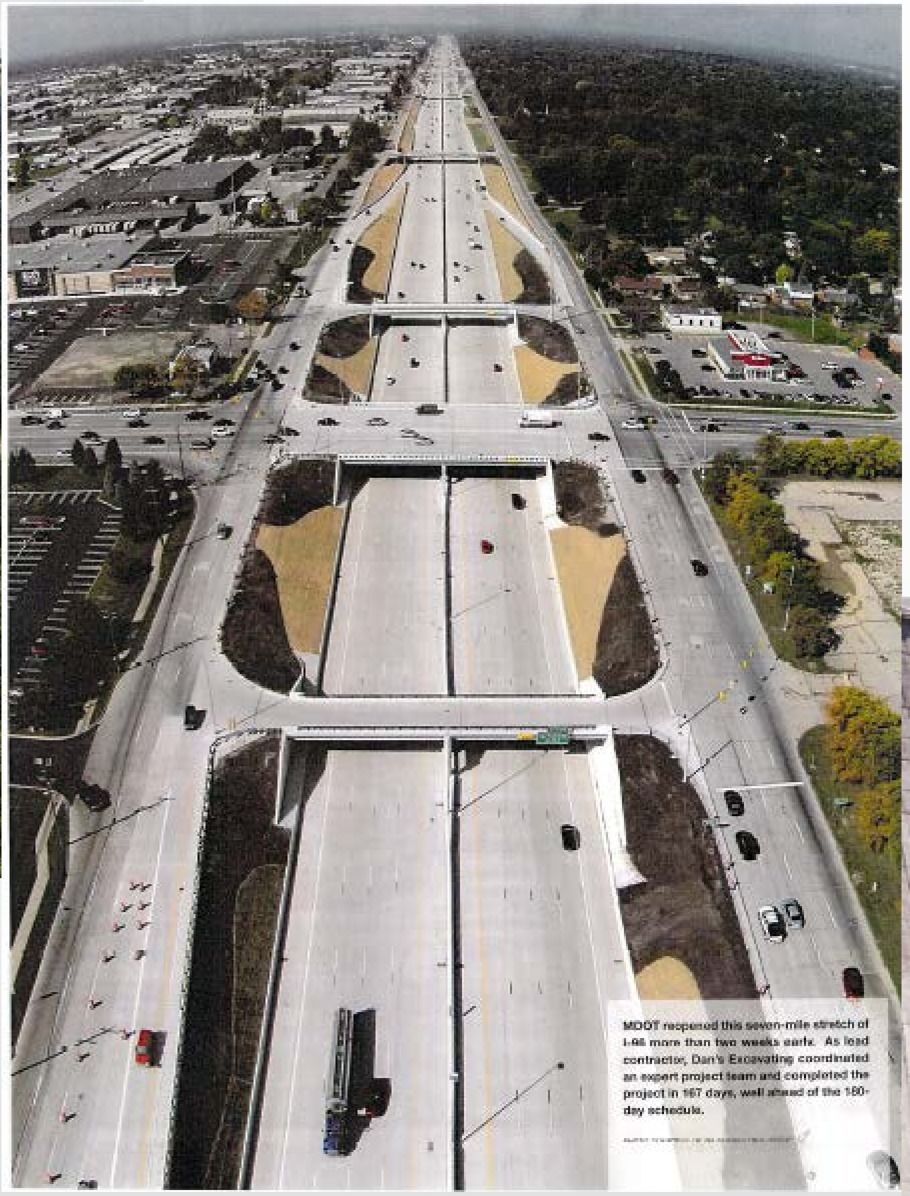
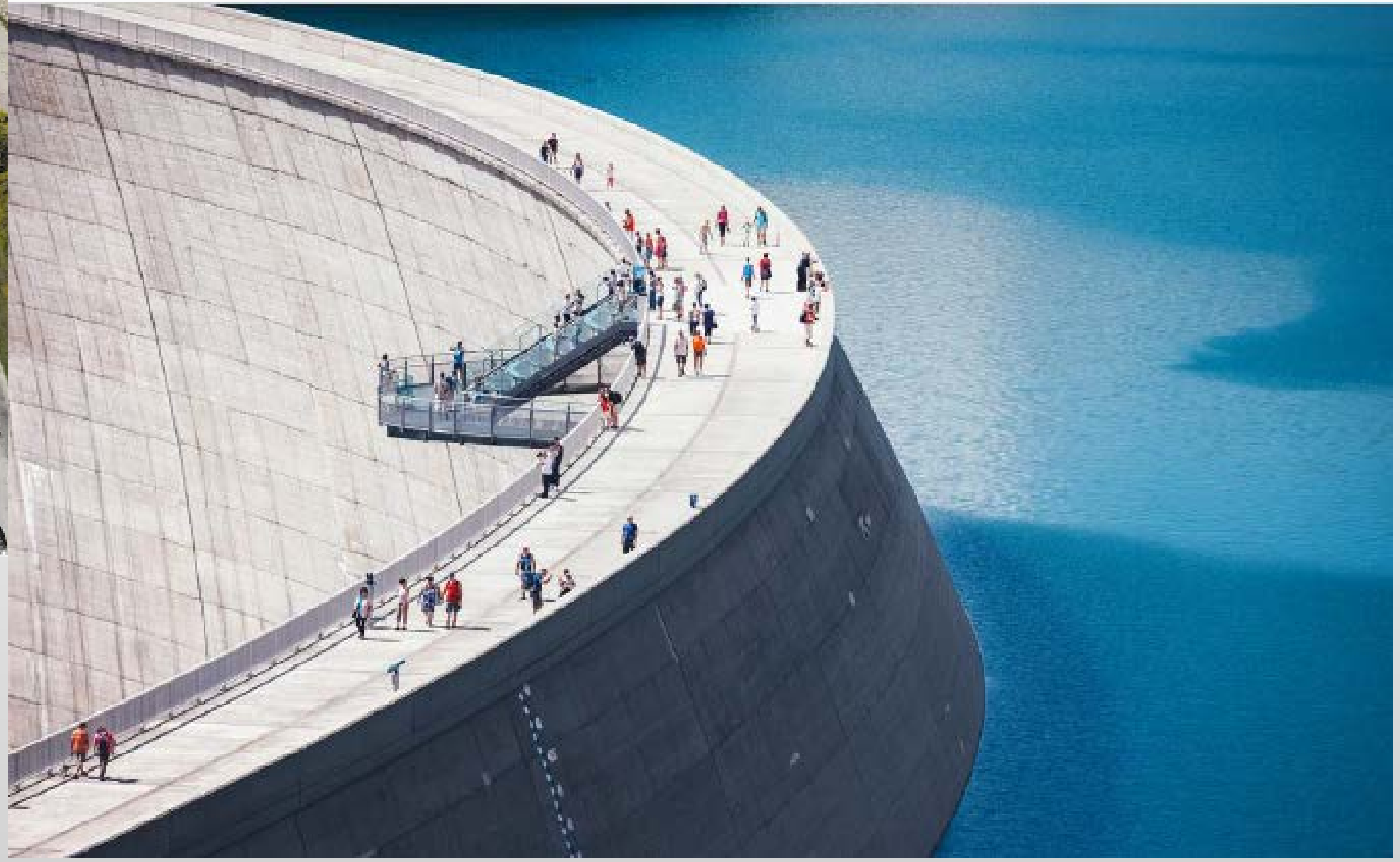
plc
portland-limestone cement

Reducing Concrete's Carbon Footprint using Portland-Limestone Cements

Ohio Concrete - November 2, 2021

We can’t live without concrete…

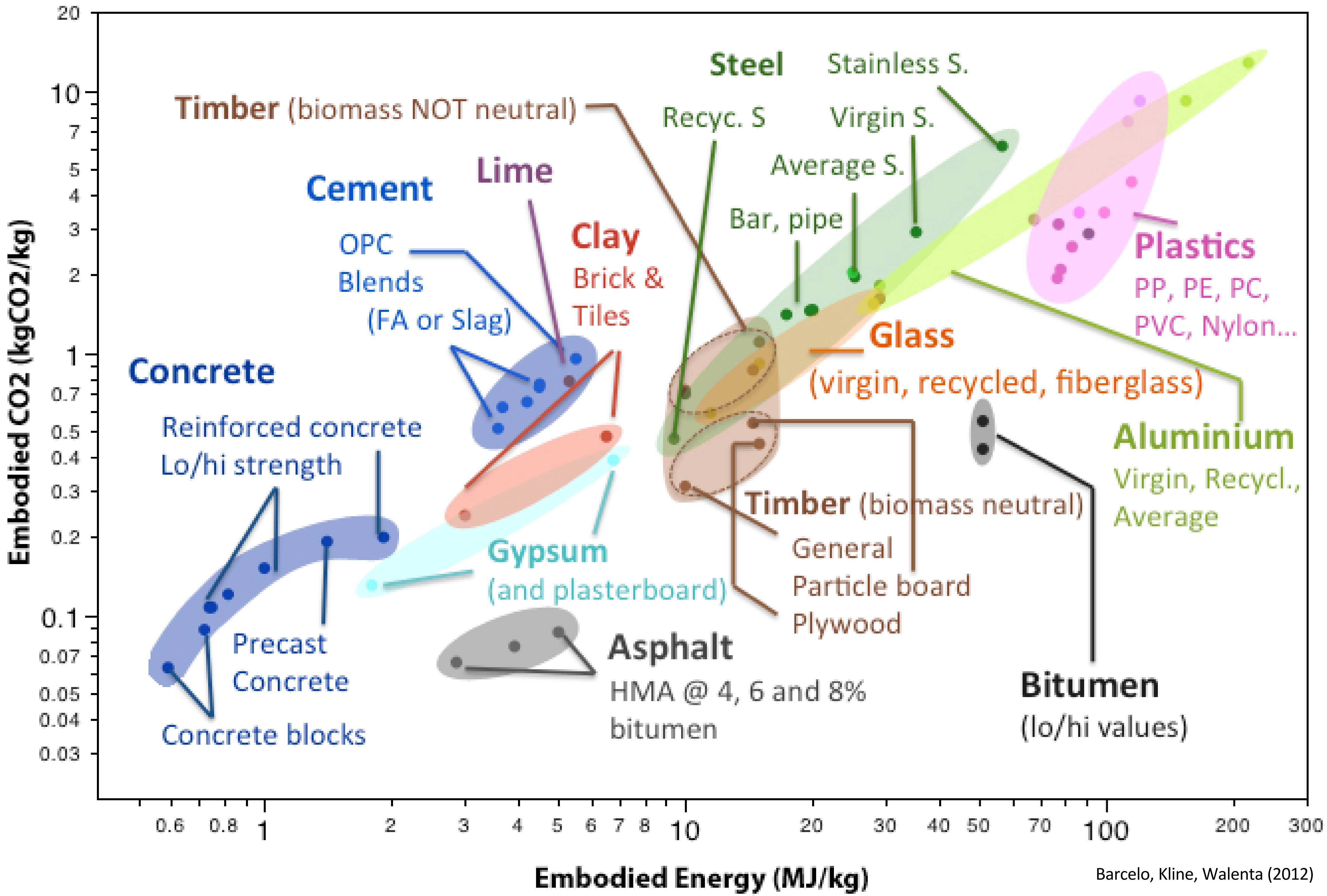




PCA Since 1916 America's Cement Manufacturers™

plc portland-limestone cement www.greenercement.org

Concrete is Environmentally Friendly



Barcelo, Kline, Walenta (2012)

PCA 2050 Roadmap to Carbon Neutrality

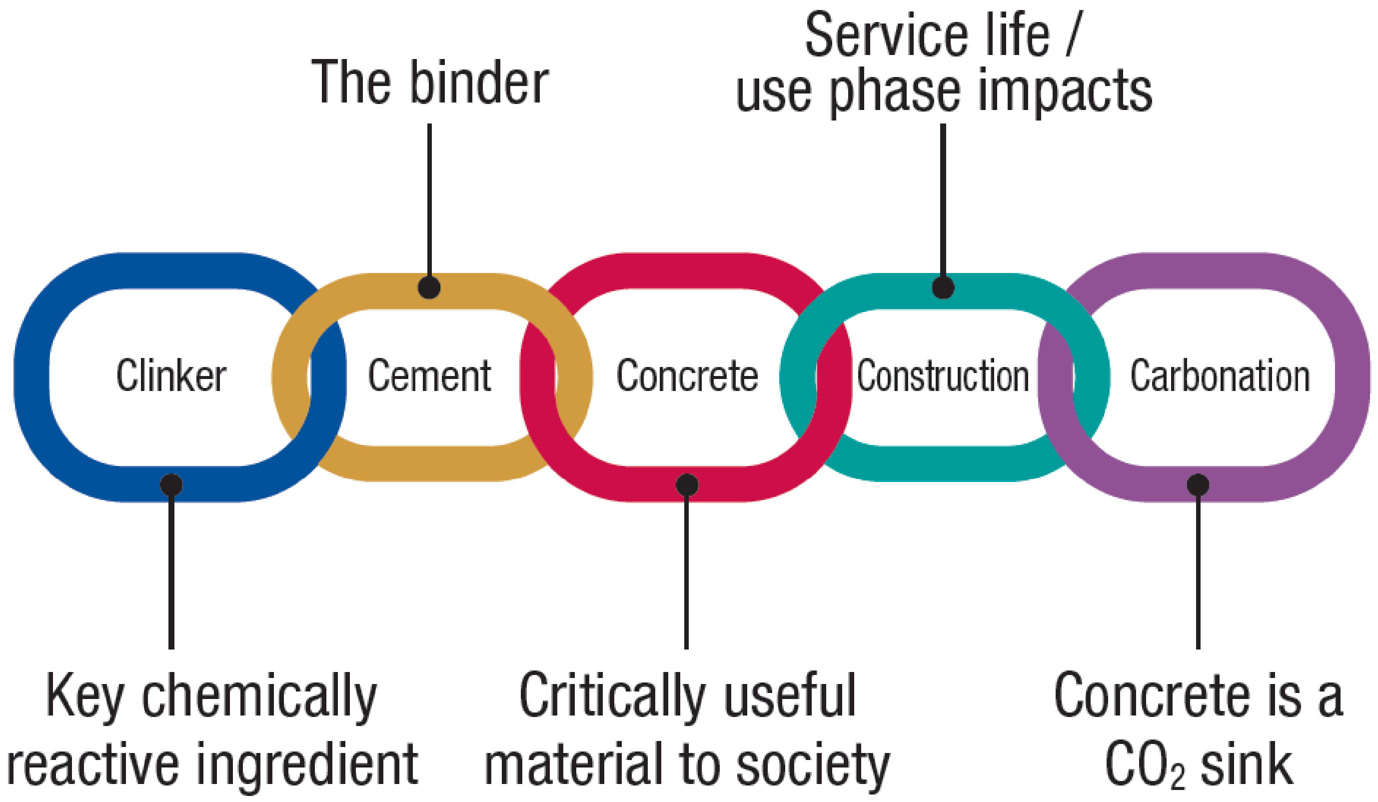
CO2 and Sustainability

Increased pressure to reduce our environmental impact from many groups: designers, regulators, even the public

Concrete is so essential to the way we live, that our industry must do its part to address climate issues

Blended cements can help position concrete as more sustainable

Roadmap executive summary



PLC is a Key Lever for the Roadmap

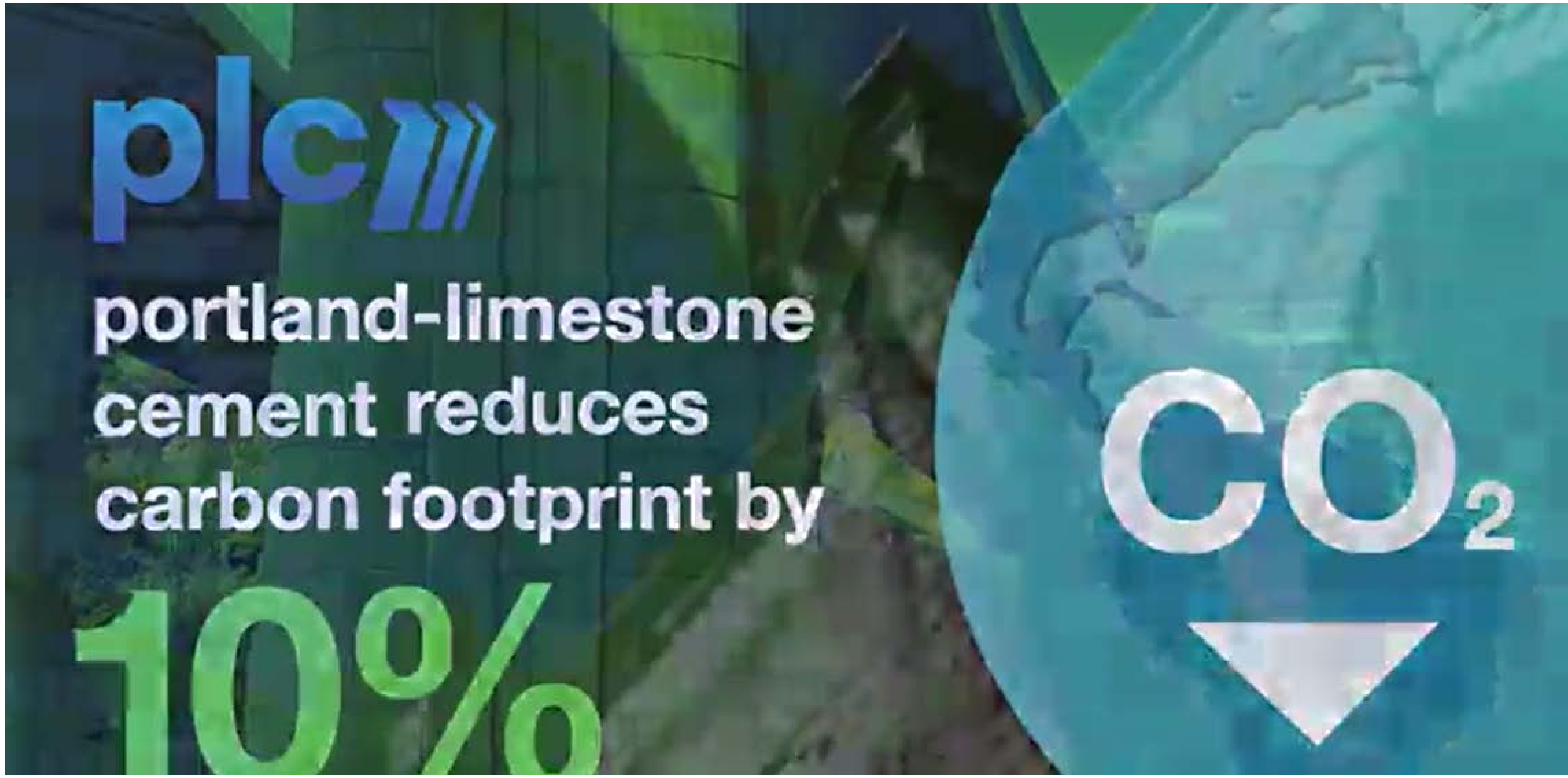
CO2 Footprint of Construction

CO2 problem?

CO2 opportunity!

PLC is proven technology

PLC can help position concrete as more sustainable



What is PLC?

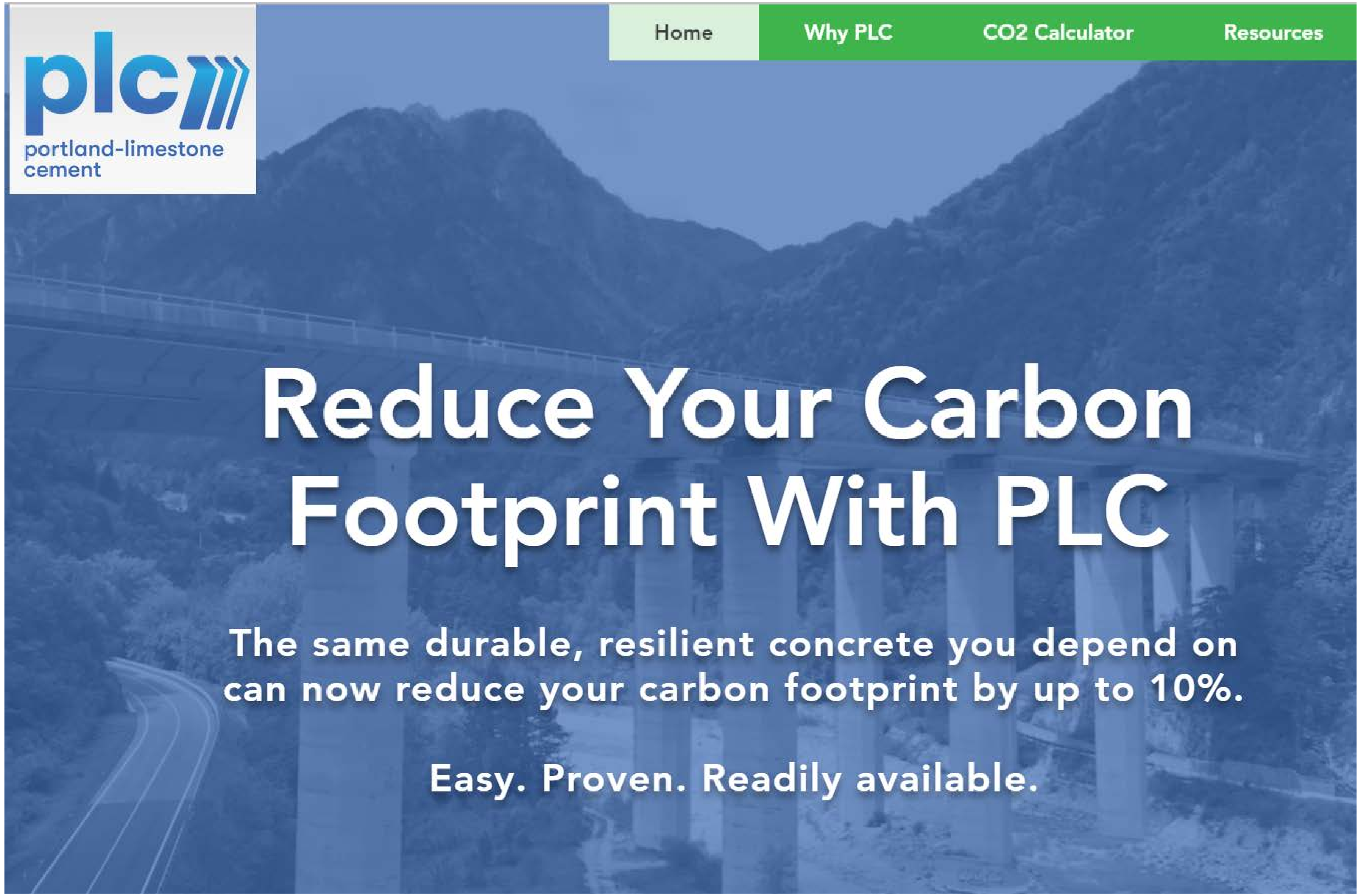
A greener cement option

A blended cement with additional limestone content, optimized for performance

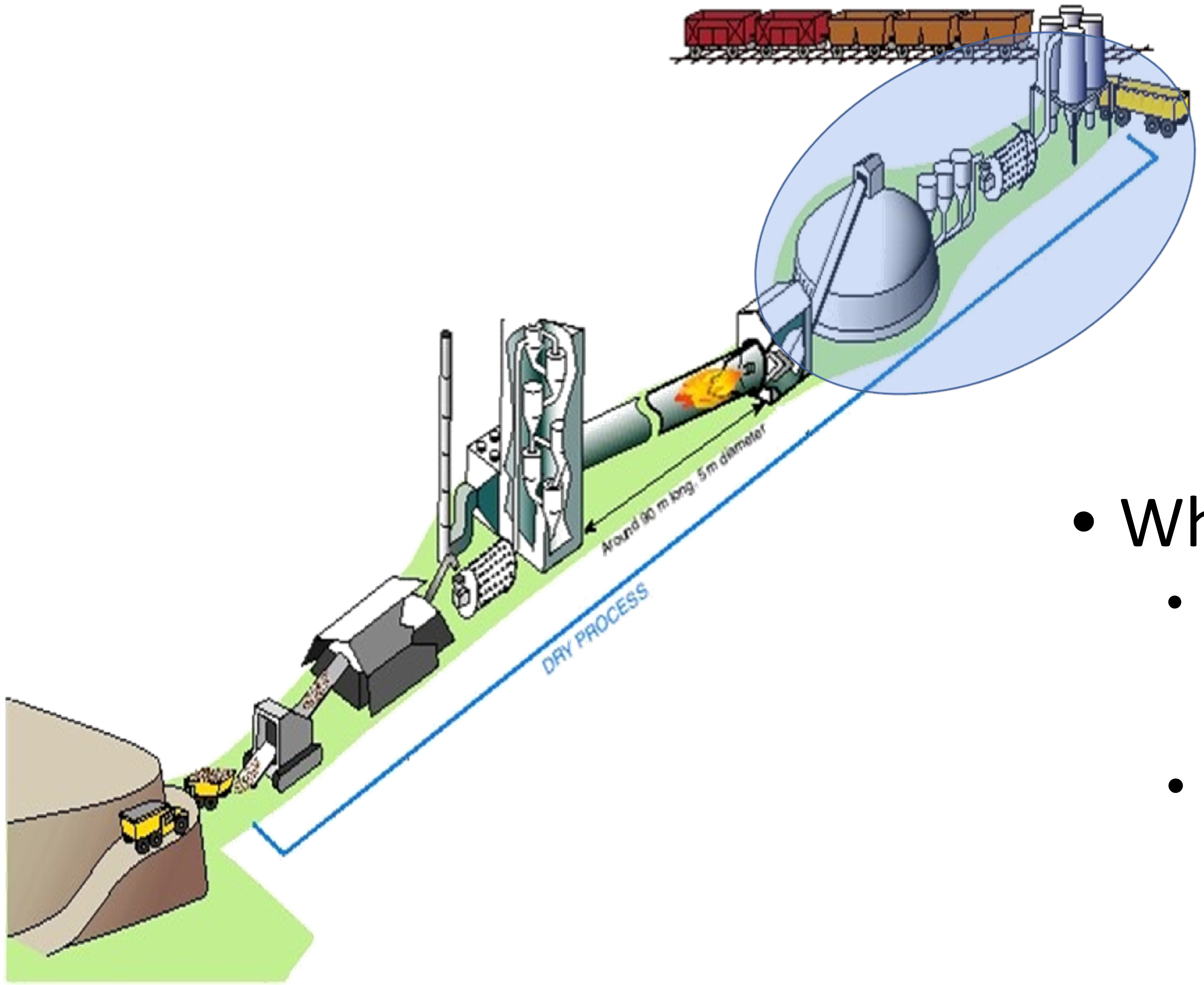
The easiest way to reduce your carbon footprint by up to 10%

Suitable for buildings, bridges, pavements, geotechnical applications

Readily available throughout the U.S. and Canada



Portland-Limestone Cement - How it's Made



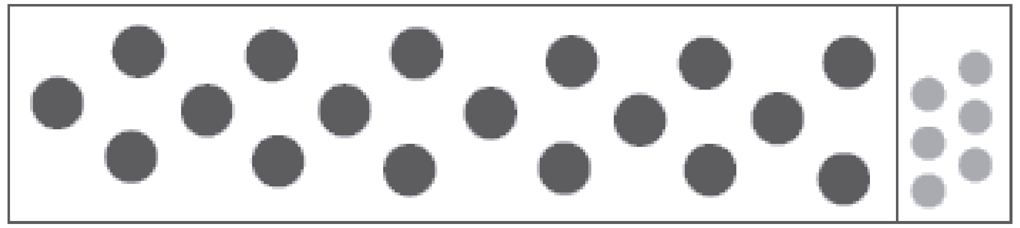
- What is PLC?
  - Type IL blended cement in ASTM C595/AASHTO M 240
    - 5% to 15% limestone by mass
  - Option to implement proven technology to obtain desired performance and improve sustainability of concrete

How is PLC Different?

- PLC is made by blending or inter-grinding regular clinker with up to 15% limestone while regular portland cement contains up to 5% limestone
- PLC is a finer ground product than regular portland cement

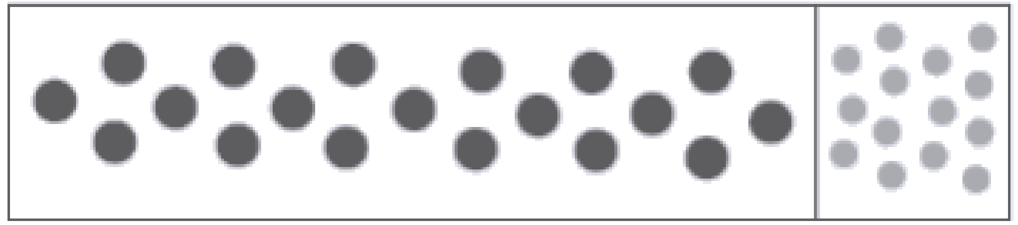
PORTLAND CEMENT

95% Ground Clinker | 5% limestone



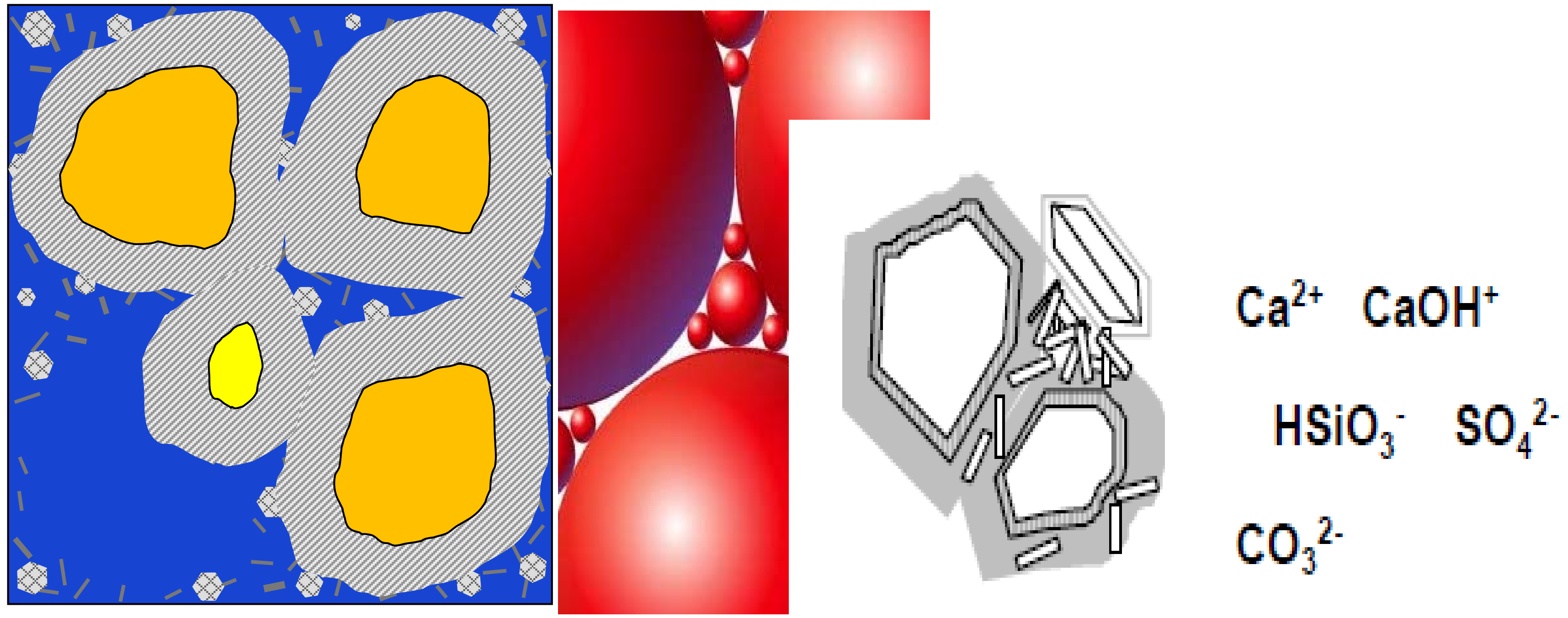
PLC

85% Ground Clinker | 15% limestone



How Limestone Works

- Particle packing
  - Improved particle size distribution
- Nucleation
  - Surfaces for precipitation
- Chemical reactions
  - Only a minor contribution



U.S. Standards

Cementitious Material Standards

C150 portland cement – Types I and I/II, II, III, and V

C595 blended cement – Types IP, IS, **IL**, and IT. Allows for pozzolans, slag cement, limestone

Long Track Record

Portland-Limestone Cements

Europeans introduced in the late 1960s

Canada has used them since 2008

U.S. introduced them in 2012

Confidence in PLC is growing

U.S. is currently more 1 MMT/year

Products on the Ohio DOT Certified List

Suppler	Plants
Ash Grove	Joliette QC, Mississauga ON
Fairborn Cement	Fairborn OH
Continental Cement	Davenport IA
Lehigh Cement Company	Logansport IN, Mason City IA, Mitchell IN, Picton ON, Speed IN
Roanoke Cement Co.	Trout Ville VA
St Marys Cement	Bowmanville ON, Detroit MI
(currently undergoing initial ODOT certification approval process)	Charlevoix MI, St Marys ON

Mix Designs with PLC

Proportioning, batching, and mixing

PLC replaces ordinary portland cement at 1:1 ratio

PLC allows for the same dosages of fly ash or other pozzolans, slag cement

As with any new material, some testing is warranted to confirm effect fresh and hardened properties

- Air content, slump, bleed potential, setting time, compressive strength

Some producers report no adjustments are needed, others tweak proportions or adjust admixture dosages

Mix Designs with PLC

Typical effects on fresh and hardened properties

Workability	Increase or decrease No significant effect on admixtures
Bleeding	Decreases with increasing fineness Generally of no concern
Setting time (initial, final)	Can be slight decrease w/increasing fineness Not a concern even up to 15% limestone
Heat of hydration	Slight increase at early ages (up to 48 hours) But less significant at later ages
Compressive strength	Can increase slightly Both early-age and long-term strengths
Scaling and freeze-thaw resistance	Use same techniques as with OPC concrete mixes: Proper air-void systems, curing, higher strengths
Sulfate resistance	Use same techniques as with OPC concrete mixes: Low w/cm, min. strength, and MS or HS designations

PLC for Special Properties

Cement modifiers

- Sulfate resistance – MS, HS
  - Sulfate-containing soils
  - Sulfate-containing groundwaters
- Heat of hydration – LH, MH
  - For mass concrete placements
  - No counterparts in CSA
- High-early strength – HE
  - For precast concrete
  - New in August 2021

Cement type	OPC C150 (M 85)	PLC C595 (M 240)	PLC CSA A3000
General use	I	IL	GUL, GULb
moderate sulfate resistance	II, II(MS)	IL(MS)	MSL
moderate heat of hydration	II(MH)	IL(MH)	-
high sulfate resistance	V	IL(HS)	HSL
low heat of hydration	IV	IL(LH)	-
high-early strength	III	IL(HE)	HEL, HELb

Working with PLC Mixes

Normal operations for:

Placing

Finishing

Curing

As fineness increases, may see:

- Slightly less bleed water
- Slightly shorter setting times
- Slightly higher water demand

Virtually the same handling and performance as OPC

Performance of PLC Concrete

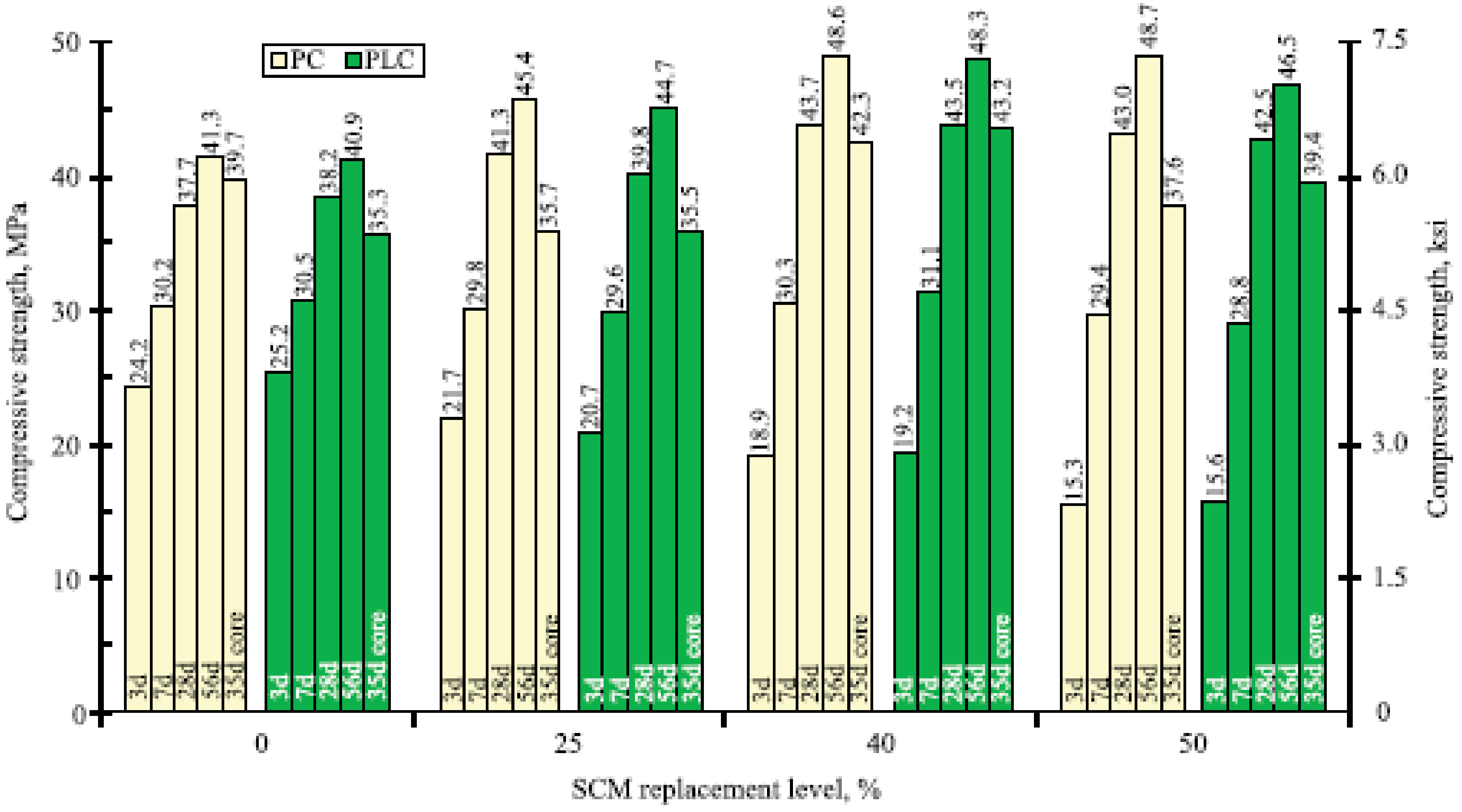
A look at hardened properties

Strength

- OPC to PLC comparisons
- With and without SCMs

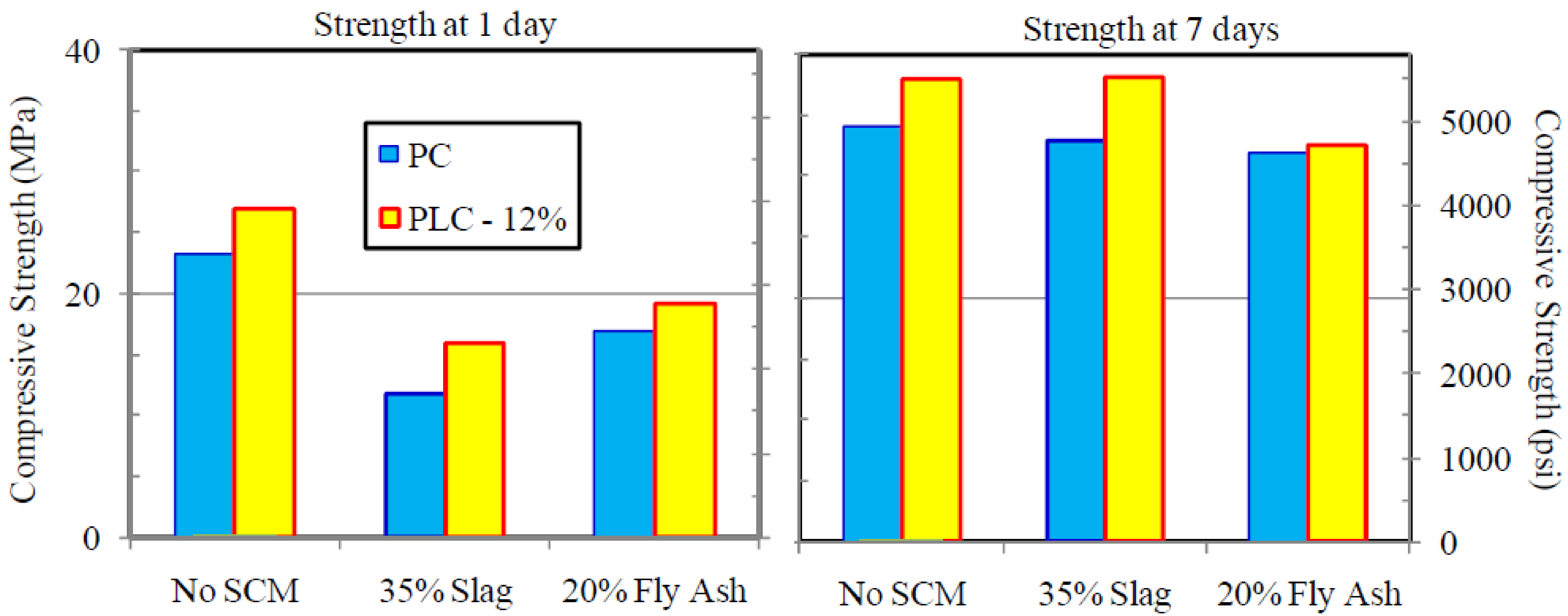
Durability

- Scaling
- Freeze-thaw resistance
- Chloride permeability
- ASR resistance
- Sulfate resistance
- Field trial results



Performance of PLC Concrete

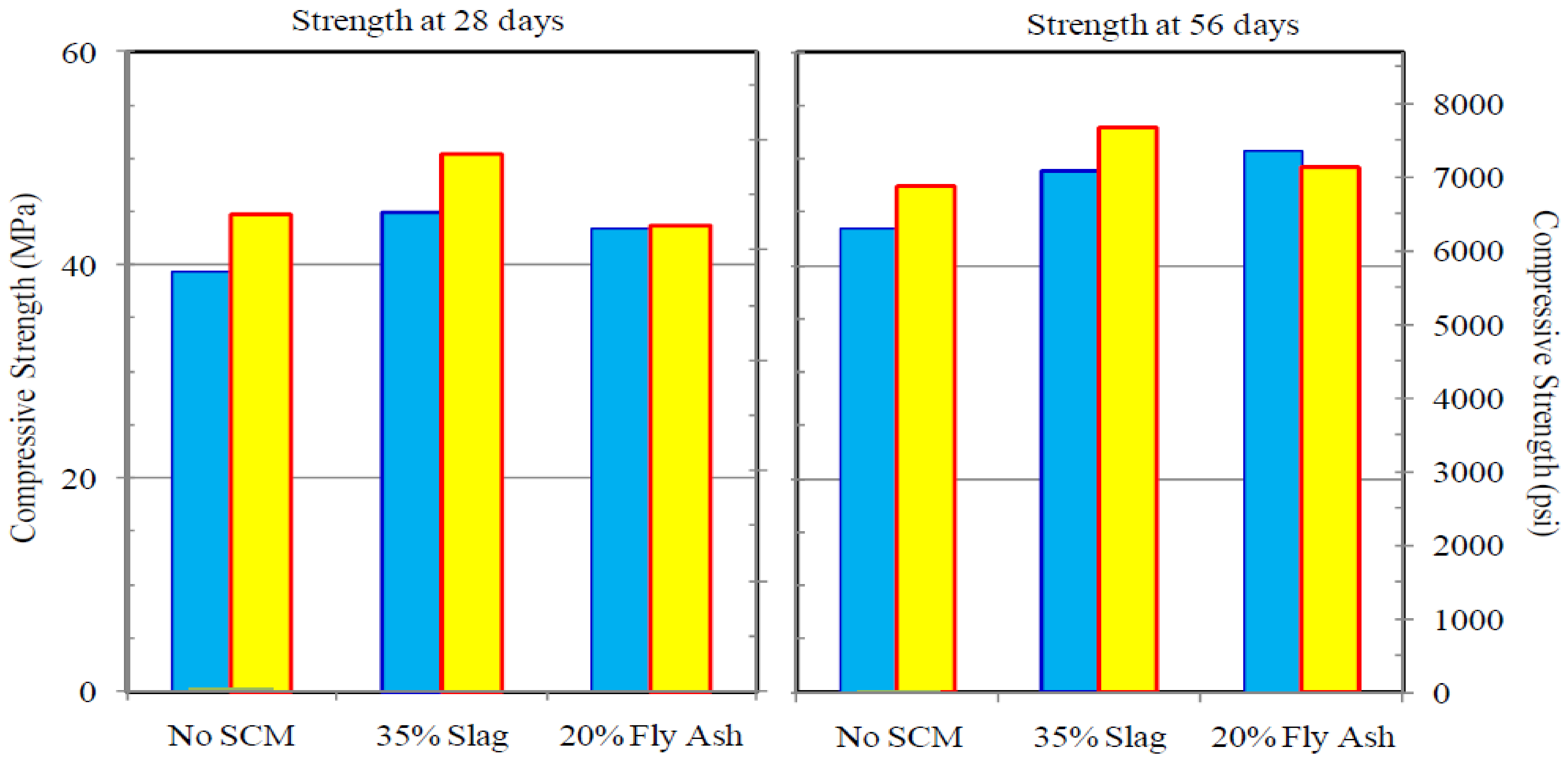
Early age strength development with and without SCMs



Thomas and Hooton 2010

Performance of PLC Concrete

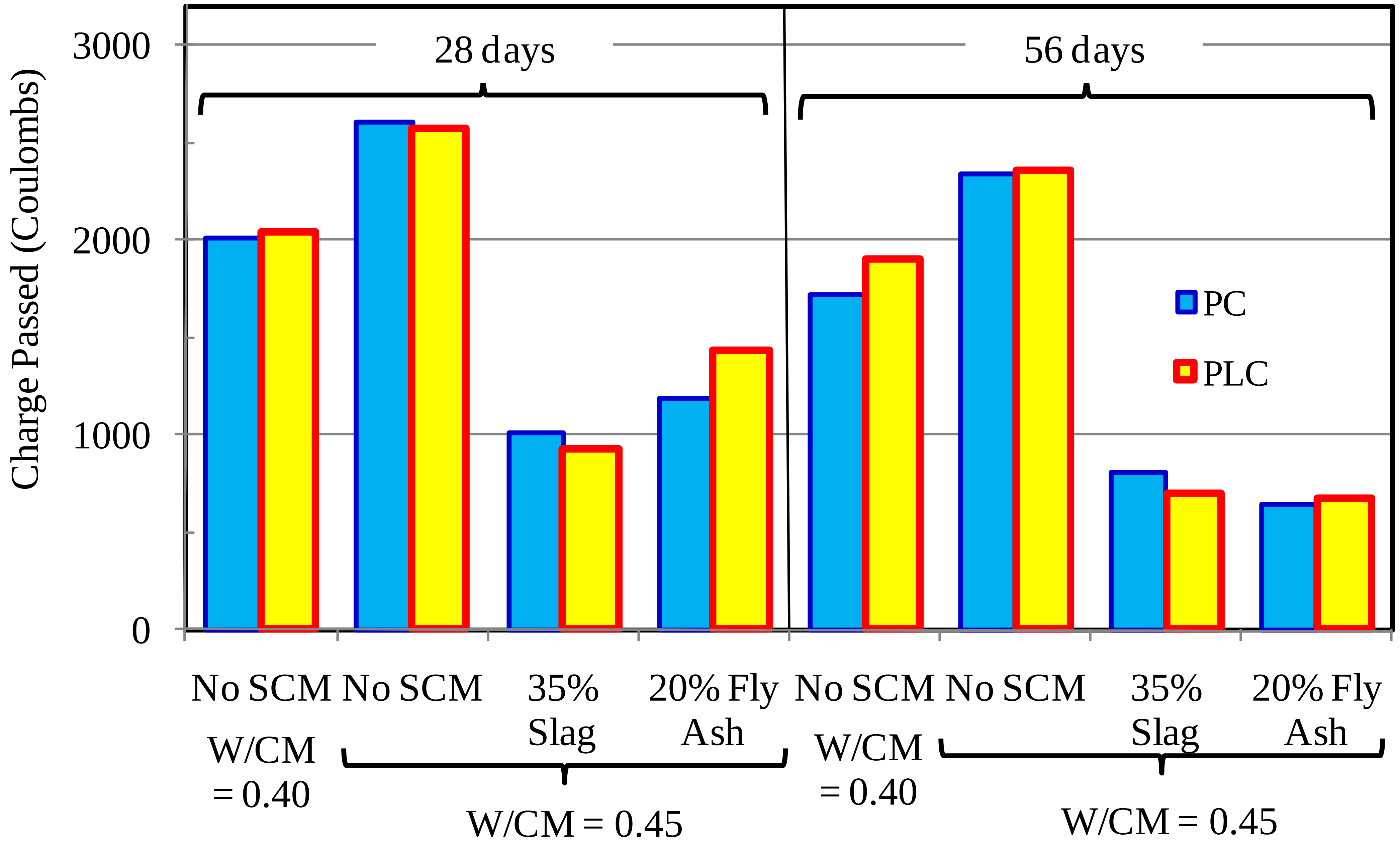
Later age strength development with and without SCMs



Thomas and Hooton 2010

Performance of PLC Concrete

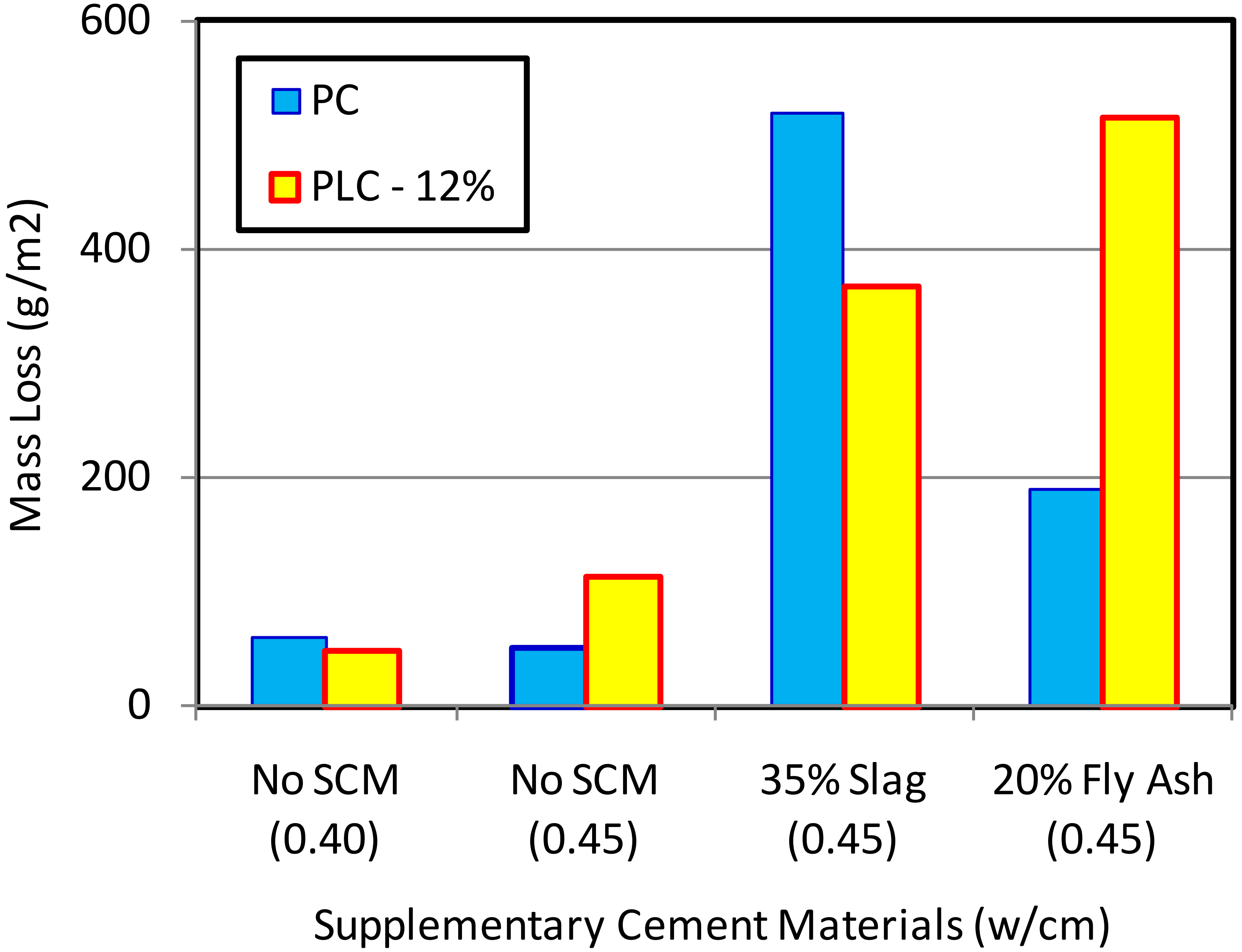
“Permeability” T277/C1202



Thomas and Hooton 2010

Performance of PLC Concrete

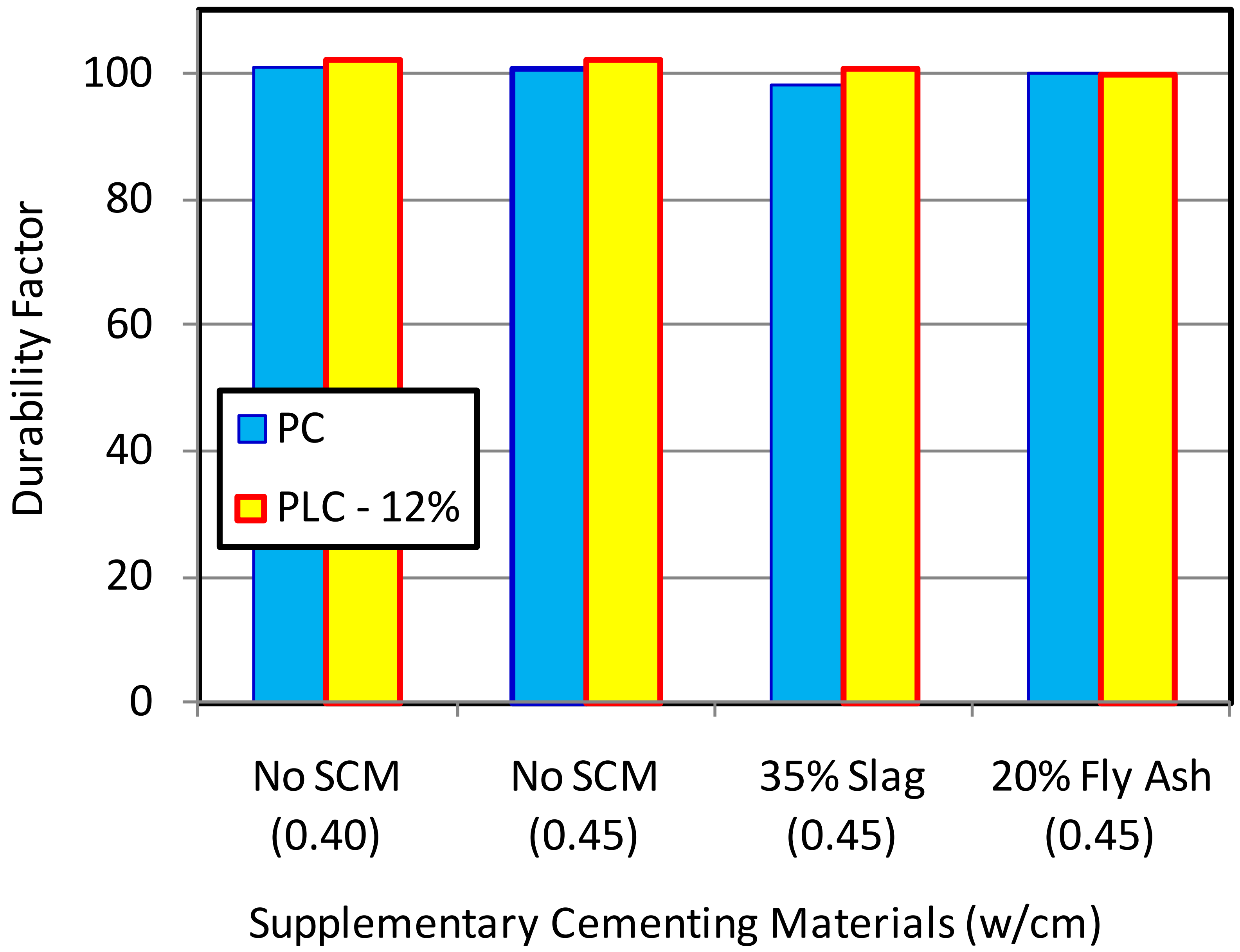
Scaling resistance (ASTM C672)



Thomas et al. 2010

Performance of PLC Concrete

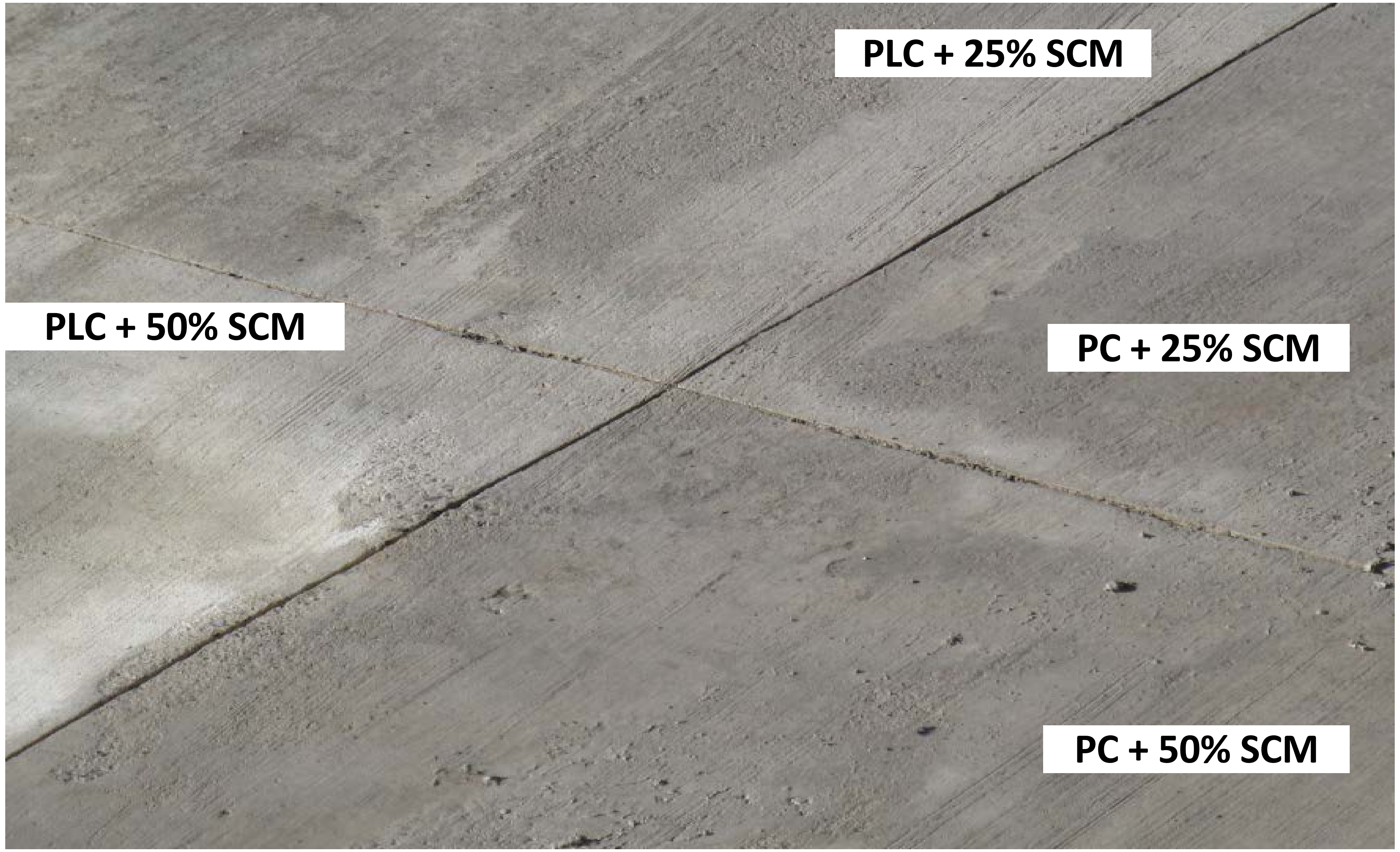
Freeze-Thaw Resistance (ASTM C666)



Thomas et al. 2010

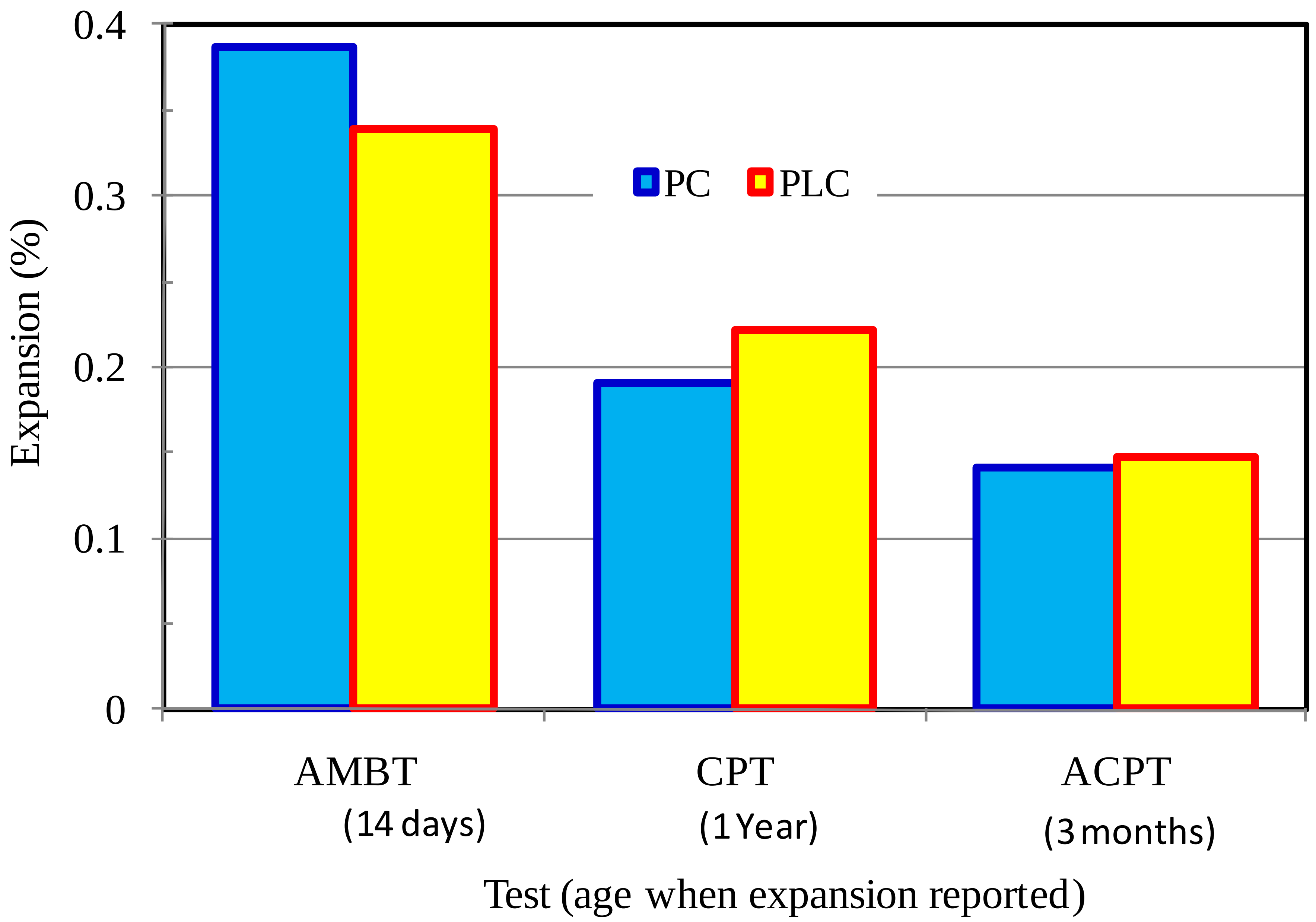
Performance of PLC Concrete

Field Trials: Pavement slab after one winter



Performance of PLC Concrete

ASR resistance



Thomas et al. 2010

PLC and Sulfate Resistance

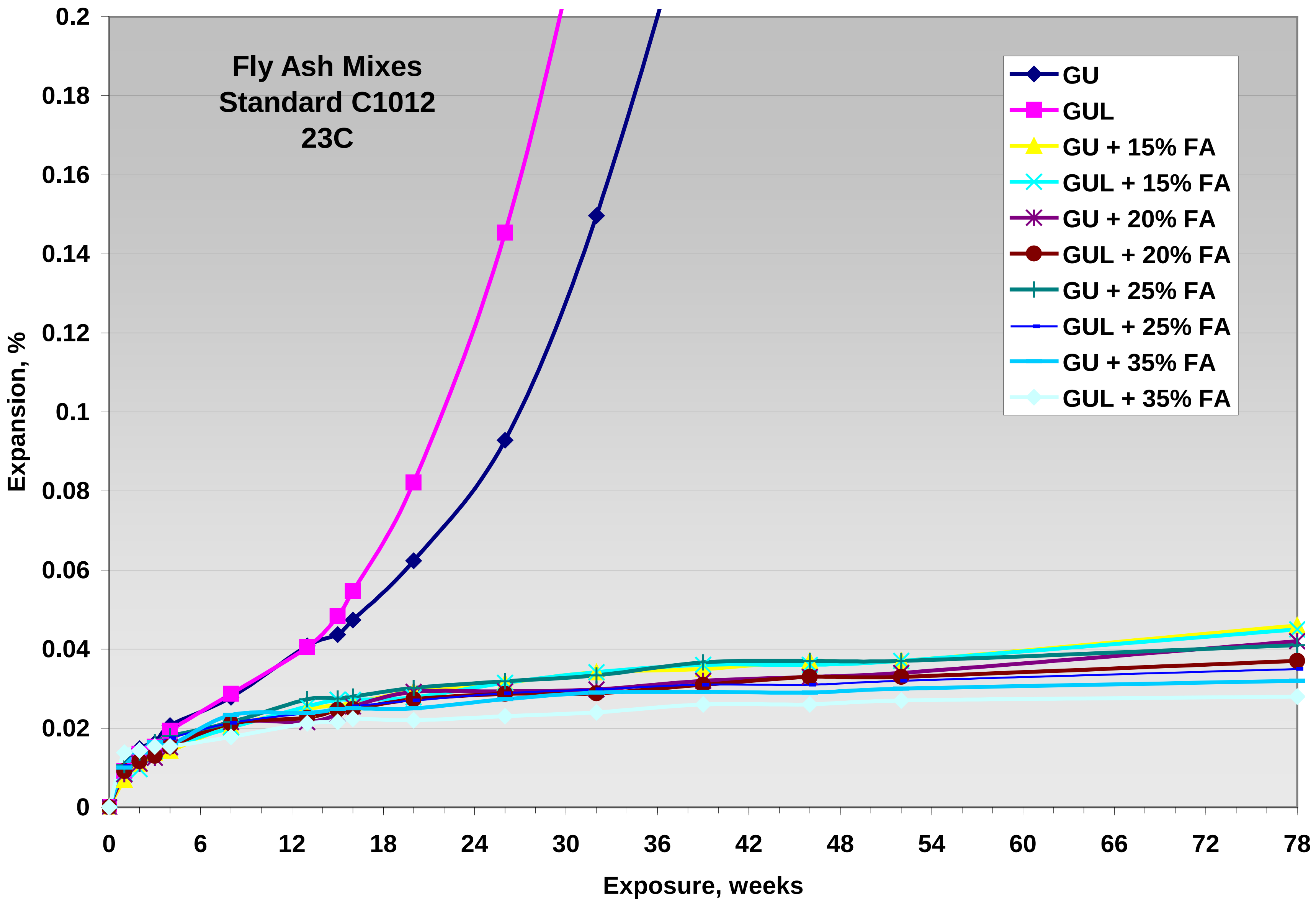
Same approach as for other blended cements

Use additional SCMs and low w/cm

Use moderate- or high-sulfate resistant types:

- Type IL(MS)
- Type IL(HS)
- Type IT(MS)
- Type IT(HS)

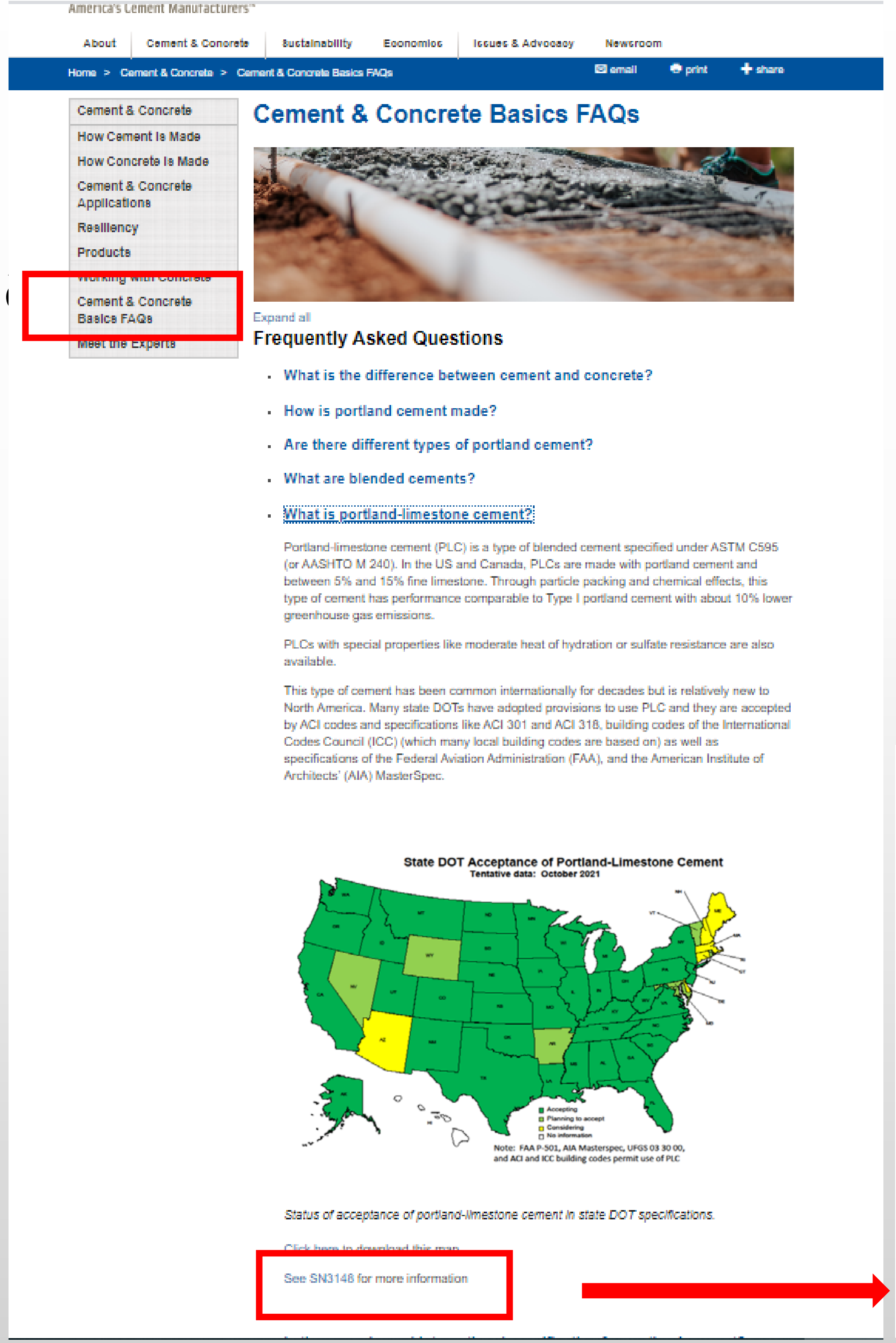
Performance confirmed by numerous research studies and decades of field exposures on real-world installations

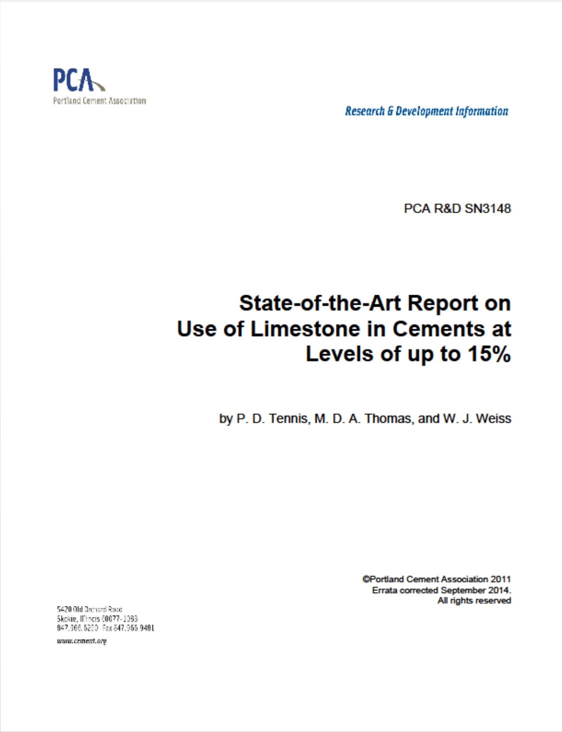


Blair and Delagrave 2012

Hardened Properties

- Summary in PCA Report SN3148 at www.cement.org
- Strength
- Scaling
- Freeze-thaw resistance
- Chloride permeability
- ASR resistance
- Sulfate resistance




PCA
Research & Development Information
PCA R&D SN3148
State-of-the-Art Report on Use of Limestone in Cements at Levels of up to 15%
by P. D. Tennis, M. D. A. Thomas, and W. J. Weiss
©Portland Cement Association 2011
Errata corrected September 2014
All rights reserved

Durability Research

2010- University of Toronto “Vault”

Over 1000 specimens in various storage solutions

PCA Since 1916
America's Cement Manufacturers™

Caltrans Research Confirms PLC Performance

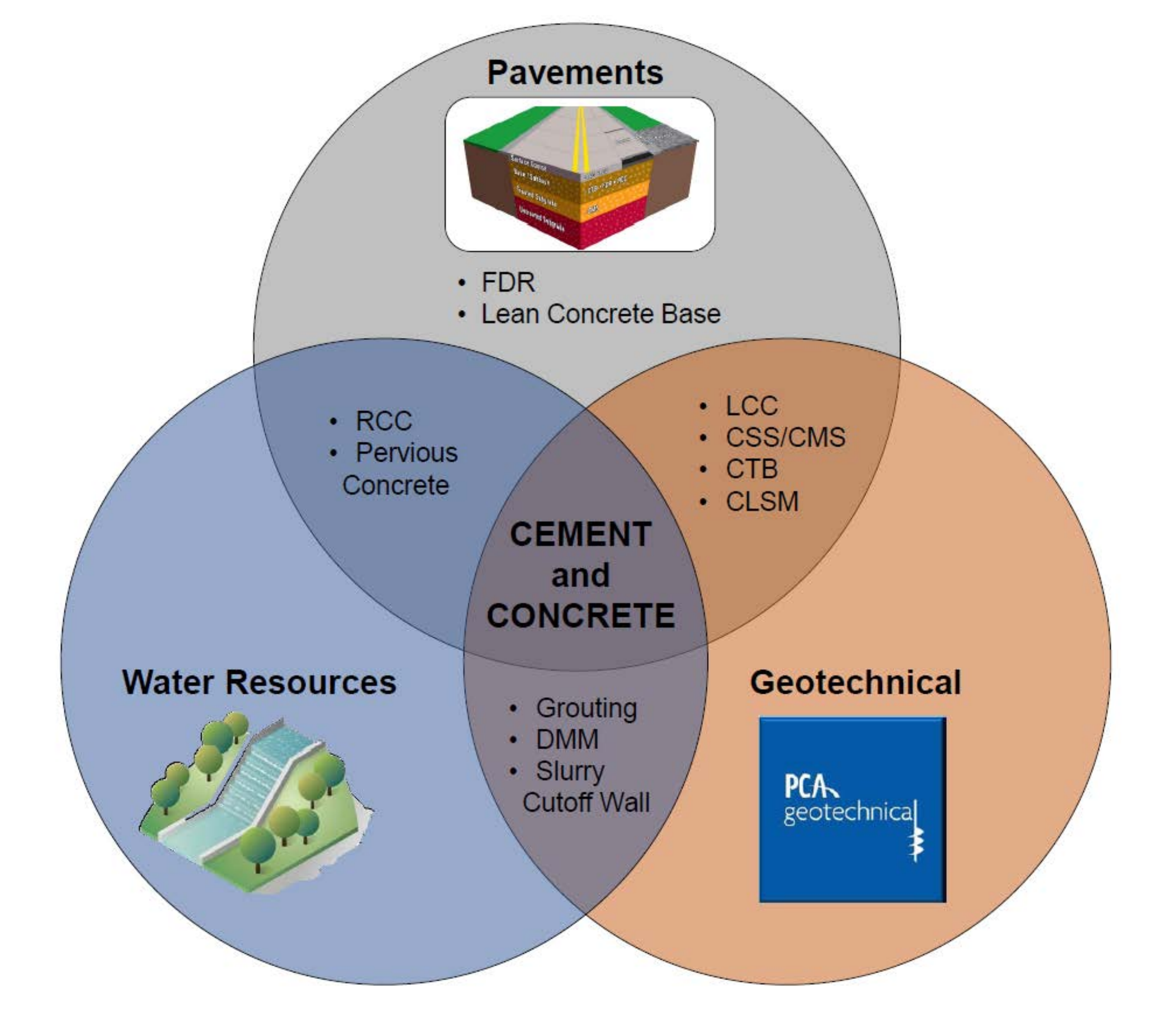
- Provide data to make informed decisions about PLCs
- Oregon State University comprehensive research program on PLC
- "Impact of Use of Portland-limestone Cement on Concrete Performance as Plain or Reinforced Material"
  - Similar set times, shrinkage, bound chloride contents, and time to corrosion initiation
  - Similar or improved ASR performance and sulfate resistance
  - Flexural strength similar to the parent system (-5% to +13%)
- Due to these positive results, Caltrans updated its specs in October 2021 (exclude FDR for now)

Caltrans

Oregon State University

PCA Research into PLC Soil-Cement

- PCA conducting research on PLC for soil-cement materials
- Supports many of the markets shown
- Direct comparisons of PLC with OPC (Type I/II)
- Testing complete, report being prepared
  - Cohesive and cohesionless soils, and aggregate base materials



Procuring PLC Concrete

Basics of specifying and ordering

A simple revision to specifications: 1:1 replacement of OPC with PLC

Same suppliers for your ready mix

Same delivery and placing equipment

National, Model, and State Specs

Type IL cements permitted in:

AIA MasterSpec 033000 Cast-in-Place Concrete

FAA P-501 Portland Cement Concrete Pavement

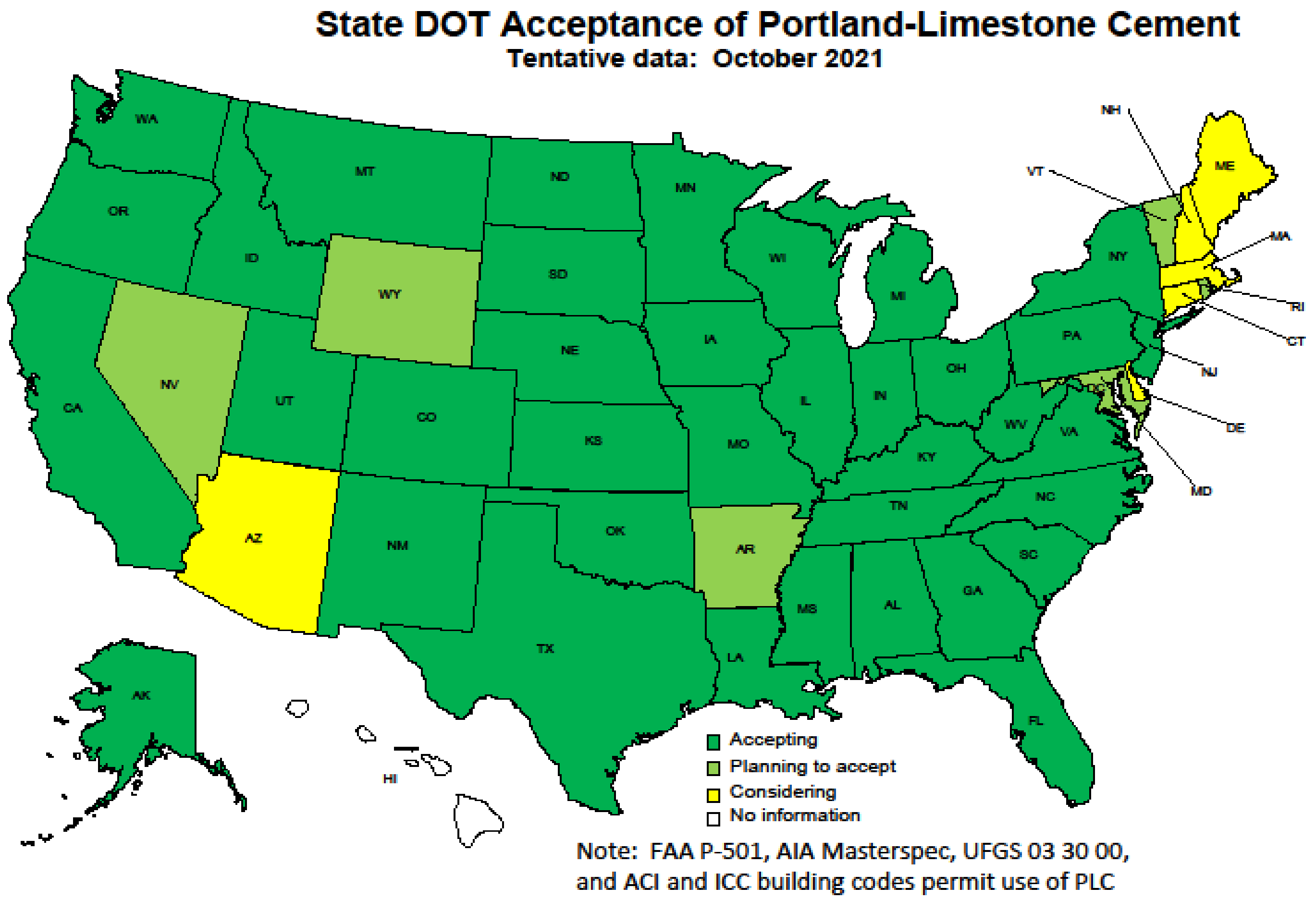
More than 34 State **DOT** specifications

Multiple **ASTM Specifications** (incl.)

- Ready-Mixed Concrete (C94)
- Concrete pipe, culverts, tile (8 standards)
- Grout for masonry (C476)
- Plaster (C926)

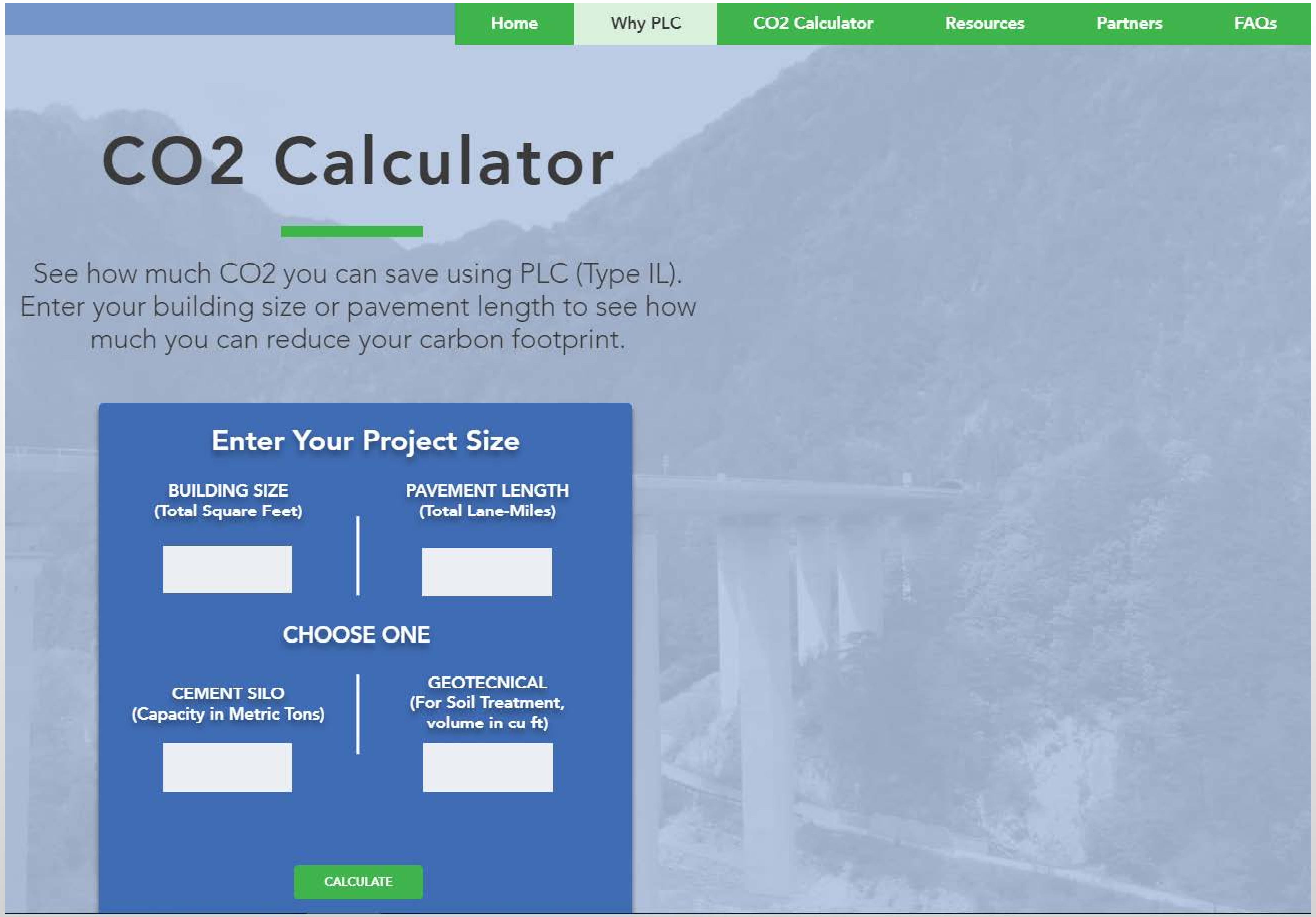
ACI 301, 318

ICC codes



greenercement.com - Your PLC Resource

- Calculators for CO2 savings
  - Basic, advanced
- Benefits of PLC
- Spec language
- Case studies
- PLC availability map
- Industry partners
- FAQs
- Contact an expert
- Mobile friendly



Greener Roads
for Right Now!

“Excellent durability and improved sustainability”

Proven technology

Easy to implement

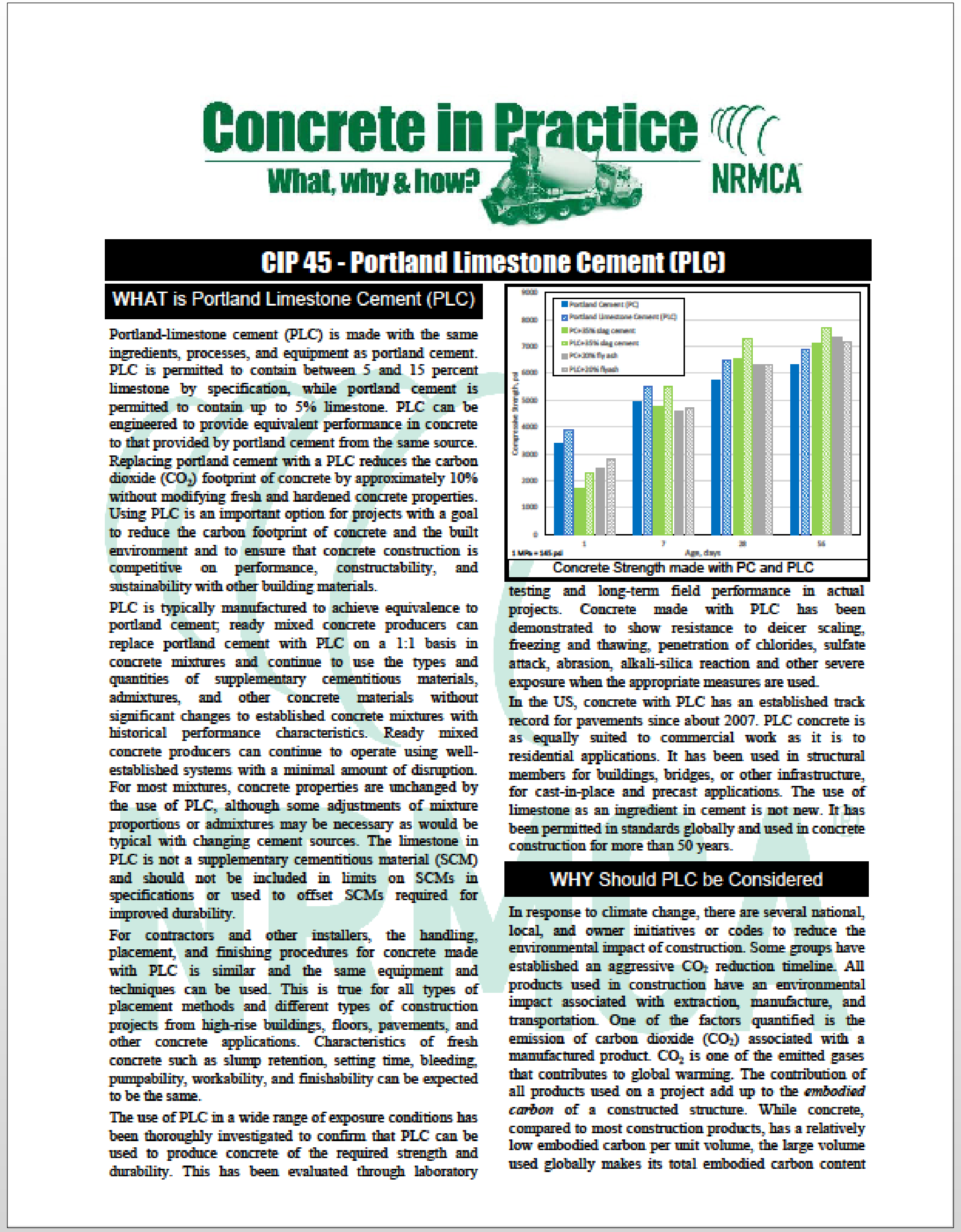
Sustainable, resilient pavements

These states were some early adopters of PLC concrete pavements – more than a decade ago:

- Colorado
- Utah
- Oklahoma

Partner Resources

- NRMCA CIP on PLC
  - Build With Strength
- ACPA Position Paper on PLC



Concrete in Practice
What, why & how?
NRMCA

CIP 45 - Portland Limestone Cement (PLC)

WHAT is Portland Limestone Cement (PLC)

Portland-limestone cement (PLC) is made with the same ingredients, processes, and equipment as portland cement. PLC is permitted to contain between 5 and 15 percent limestone by specification, while portland cement is permitted to contain up to 5% limestone. PLC can be engineered to provide equivalent performance in concrete to that provided by portland cement from the same source. Replacing portland cement with a PLC reduces the carbon dioxide (CO_2) footprint of concrete by approximately 10% without modifying fresh and hardened concrete properties. Using PLC is an important option for projects with a goal to reduce the carbon footprint of concrete and the built environment and to ensure that concrete construction is competitive on performance, constructability, and sustainability with other building materials.

PLC is typically manufactured to achieve equivalence to portland cement; ready mixed concrete producers can replace portland cement with PLC on a 1:1 basis in concrete mixtures and continue to use the types and quantities of supplementary cementitious materials, admixtures, and other concrete materials without significant changes to established concrete mixtures with historical performance characteristics. Ready mixed concrete producers can continue to operate using well-established systems with a minimal amount of disruption. For most mixtures, concrete properties are unchanged by the use of PLC, although some adjustments of mixture proportions or admixtures may be necessary as would be typical with changing cement sources. The limestone in PLC is not a supplementary cementitious material (SCM) and should not be included in limits on SCMs in specifications or used to offset SCMs required for improved durability.

For contractors and other installers, the handling, placement, and finishing procedures for concrete made with PLC is similar and the same equipment and techniques can be used. This is true for all types of placement methods and different types of construction projects from high-rise buildings, floors, pavements, and other concrete applications. Characteristics of fresh concrete such as slump retention, setting time, bleeding, pumpability, workability, and finishability can be expected to be the same.

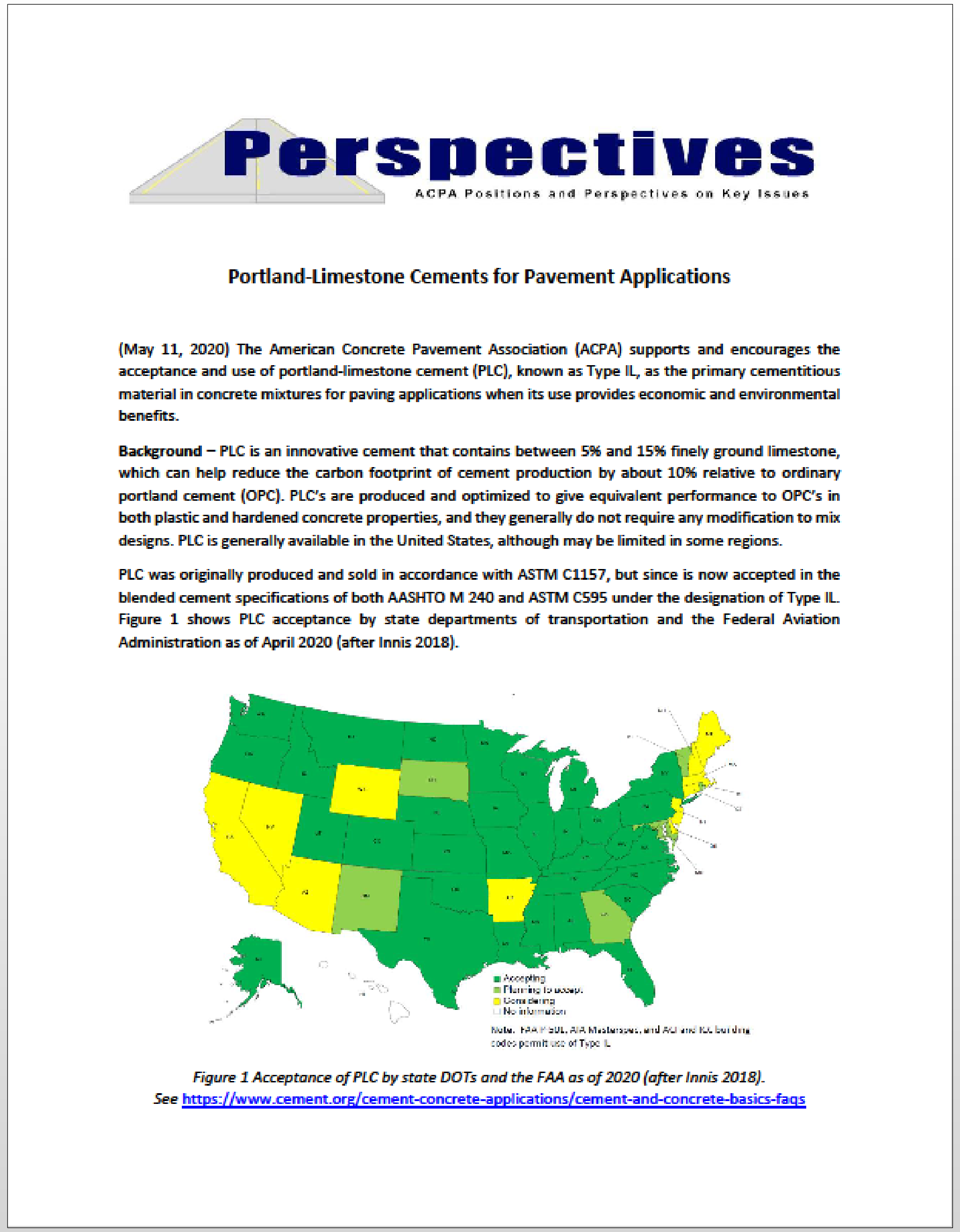
The use of PLC in a wide range of exposure conditions has been thoroughly investigated to confirm that PLC can be used to produce concrete of the required strength and durability. This has been evaluated through laboratory testing and long-term field performance in actual projects. Concrete made with PLC has been demonstrated to show resistance to deicer scaling, freezing and thawing, penetration of chlorides, sulfate attack, abrasion, alkali-silica reaction and other severe exposure when the appropriate measures are used.

In the US, concrete with PLC has an established track record for pavements since about 2007. PLC concrete is as equally suited to commercial work as it is to residential applications. It has been used in structural members for buildings, bridges, or other infrastructure, for cast-in-place and precast applications. The use of limestone as an ingredient in cement is not new. It has been permitted in standards globally and used in concrete construction for more than 50 years.

Concrete Strength made with PC and PLC

WHY Should PLC be Considered

In response to climate change, there are several national, local, and owner initiatives or codes to reduce the environmental impact of construction. Some groups have established an aggressive CO_2 reduction timeline. All products used in construction have an environmental impact associated with extraction, manufacture, and transportation. One of the factors quantified is the emission of carbon dioxide (CO_2) associated with a manufactured product. CO_2 is one of the emitted gases that contributes to global warming. The contribution of all products used on a project add up to the *embodied carbon* of a constructed structure. While concrete, compared to most construction products, has a relatively low embodied carbon per unit volume, the large volume used globally makes its total embodied carbon content



Perspectives
ACPA Positions and Perspectives on Key Issues

Portland-Limestone Cements for Pavement Applications

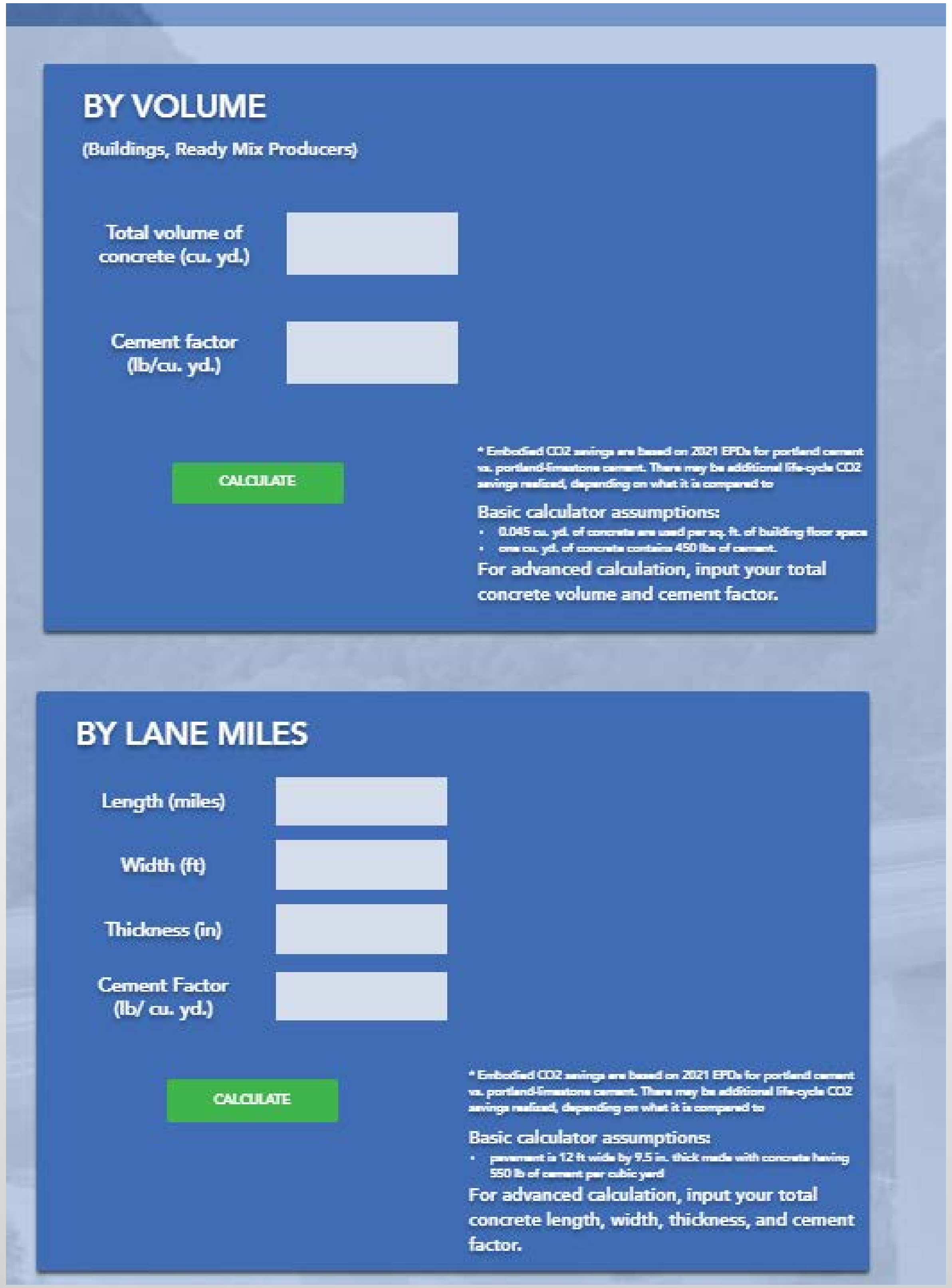
(May 11, 2020) The American Concrete Pavement Association (ACPA) supports and encourages the acceptance and use of portland-limestone cement (PLC), known as Type IL, as the primary cementitious material in concrete mixtures for paving applications when its use provides economic and environmental benefits.

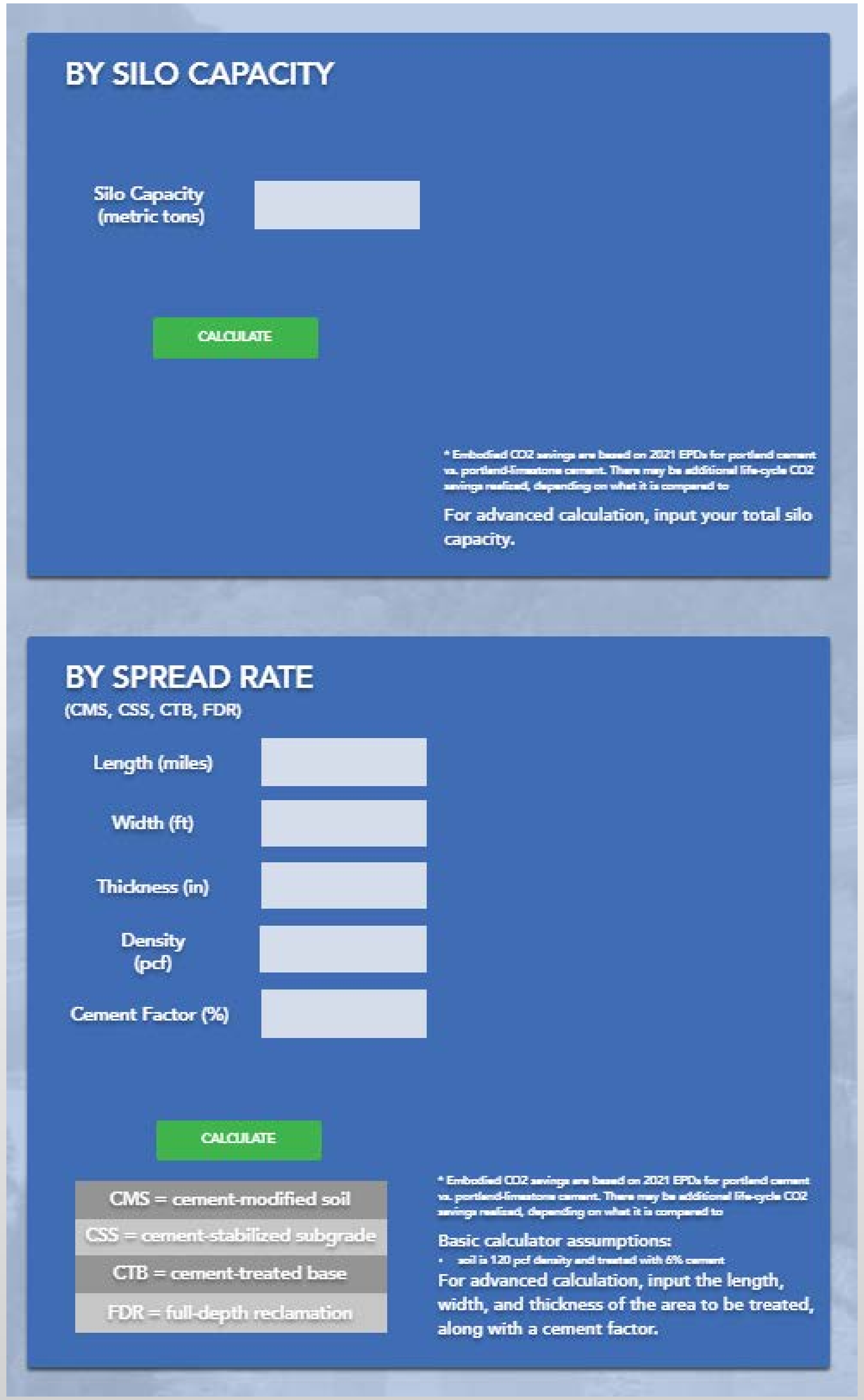
Background – PLC is an innovative cement that contains between 5% and 15% finely ground limestone, which can help reduce the carbon footprint of cement production by about 10% relative to ordinary portland cement (OPC). PLC's are produced and optimized to give equivalent performance to OPC's in both plastic and hardened concrete properties, and they generally do not require any modification to mix designs. PLC is generally available in the United States, although may be limited in some regions.

PLC was originally produced and sold in accordance with ASTM C1157, but since is now accepted in the blended cement specifications of both AASHTO M 240 and ASTM C595 under the designation of Type IL. Figure 1 shows PLC acceptance by state departments of transportation and the Federal Aviation Administration as of April 2020 (after Innis 2018).

Figure 1 Acceptance of PLC by state DOTs and the FAA as of 2020 (after Innis 2018).
See https://www.cement.org/cement-concrete-applications/cement-and-concrete-basics-faqs

greenercement.com - Calculators





PCA Since 1916
America's Cement Manufacturers™

Portland Limestone Cements

Using www.greenercement.com calculator to demonstrate CO2 savings

Then using the EPA "equivalent CO2" calculator…
https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

2018

2019

2020

2021

Total

OR 54200 MTonnes

Real-World Projects with PLC

Pan Am Games projects used PLC to support lower carbon initiative

Portland-Limestone Cements

York Region Annex used 10960 tonnes of PLC

Greenhouse gas emissions from

237

Passenger vehicles driven for one year

-or-

2,719,603

Miles driven by an average passenger vehicle

Source: Greenercement.com

Project – Wastewater Treatment Plant, Woodward WWTP, Hamilton, ON

Contractor – North America Const

Type IL and slag specified (30-40%)

23,000 m^3 (30,000 yd^3)

Woodward Upgrade Project Update - November 2020 - YouTube

Project – West Park Healthcare Centre, Toronto, ON

Contractor – EllisDon

Type IL and slag (10-50%)

35,000 m^3 (45,000 yd^3)

West Park Healthcare Centre New Hospital Flythrough - YouTube

PCA® Since 1916
America's Cement Manufacturers™

Davis Wade Stadium

Mississippi State University

- $75M expansion & renovation
- Design focus on sustainability
- OPC and PLC mixes
- Most with 50% SCM replacement – 30% slag + 20% Class C fly ash
- Study part of MSU research

PCA Since 1916
America's Cement Manufacturers™

Ben Lomond High School – Ogden, Utah

- Seismic remodel, reconstruction in 2010
- CMU mixes
  - PLC
  - 0-10% Class F fly ash
- CMU unit styles
  - 70,000 smooth face
  - 12,000 split face
  - 110,000 honed face

University of Utah Meldrum Building

- Constructed 2009-2010
- Cementitious materials
  - 80% PLC
  - 20% Class F Fly ash
- SCC mixtures
- Architectural finishes
- Lightweight
- Winter placement
- Compressive strength

  4000 psi specified
    - 7 Day Field Range: 6100-6600 psi

IW EPDs for Cement

2016 and 2021 GWP results

L to R

Portland 2016:

1040 kg CO2eq

Portland 2021:

922 (11.3% drop from 2016)

PLC 2021:

846 (8.3% lower than 2021 portland)


PCA America's Cement Manufacturers

ENVIRONMENTAL PRODUCT DECLARATION

Portland Cements

(per ASTM C150, ASTM C1157, AASHTO M 85 or CSA A3001)

Committed to Sustainability

The United States cement industry is dedicated to manufacturing a superior product while constantly improving energy efficiency, minimizing emissions, and reducing environmental impacts.

This Environmental Product Declaration (EPD) was developed to document the environmental impacts of our products. Inside, you will find ASTM-certified, ISO-compliant information on cement's environmental footprint, including energy use and global warming potential. This is intended for business-to-business communication.

Our goal is to balance society's need for cement products with stewardship of the air, land, and water along with conservation of energy and natural resources.

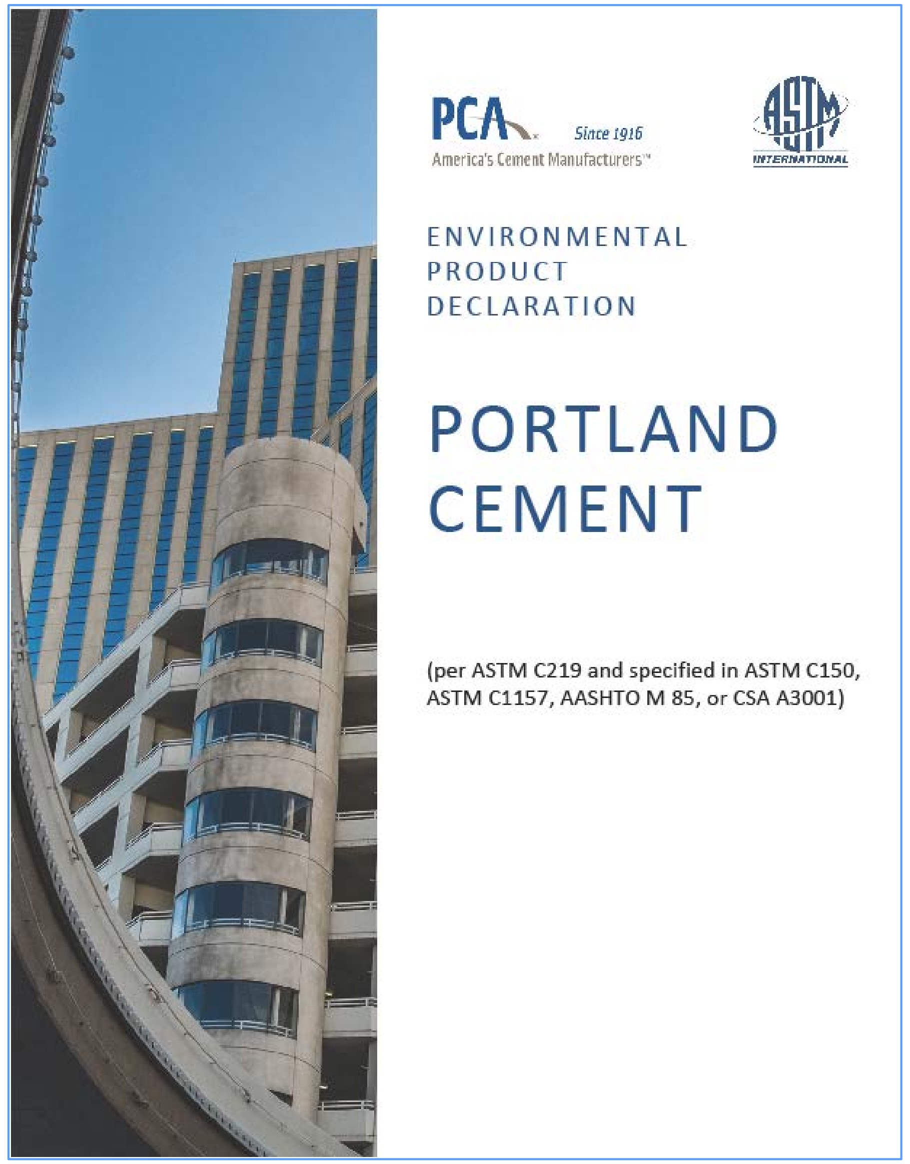
Cement or Concrete?

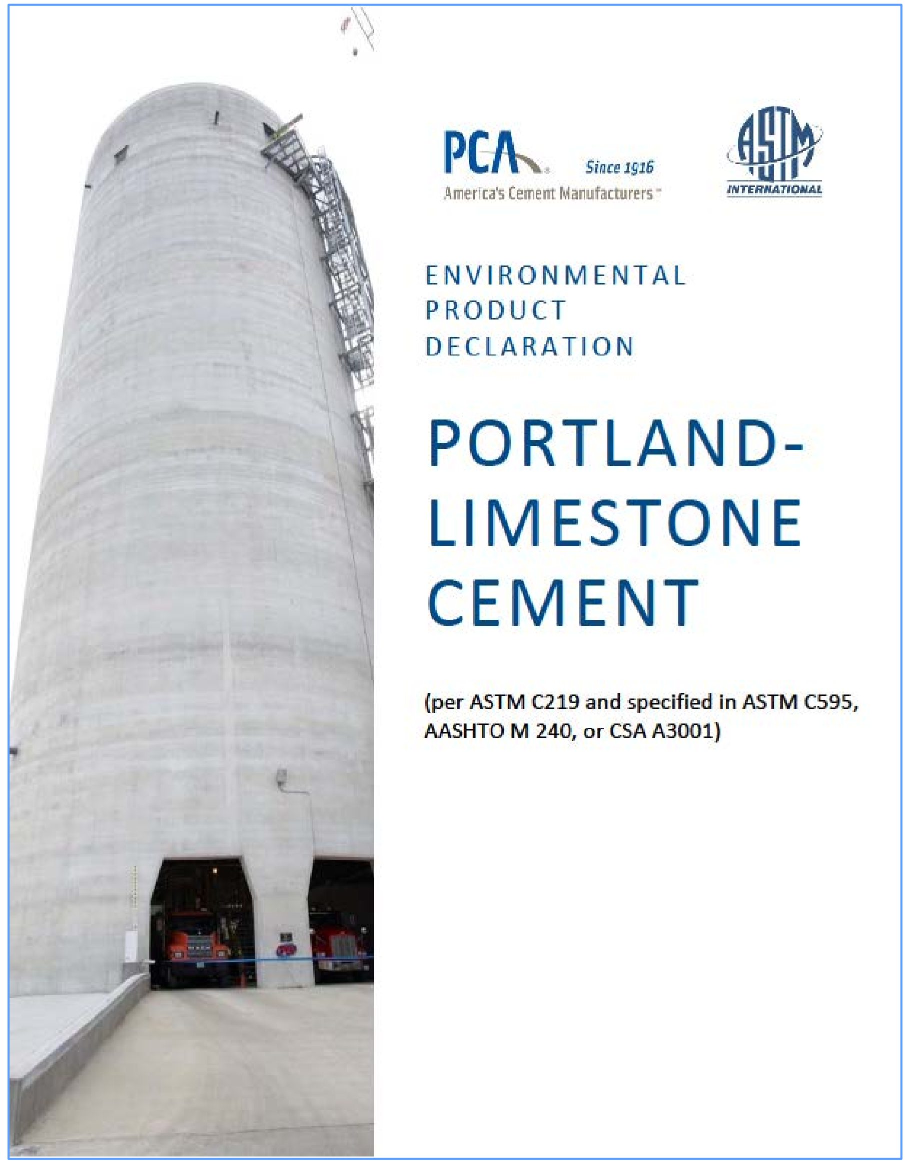
Cement is actually an ingredient of concrete. It is the fine powder that, when mixed with water, sand, and gravel or crushed stone, forms the rock-like mass known as concrete.

Cement acts as the binding agent or glue. A chemical reaction called hydration is triggered when water and cement are mixed in the right proportions. This reaction causes the cement to harden and bind the aggregate into a solid mass.

When freshly mixed, concrete can be molded into almost any form. Yet when hardened, its strength and durability often exceed that of natural stone.

Page 1 of 11





EPDs -> LCA

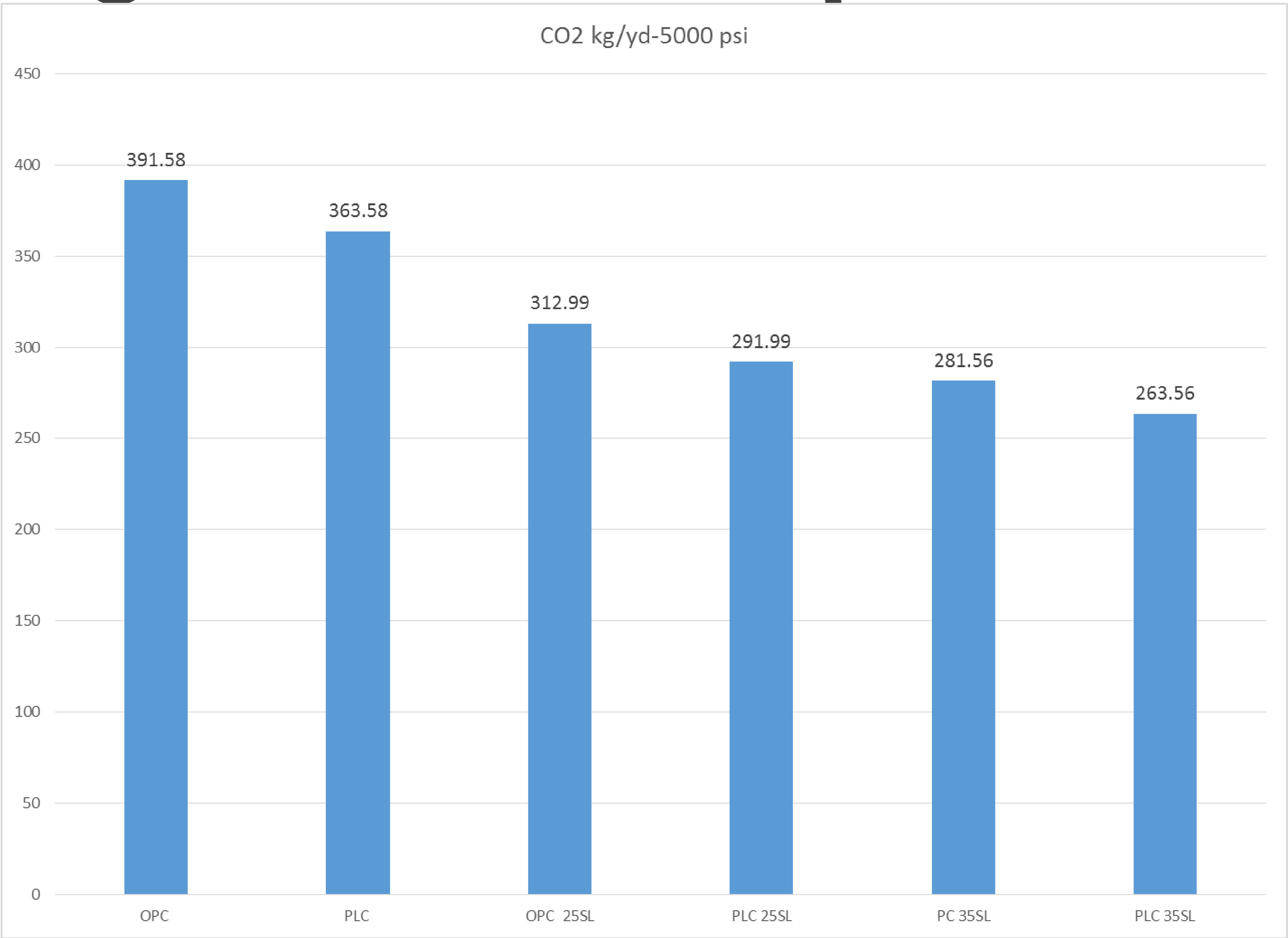
2021 PCA Industry Wide EPDs

for OPC and PLC cements

Impact category and inventory indicators	Unit	Portland Cements 1 metric ton
Global warming potential, GWP 100, IPCC 2013	kg CO_2 eq	**922**
Ozone depletion potential, ODP	kg CFC-11 eq	**2.10E-05**
Acidification potential, AP	kg SO_2 eq	**1.75**
Eutrophication potential, EP	kg N eq	**1.02E**
Smog formation potential, SFP	kg O_3 eq	**32.9**

Impact category and inventory indicators	Unit	PLC Cement 1 metric ton
Global warming potential, GWP 100, IPCC 2013	kg CO_2 eq	**846**
Ozone depletion potential, ODP	kg CFC-11 eq	**2.17E-05**
Acidification potential, AP	kg SO_2 eq	**1.64**
Eutrophication potential, EP	kg N eq	**0.94**
Smog formation potential, SFP	kg O_3 eq	**30.2**

Lowering Carbon Footprints of Mixes



5000 psi concrete mixes comparing OPC and PLC with various SCM contents

Green Rating Systems

Potential credits for PLC

LEED V4, beta V4.1

LEED MRc2

- Option 1 Type III EPD
- Option 2 Optimization less than 10% reduction in GWP vs. baseline

Maximum of 2 points

Applies to ready mix concrete and masonry grout

Option 2. Embodied Carbon/LCA Optimization (1 point)

Use products that have a compliant embodied carbon optimization report or action plan separate from the LCA or EPD. Use at least 5 permanently installed products sourced from at least three different manufacturers. Products are valued according to the table below.

<table>
<tr><th>Report Type</th><th>Reference Document(s) for the Optimization Report</th><th>Report Verification</th><th>Valuation</th></tr>
<tr><td>Embodied Carbon/LCA Action Plan</td><td>Product-specific LCA or product-specific Type III EPD</td><td>Prepared by the manufacturer and signed by company executive</td><td>½ product</td></tr>
<tr><td>Reductions in Embodied Carbon: less than 10% reduction in GWP relative to baseline</td><td rowspan="2">Baseline: Product-specific LCA, Product-specific Type III EPD, or Industry-wide Type III EPD
Optimized: Product-specific LCA or product-specific Type III EPD</td><td rowspan="3">Comparative analysis is verified by an independent party</td><td>1 product</td></tr>
<tr><td>Reductions in Embodied Carbon: 10%+ reduction in GWP relative to baseline</td><td>1.5 products</td></tr>
<tr><td>Reductions in Embodied Carbon: 20%+ reduction in GWP and 5%+ reduction in two additional impact categories, relative to baseline</td><td>Baseline: Product-specific LCA or Product-specific Type III EPD
Optimized: Product-specific LCA or product-specific Type III EPD</td><td>2 products</td></tr>
</table>

Note: Reference documents for the optimization reports must be compliant with Option 1.

plc
portland-limestone cement

Reducing Concrete's Carbon Footprint using PLCs

Ohio Concrete - November 2, 2021

Shawn Kalyn, St Marys Cement, a Votorantim Company
Jamie Farny, Portland Cement Association