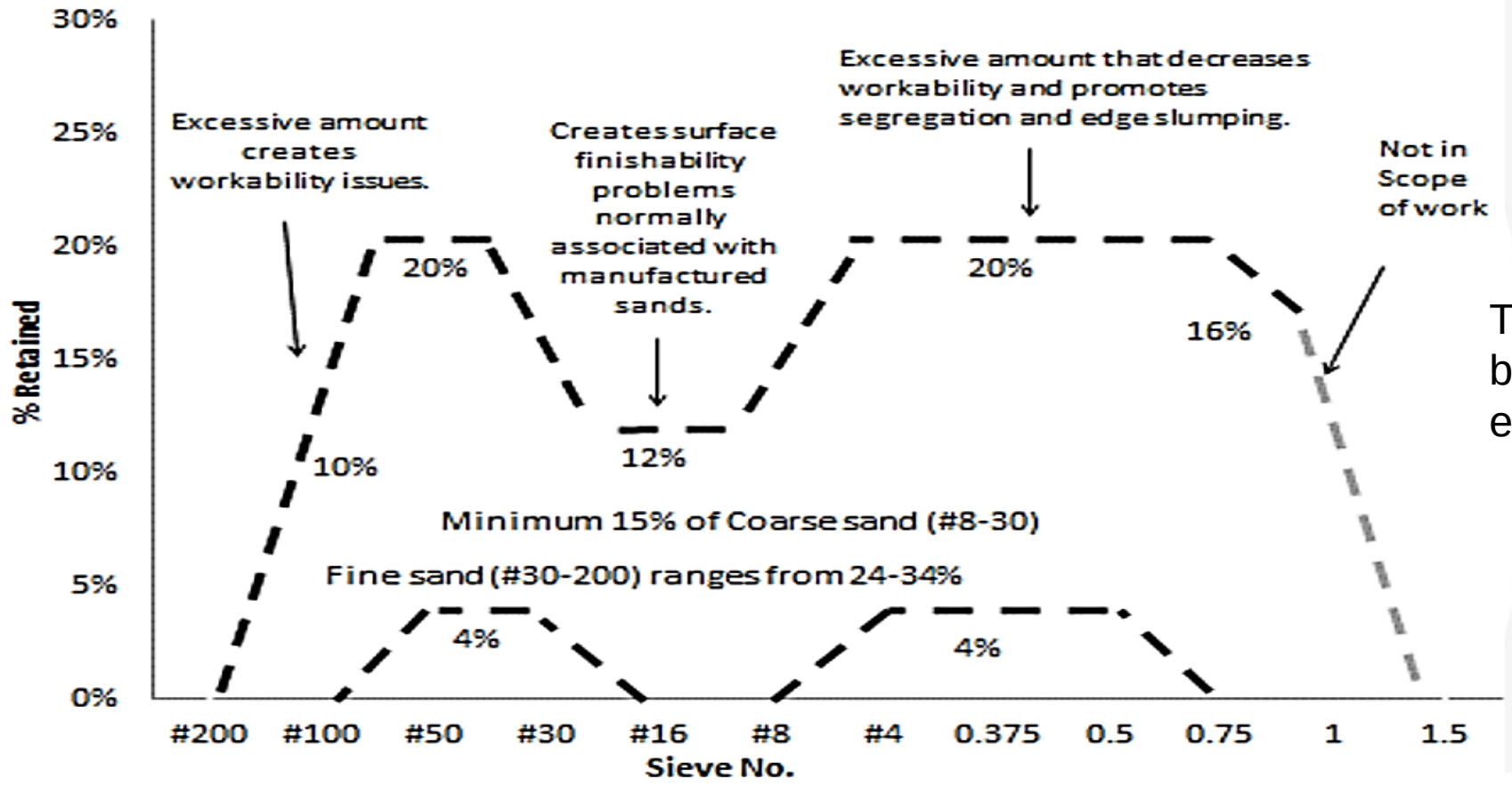
ASTM C595 Blended Cements

- Produced by cement manufacturers
- Type IP(X), Type IS(X), and Type IT (X)(Y)
  - Blended with pozzolan, slag cement, limestone or ternary blend
- Type IL will reduce carbon footprint by 8 to 10 percent with little impact on behavior
  - Pretty much all you're going to get going forward?
- Can be designated as moderate sulfate resistance (MS), high sulfate resistance (HS), moderate heat (MH), or low heat (LH)



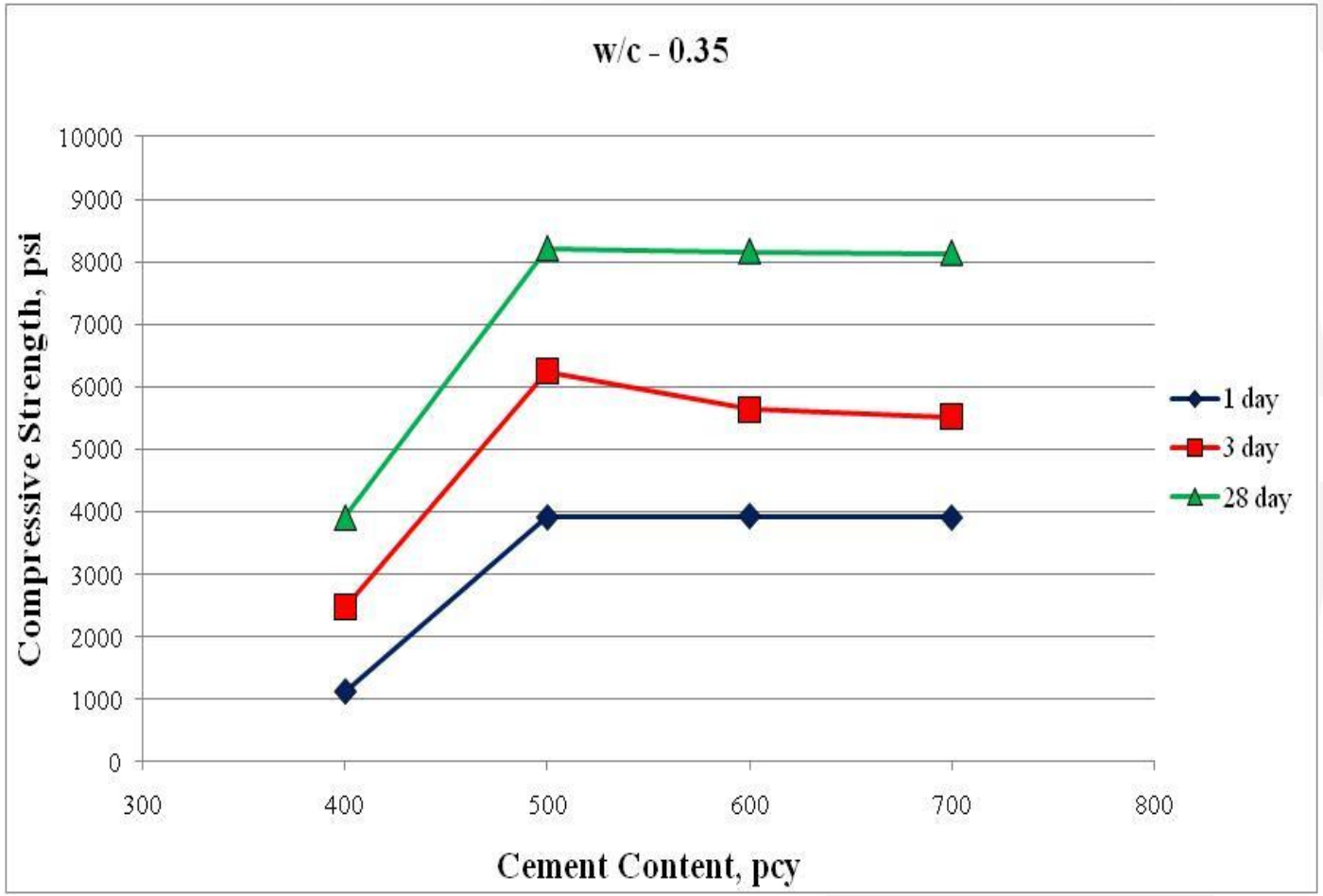
Reduce Cementitious Content in Concrete

- Use optimized aggregate grading to maximize aggregate content



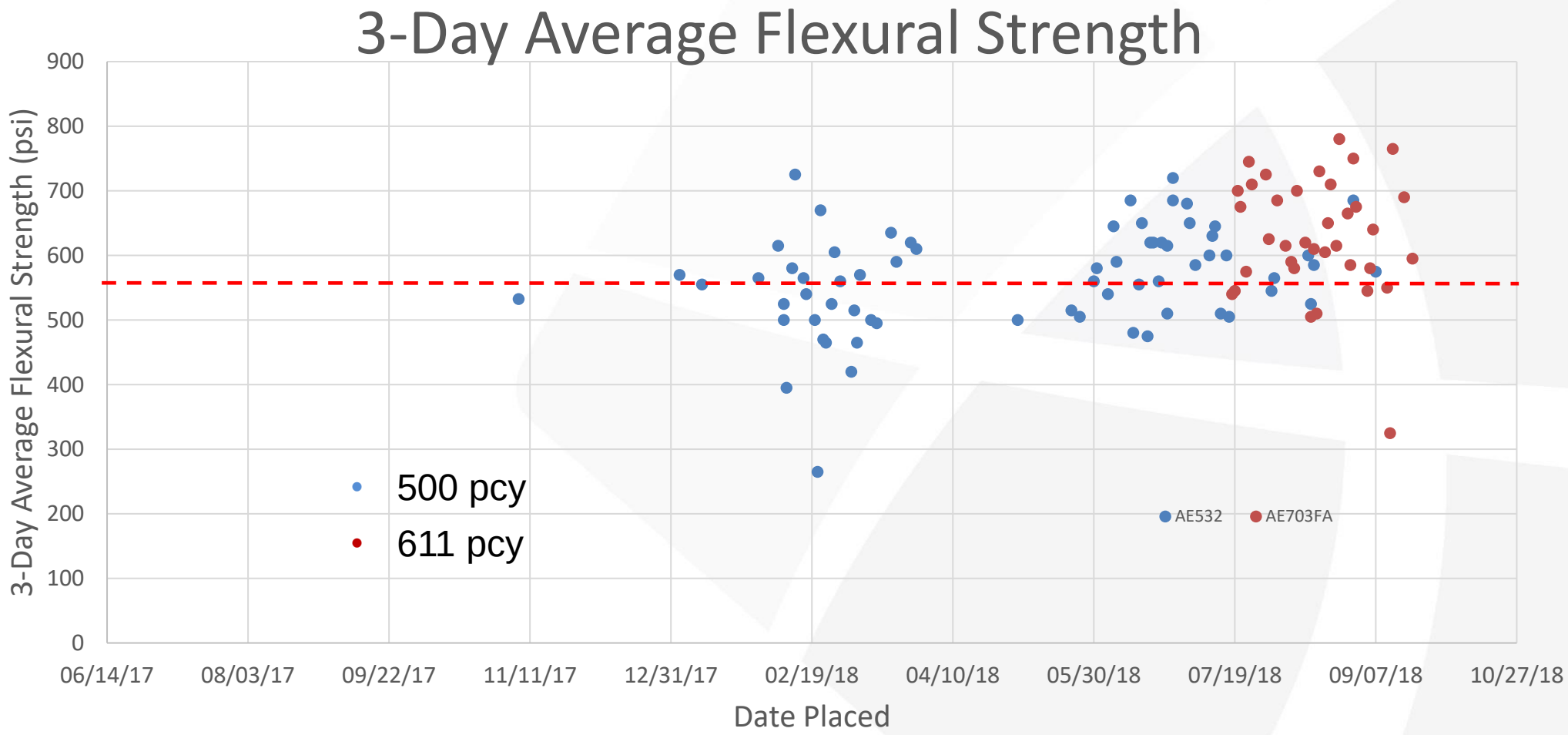
Tarantula curved based on Tyler Ley et al.

A Common Fallacy: Increasing Cement Content Increases Strength

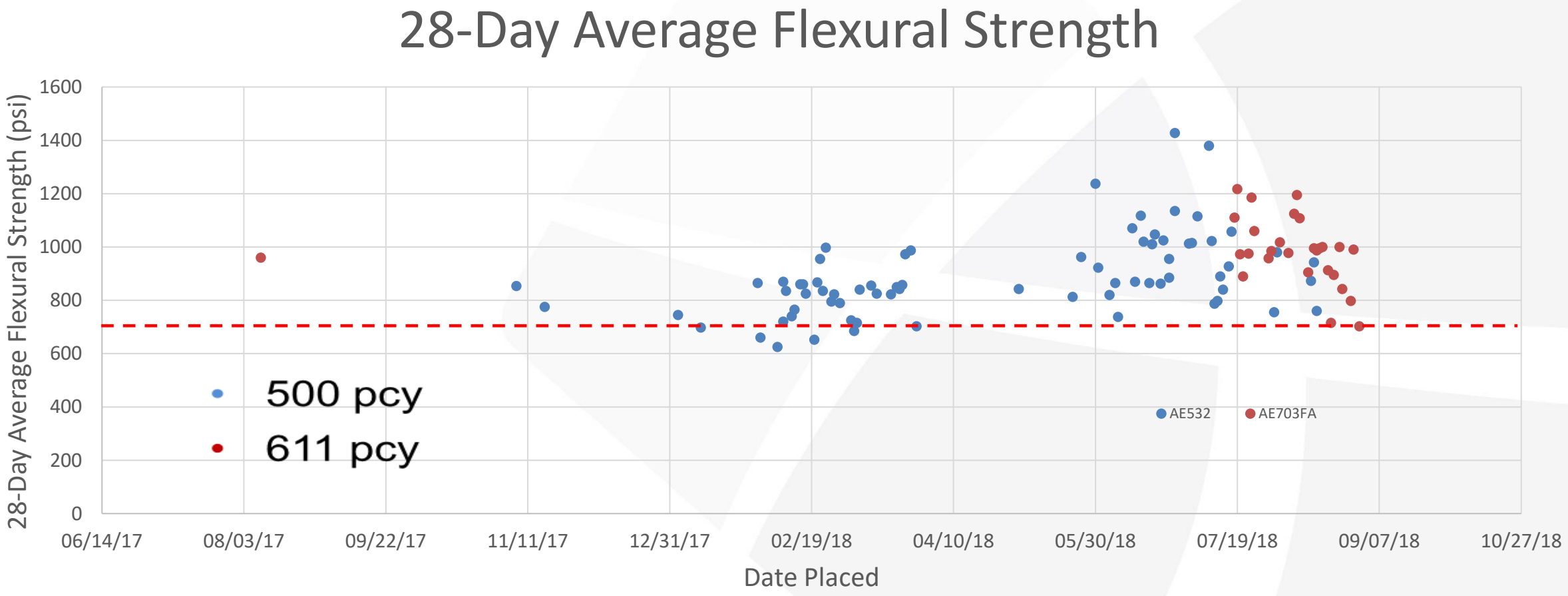


Based on Taylor and Wilson

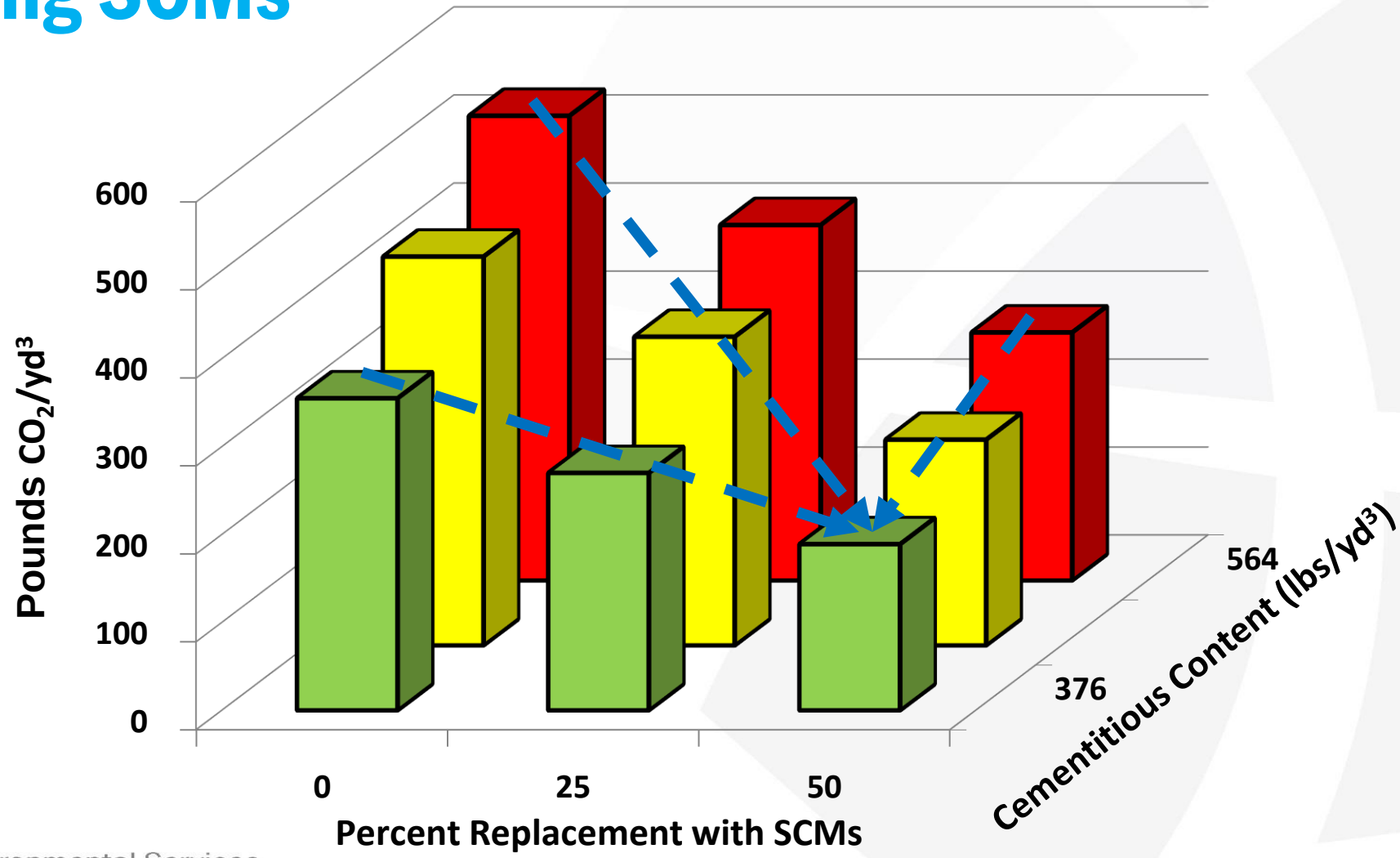
Real Data from Project NEON in Las Vegas



Project NEON Concrete



Reducing GHG Emissions by Minimizing Cement Content and Increasing SCMs



AC 150/5370-10H Item P-501

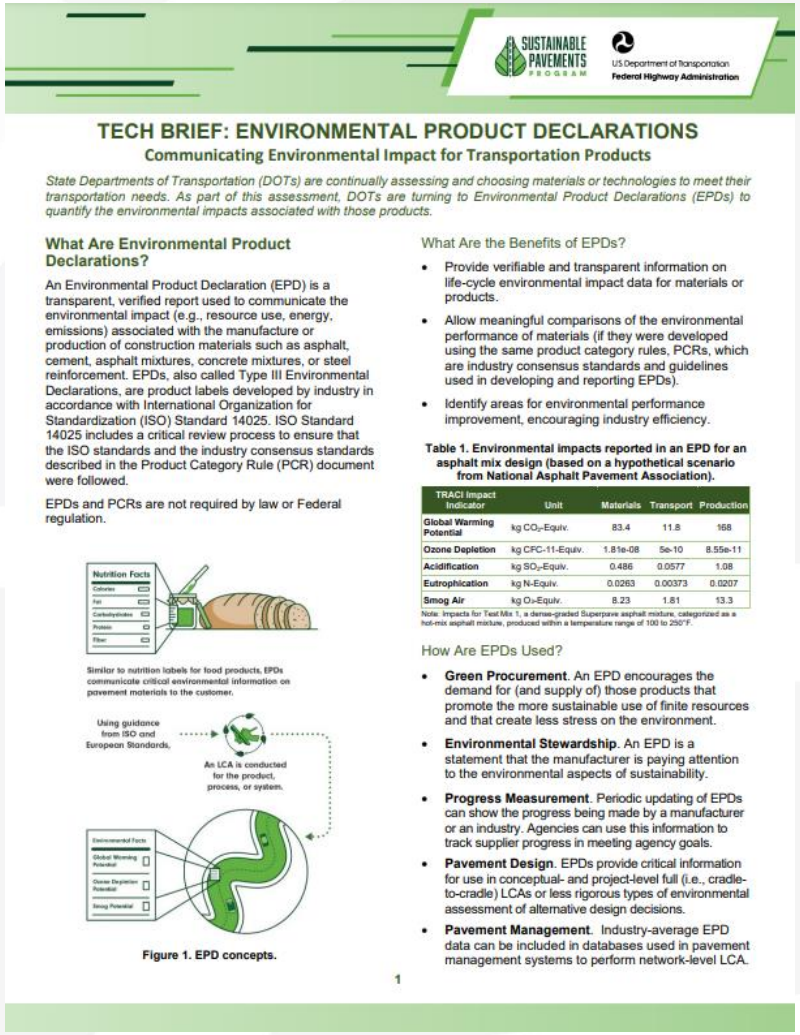
- Allows blended cement and several SCMs
  - Does not allow ASTM C595 IT, but may be specified with concurrence of FAA
  - Class F fly ash with < 15% CaO and Class N natural pozzolan with LOI < 6%
    - Both with total alkalis < 3%
    - Total replacement rate of between 20% and 30% unless used with slag cement, then 10% maximum
  - Slag cement between 25% and 55% of total cementitious
- Total cementitious content 470 pcy in non-freeze areas and 517 pcy where severe F-T, deicers, or sulfate exposure is expected
    - Can be reduced further with approval of FAA

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

Environmental Product Declarations EPD?

- EPDs communicate potential environmental impacts of a product or process
- ISO has established processes that use life-cycle assessment (LCA) methods to develop Type III declarations = EPDs
- EPDs are preferred because they provide a high level of confidence as the information provided has followed a standardized and transparent scientific process



SUSTAINABLE PAVEMENTS PROGRAM
U.S. Department of Transportation
Federal Highway Administration

TECH BRIEF: ENVIRONMENTAL PRODUCT DECLARATIONS

Communicating Environmental Impact for Transportation Products

State Departments of Transportation (DOTs) are continually assessing and choosing materials or technologies to meet their transportation needs. As part of this assessment, DOTs are turning to Environmental Product Declarations (EPDs) to quantify the environmental impacts associated with those products.

What Are Environmental Product Declarations?

An Environmental Product Declaration (EPD) is a transparent, verified report used to communicate the environmental impact (e.g., resource use, energy, emissions) associated with the manufacture or production of construction materials such as asphalt, cement, asphalt mixtures, concrete mixtures, or steel reinforcement. EPDs, also called Type III Environmental Declarations, are product labels developed by industry in accordance with International Organization for Standardization (ISO) Standard 14025. ISO Standard 14025 includes a critical review process to ensure that the ISO standards and the industry consensus standards described in the Product Category Rule (PCR) document were followed.

EPDs and PCRs are not required by law or Federal regulation.

Similar to nutrition labels for food products, EPDs communicate critical environmental information on pavement materials to the customer.

Using guidance from ISO and European Standards,

An LCA is conducted for the product, process, or system.

Figure 1. EPD concepts.

What Are the Benefits of EPDs?

- Provide verifiable and transparent information on life-cycle environmental impact data for materials or products.
- Allow meaningful comparisons of the environmental performance of materials (if they were developed using the same product category rules, PCRs, which are industry consensus standards and guidelines used in developing and reporting EPDs).
- Identify areas for environmental performance improvement, encouraging industry efficiency.

Table 1. Environmental impacts reported in an EPD for an asphalt mix design (based on a hypothetical scenario from National Asphalt Pavement Association).

TRACI Impact Indicator	Unit	Materials	Transport	Production
Global Warming Potential	kg CO_2-Equiv.	83.4	11.8	168
Ozone Depletion	kg CFC-11-Equiv.	1.81e-08	5e-10	8.55e-11
Acidification	kg SO_2-Equiv.	0.486	0.0577	1.08
Eutrophication	kg N-Equiv.	0.0263	0.00373	0.0207
Smog Air	kg O_3-Equiv.	8.23	1.81	13.3

Note: Impacts for Test Mix 1, a dense-graded Superpave asphalt mixture, categorized as a hot-mix asphalt mixture, produced within a temperature range of 100 to 250°F.

How Are EPDs Used?

- **Green Procurement**. An EPD encourages the demand for (and supply of) those products that promote the more sustainable use of finite resources and that create less stress on the environment.
- **Environmental Stewardship**. An EPD is a statement that the manufacturer is paying attention to the environmental aspects of sustainability.
- **Progress Measurement**. Periodic updating of EPDs can show the progress being made by a manufacturer or an industry. Agencies can use this information to track supplier progress in meeting agency goals.
- **Pavement Design**. EPDs provide critical information for use in conceptual- and project-level full (i.e., cradle-to-cradle) LCAs or less rigorous types of environmental assessment of alternative design decisions.
- **Pavement Management**. Industry-average EPD data can be included in databases used in pavement management systems to perform network-level LCA.

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https://www.fhwa.dot.gov/pavement/sustainability/hif19087.pdf

Development of EPDs

Adapted from N. Santero
by John Harvey

PCR: the framework

Product Category Rule (PCR)

"Set of specific rules, requirements, and guidelines for developing Type III environmental product declarations for one or more product categories" (ISO 14025)

LCA: the analysis

Life Cycle Assessment (LCA)

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040)

EPD: the declaration

Environmental Product Declaration (EPD)

"Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information" (ISO 14025) as defined in a PCR which is based on LCA

Example: Specific 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

Current Initiative: MnROAD Reduced GHG Emissions Test Site

- A test site is under development at MnROAD to evaluate strategies to reduce GHG emission in concrete paving
- 16 test cells
  - 1 control cell
  - 3 carbon mineralization cells
  - 1 optimized concrete
  - 6 alternative SCM cells
  - 5 alkali-activated cements
- Construction scheduled for summer 2022

Summary

- Sustainable concrete pavement practices are available for Airports
  - Sustainable solutions require a life cycle perspective
  - Evaluating cradle to construction only will result in short-sighted decisions
- Strive to optimize your cement and concrete
- Use rigorous verification to avoid “greenwashing”
- As an industry, the future is bright

Questions?

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