portland-limestone cement

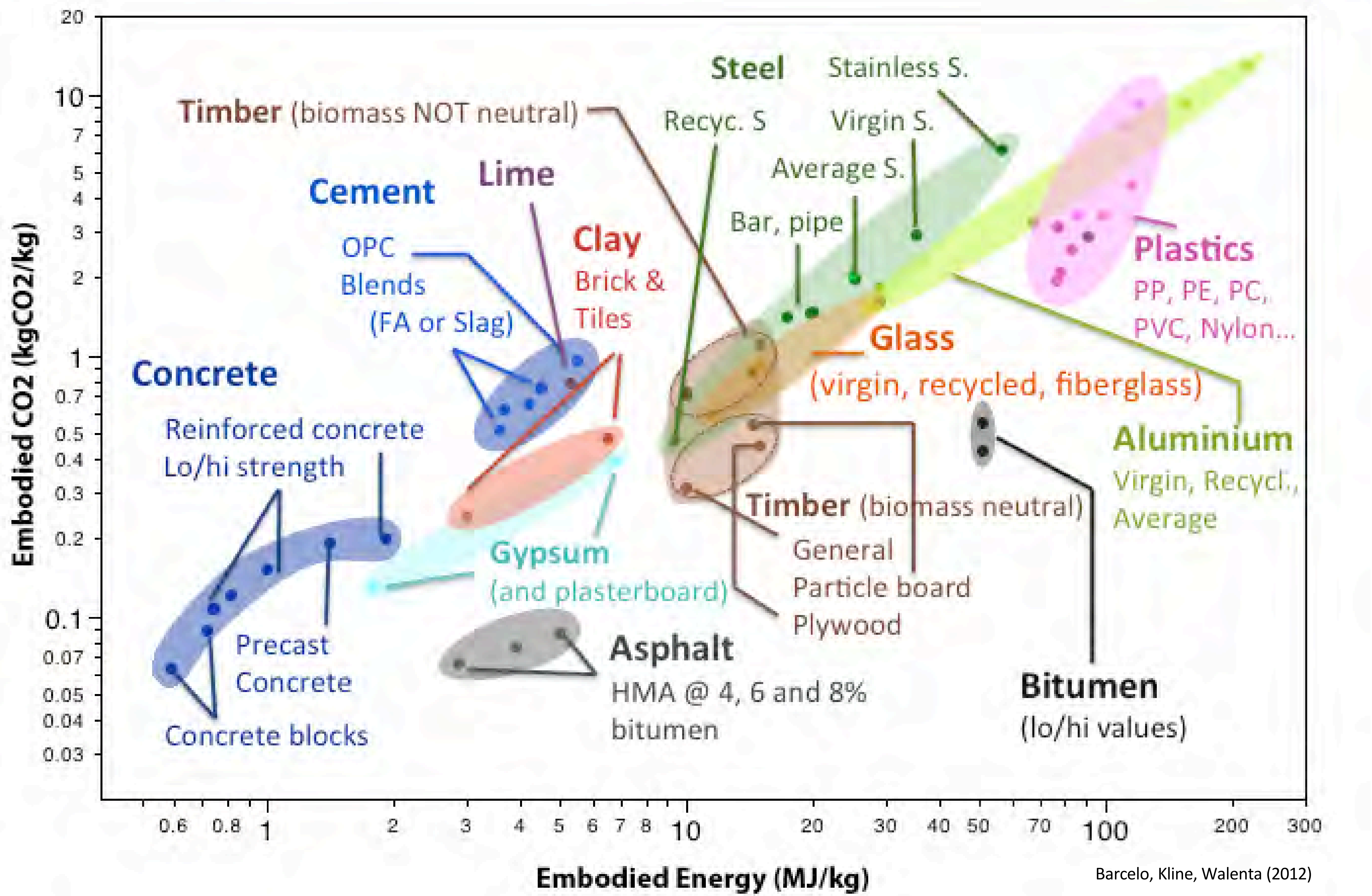
Reducing Concrete's Carbon Footprint

NESMEA - October 26, 2021

Portland-limestone cements

Embracing their use to reduce concrete's carbon footprint

Concrete is Environmentally Friendly



Barcelo, Kline, Walenta (2012)

PCA 2050 Roadmap to Carbon Neutrality

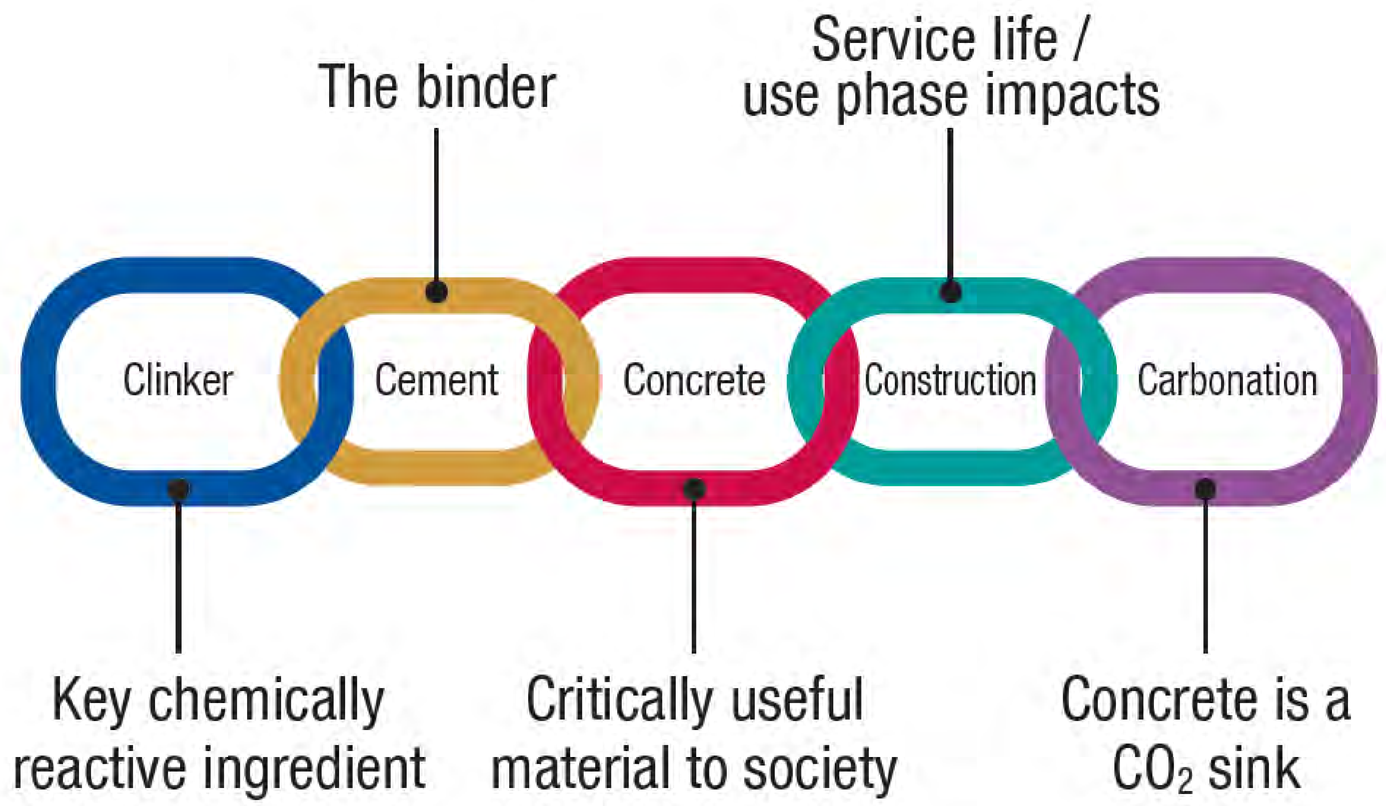
CO2 and Sustainability

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

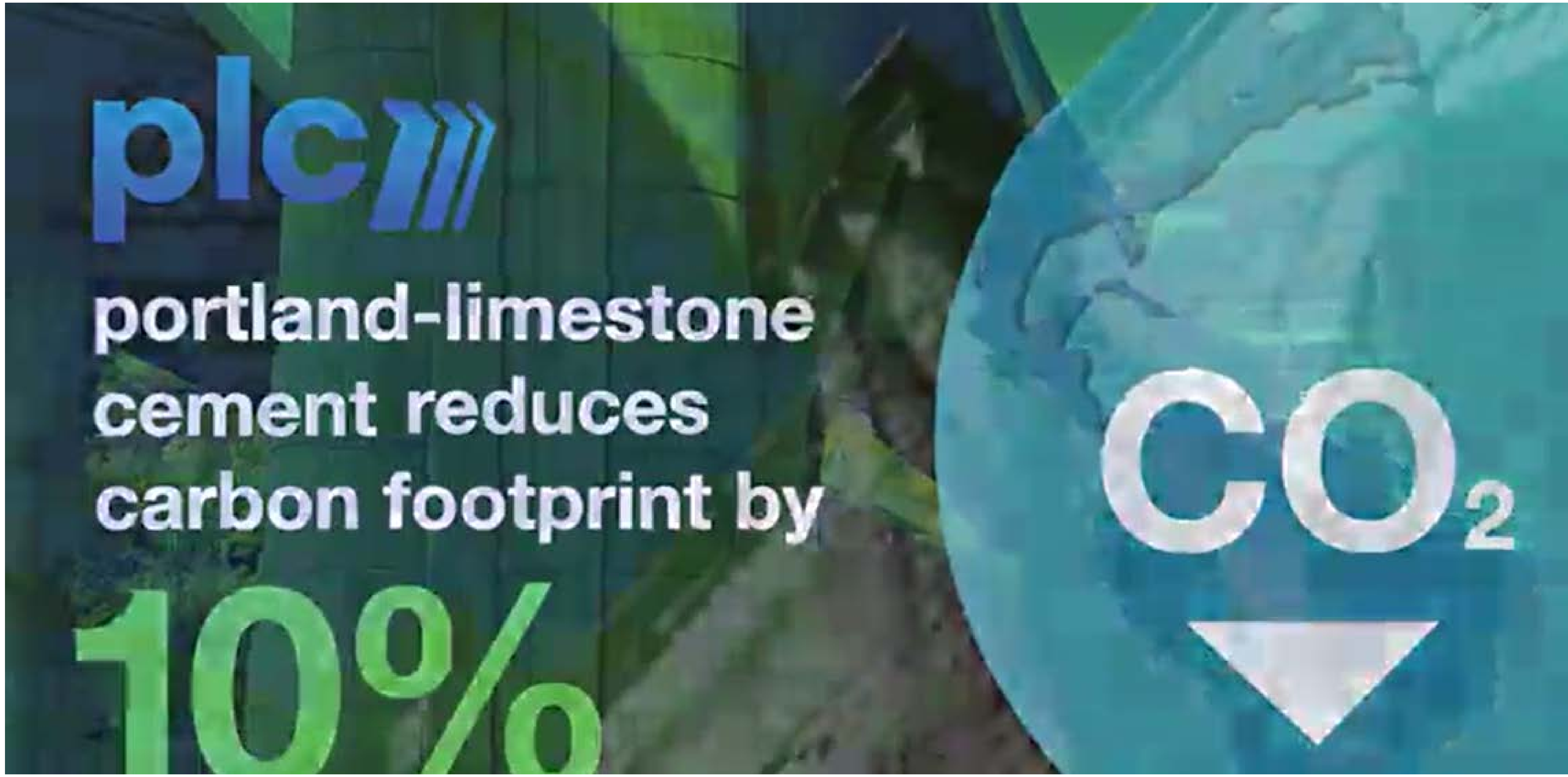
CO2 Footprint of Construction

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

Evolving Cement Specifications

Environmentally driven changes

Performance cements C1157 (1992)

Portland cements

- Limestone (2004, 2007)
- Inorganic processing additions (2009)

Blended cements

- Nomenclature (2006)
- Type IT (2009)
- **Type IL (2012)**

U.S. and Canadian Standards

Cementitious Materials and Concrete Standards

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

A3000 portland cement – Types GU, MS, HE, and HS

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

A3000 blended cement – Types GUb, GULb, MSb, MSLb, HEb, HELb, HSb, HSLb. Similarly allows for pozzolans, slag cement, limestone

A3000 PLC - Types GUL, MSL, HEL, and HSL (not considered a blended cement)

C1157 hydraulic cement – Types GU, HE, MS, HS, MH, LH. "Performance" specification does not specify chemical composition, but allows for pozzolans, slag cement, and limestone

No counterpart in Canada, already covered by A3000 portland and blended categories

C94 ready-mixed concrete – equal recognition of C150, C595, and C1157 and equal handling of SCMs

A23.1 ready-mixed and precast concrete – equal recognition of A3000 materials and equal handling of SCMs

Long Track Record

Blended limestone cements

History of good performance, even at higher limestone contents than the U.S.

Europeans introduced in the late 1960s

Canada has used them since the late 2000s

U.S. standards in place since 2012 (even earlier as C1157 performance cements)

Market share for blended cements grows as users gain comfort working with them

U.S. is currently more 1 MMT/year

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 effects on 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:

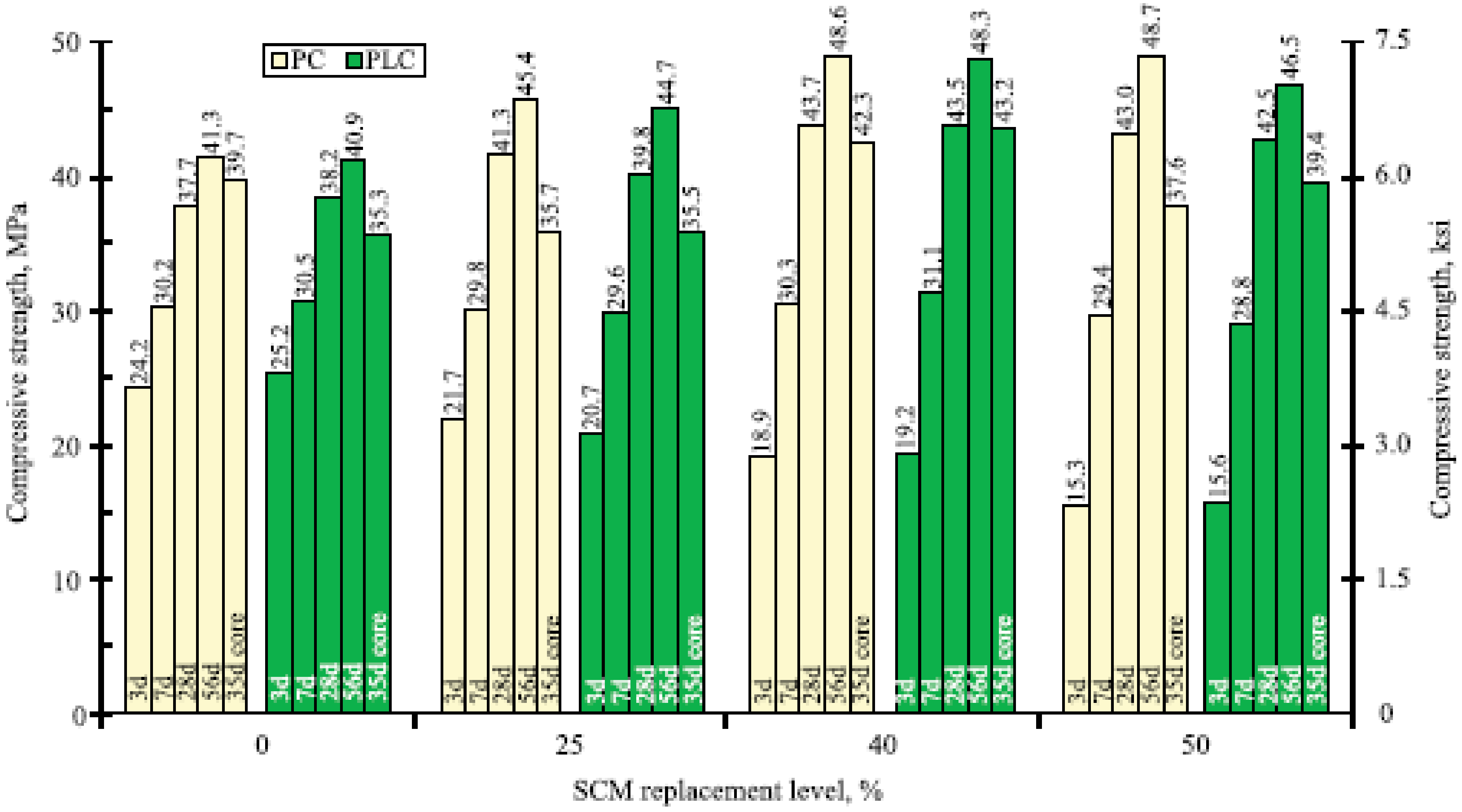
- Slightly less bleed water
- Slightly shorter setting times
- Slightly higher water demand

Virtually the same handling and performance as OPC

Performance of PLC Concrete

A look at hardened properties

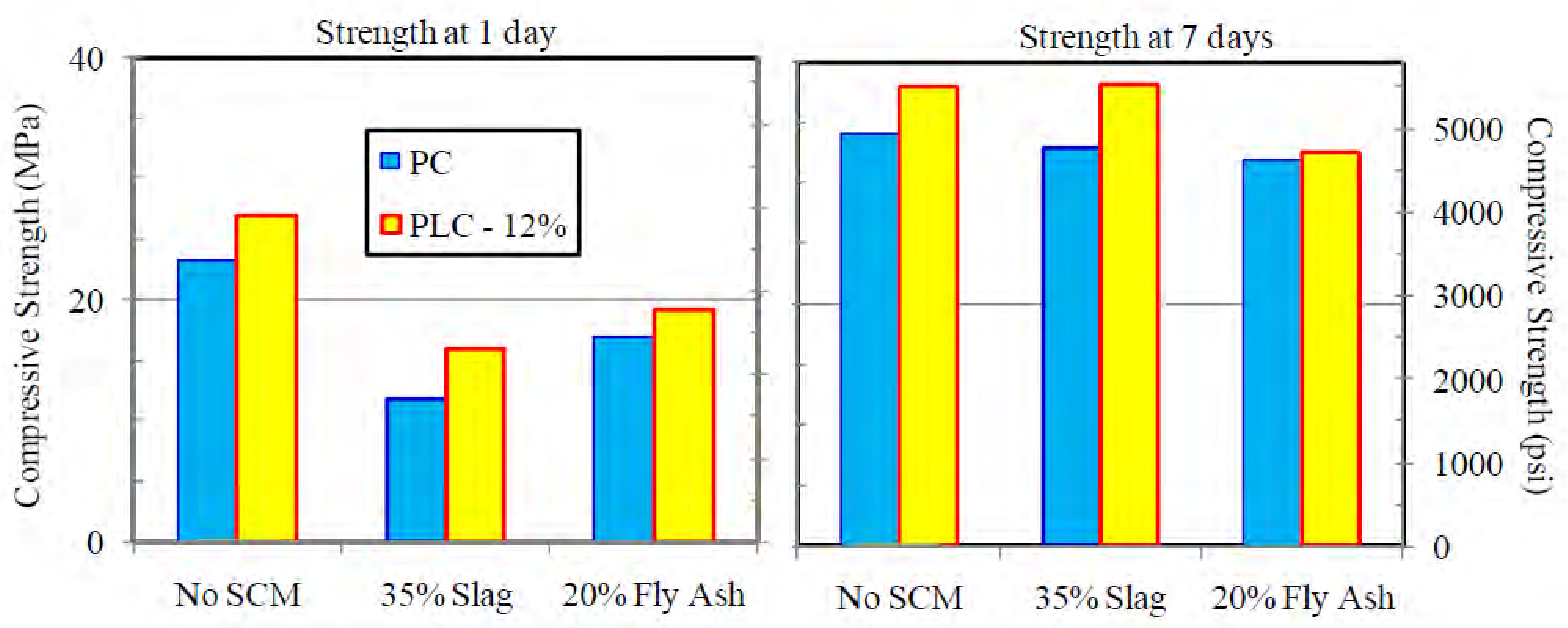
- Strength
  - OPC to PLC comparisons
  - With and without SCMs
- Durability
  - Scaling
  - Freeze-thaw resistance
  - Chloride permeability
  - ASR resistance
  - Sulfate resistance
  - Field trial results



Thomas, and others 2010

Performance of PLC Concrete

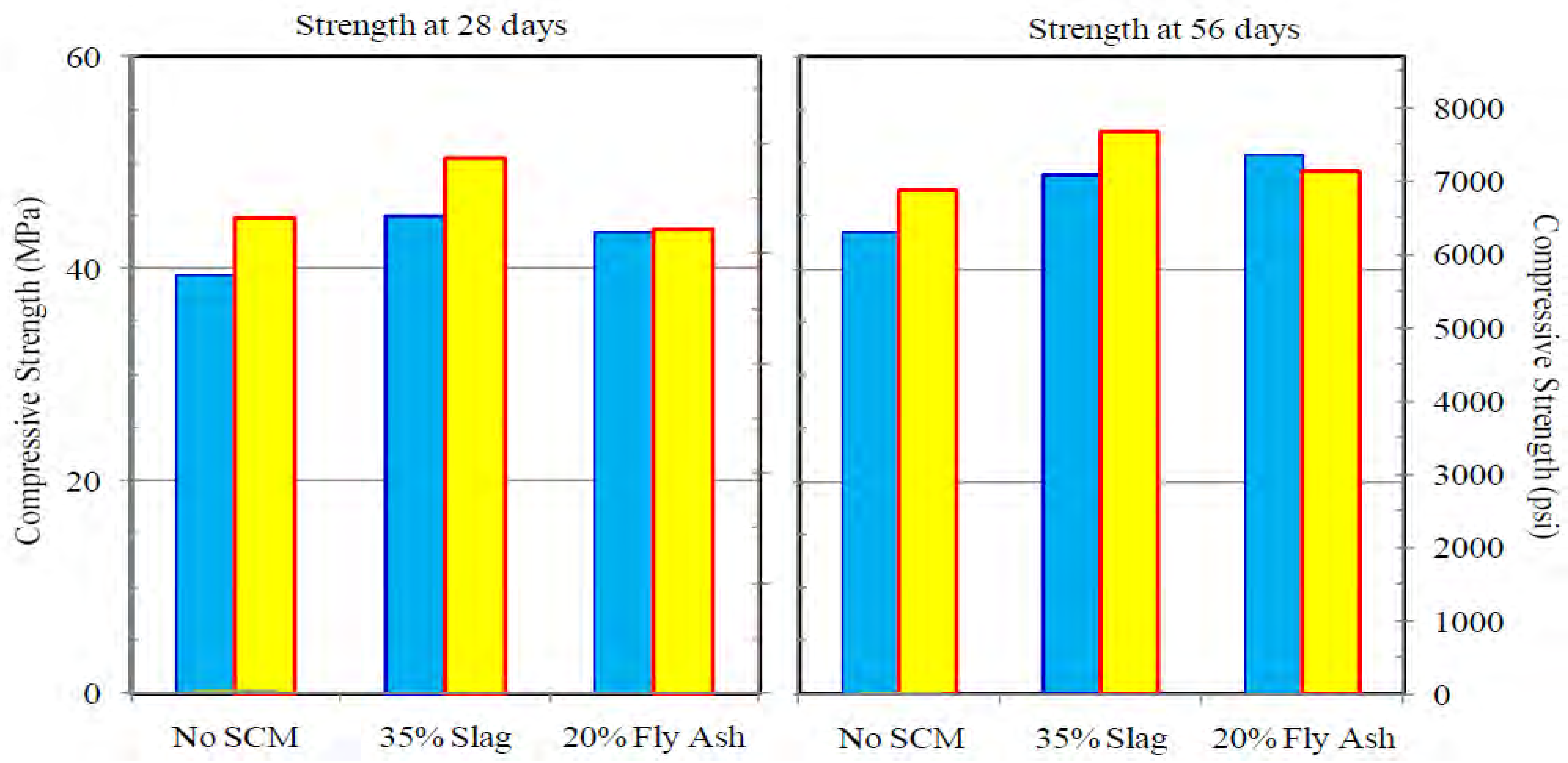
Early age strength development with and without SCMs



Thomas and Hooton 2010

Performance of PLC Concrete

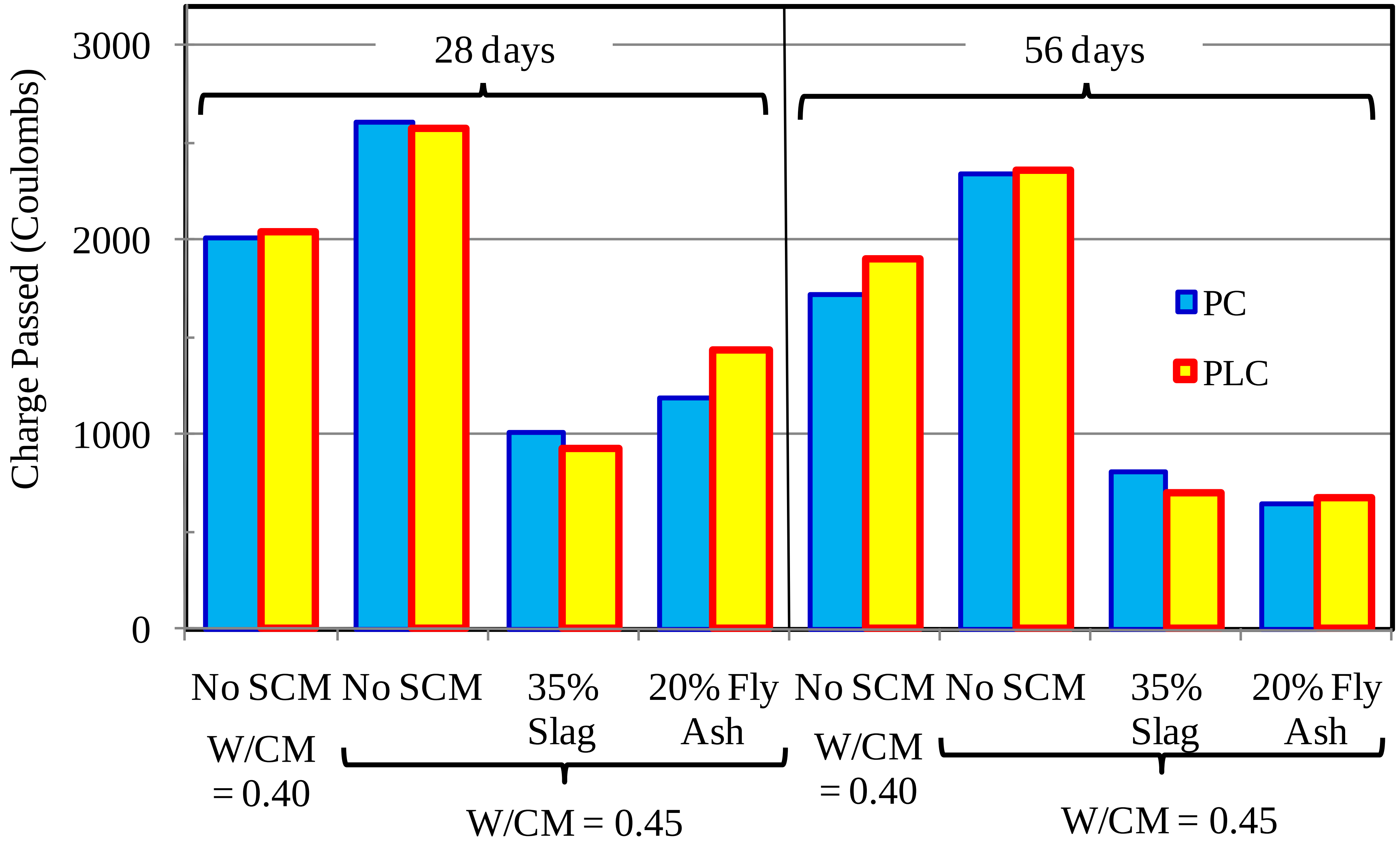
Later age strength development with and without SCMs



Thomas and Hooton 2010

Performance of PLC Concrete

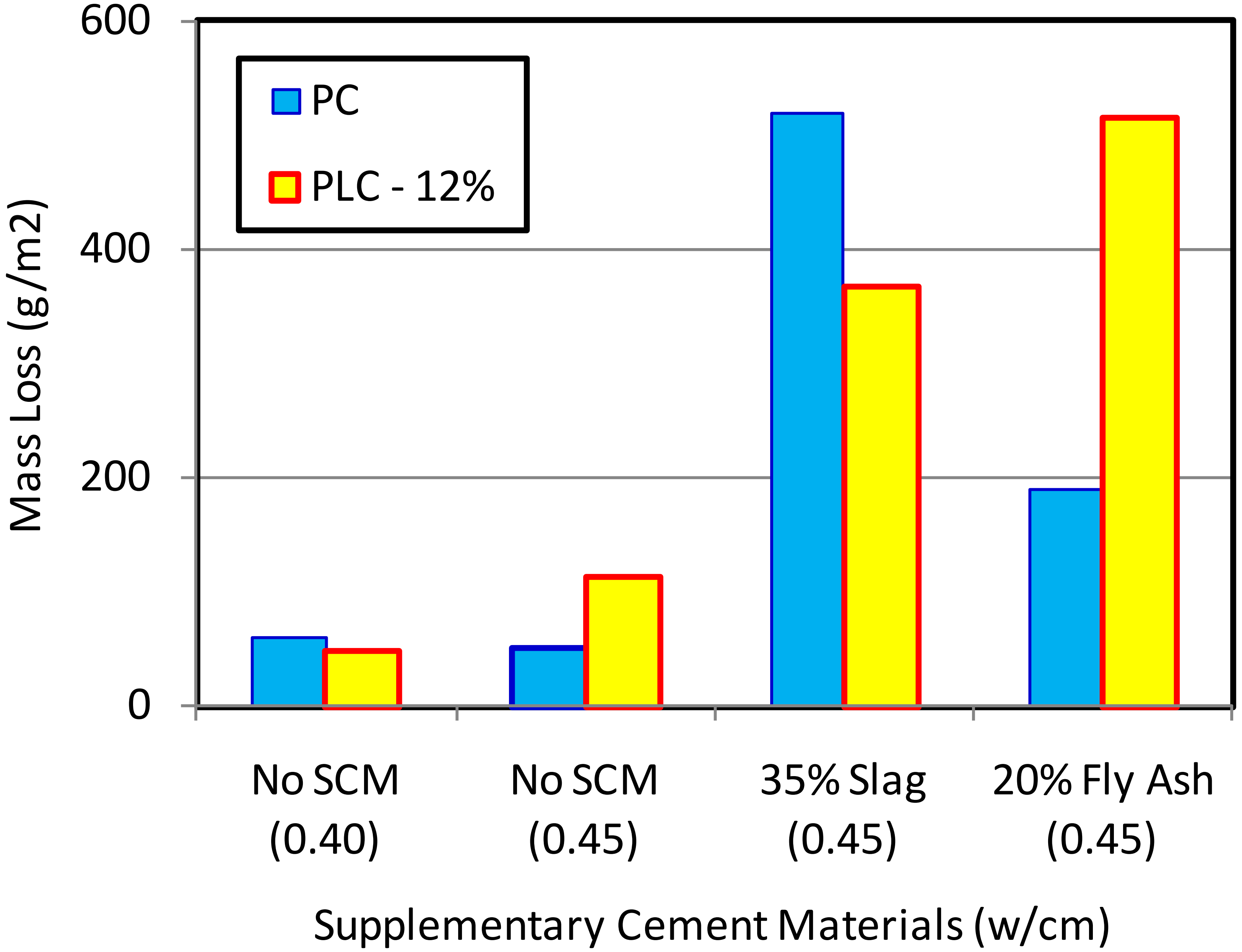
"Permeability" T277/C1202



Thomas and Hooton 2010

Performance of PLC Concrete

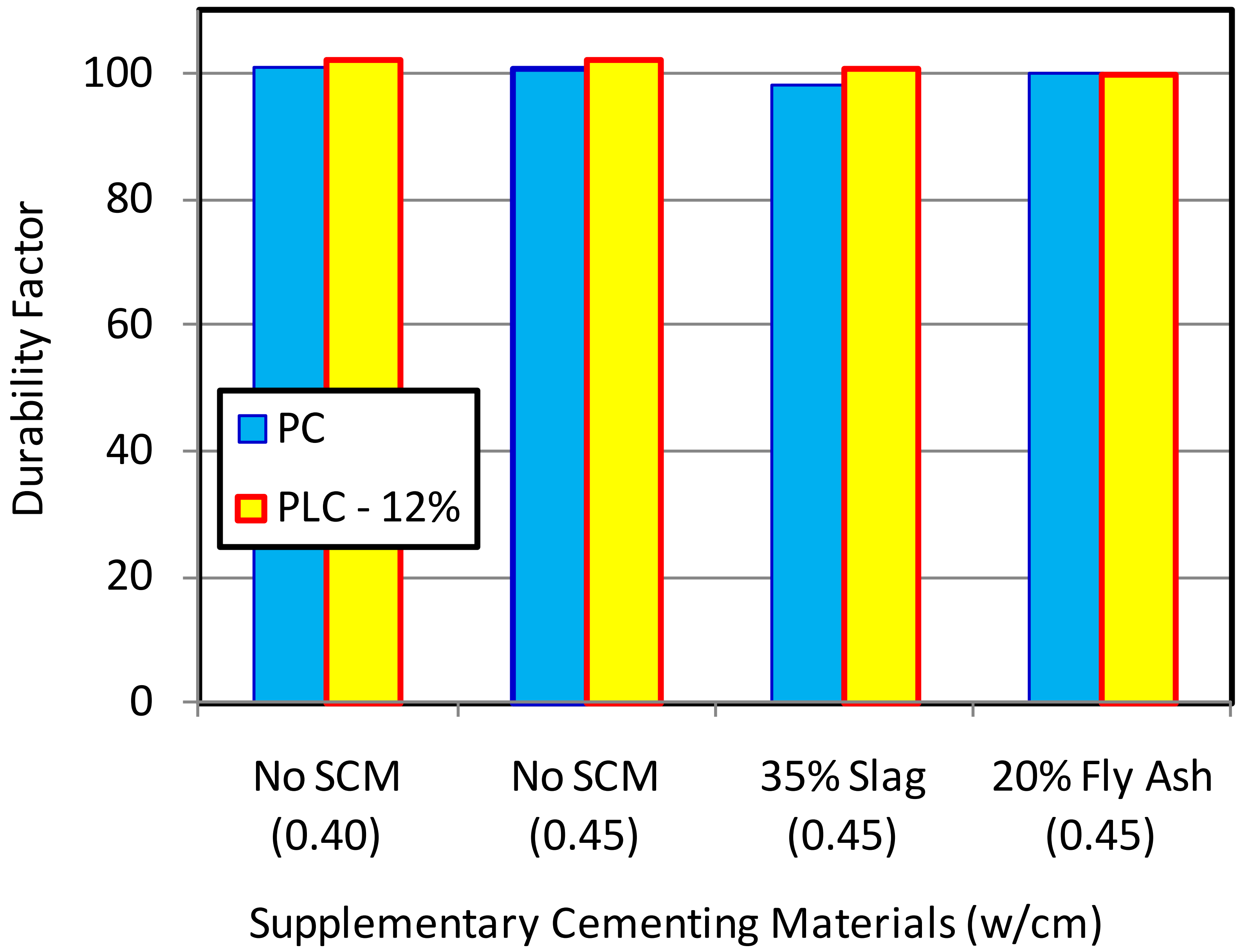
Scaling resistance (ASTM C672)



Thomas et al. 2010

Performance of PLC Concrete

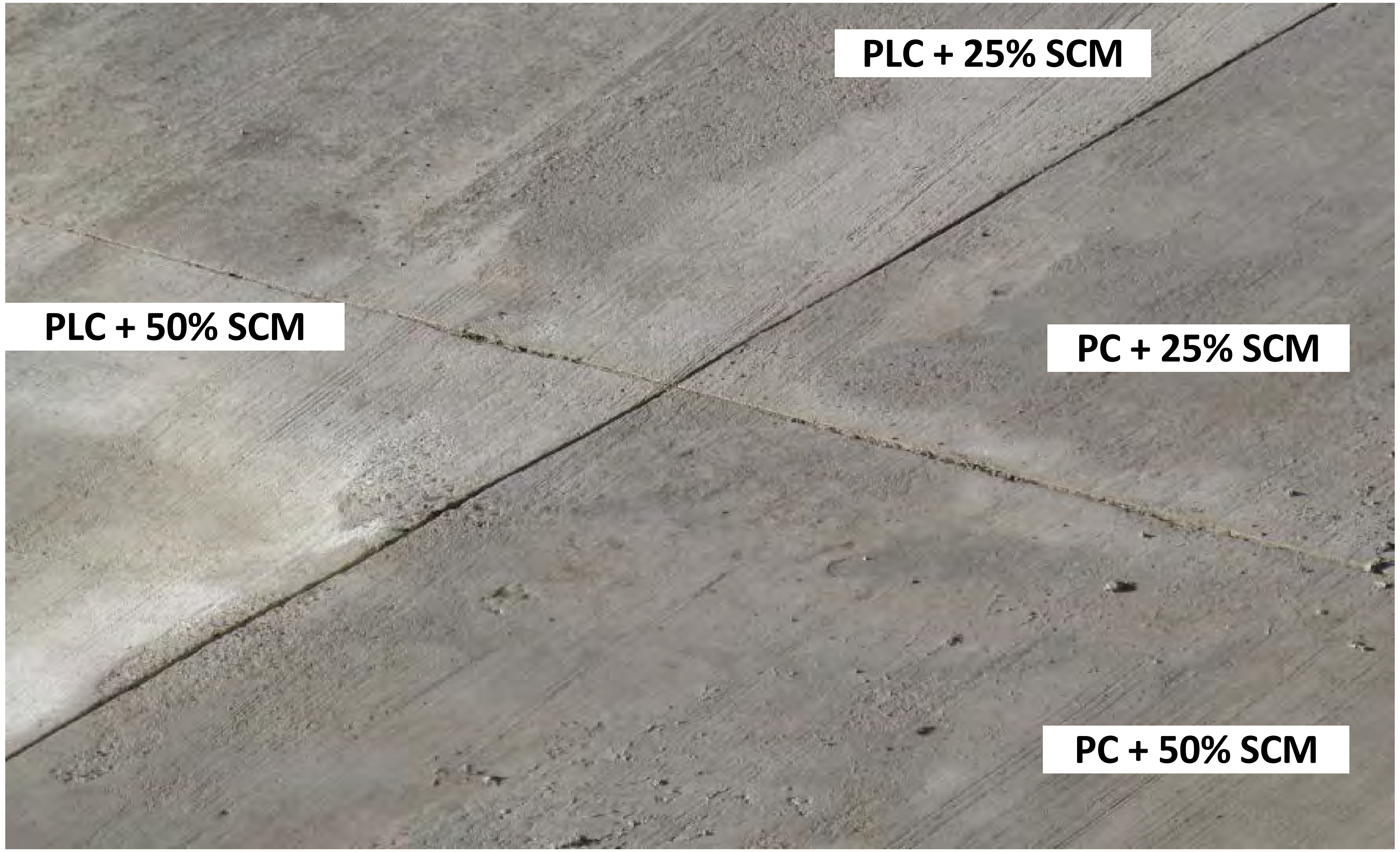
Freeze-Thaw Resistance (ASTM C666)



Thomas et al. 2010

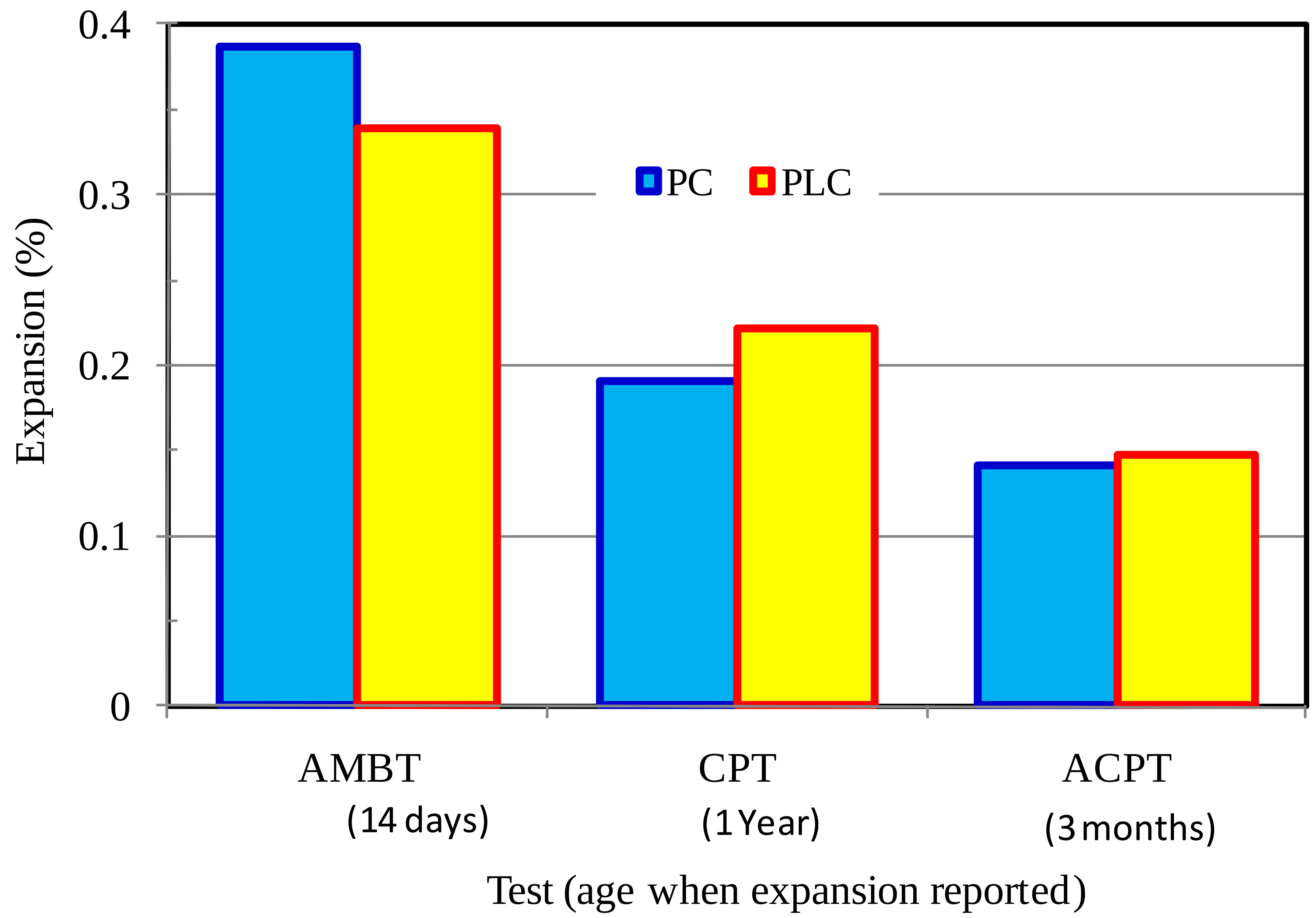
Performance of PLC Concrete

Field Trials: Pavement slab after one winter



Performance of PLC Concrete

ASR resistance



Thomas et al. 2010

PLC and Sulfate Resistance

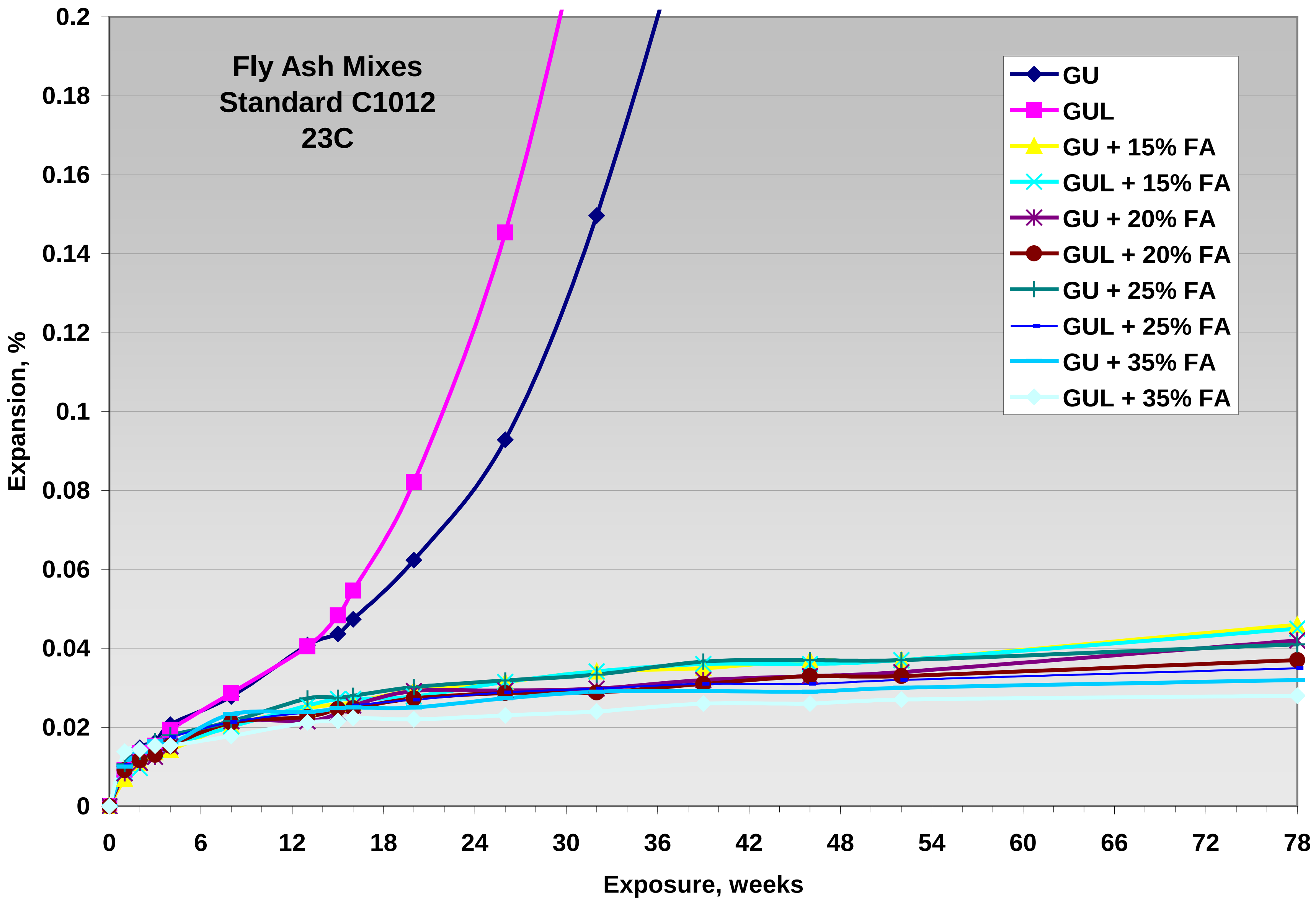
Same approach as for other blended cements

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

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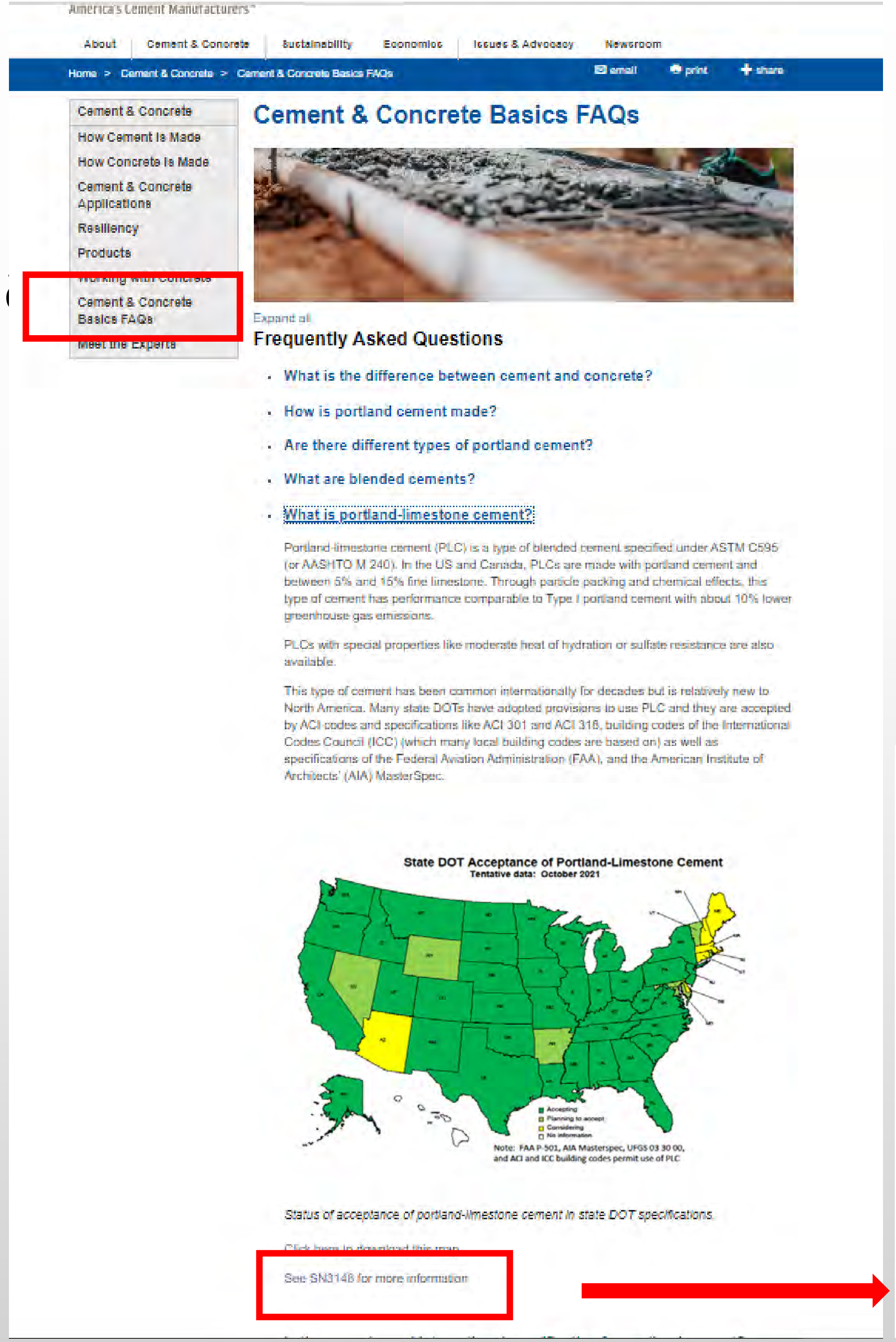
Hardened Properties

- Summary in PCA Report SN3148 at www.cement.org
- Strength
- Scaling
- Freeze-thaw resistance
- Chloride permeability
- ASR resistance
- Sulfate resistance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How Concrete Is Made
Cement & Concrete Applications
Resiliency
Products
Cement & Concrete Basics FAQs

Cement & Concrete Basics FAQs

Expand all

Frequently Asked Questions

- What is the difference between cement and concrete?
- How is portland cement made?
- Are there different types of portland cement?
- What are blended cements?
- What is portland-limestone cement?

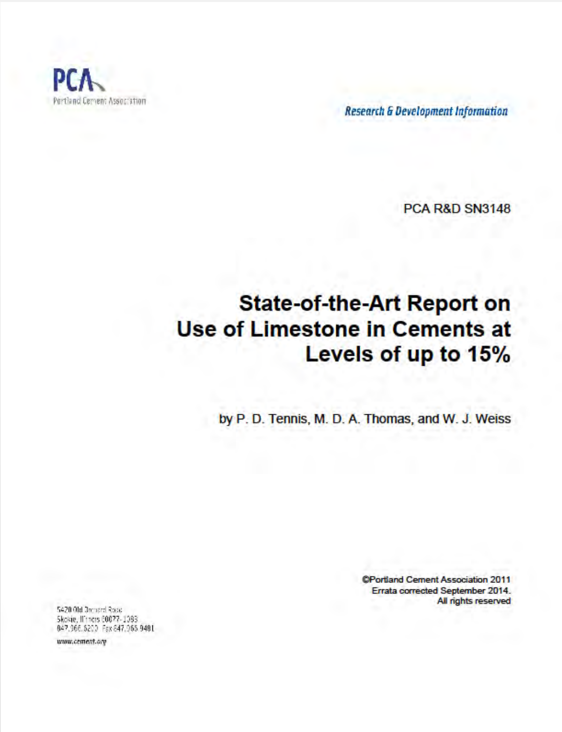
Portland-limestone cement (PLC) is a type of blended cement specified under ASTM C595 (or AASHTO M 240). In the US and Canada, PLCs are made with portland cement and between 5% and 15% fine limestone. Through particle packing and chemical effects, this type of cement has performance comparable to Type I portland cement with about 10% lower greenhouse gas emissions.

PLCs with special properties like moderate heat of hydration or sulfate resistance are also available.

This type of cement has been common internationally for decades but is relatively new to North America. Many state DOTs have adopted provisions to use PLC and they are accepted by ACI codes and specifications like ACI 301 and ACI 318, building codes of the International Codes Council (ICC) (which many local building codes are based on) as well as specifications of the Federal Aviation Administration (FAA), and the American Institute of Architects' (AIA) MasterSpec.

Status of acceptance of portland-limestone cement in state DOT specifications.

See SN3148 for more information


PCA Portland Cement Association

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

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Errata corrected September 2014.
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5420 Old Orchard Road
Skokie, Illinois 60077-1083
847.966.6200 Fax 847.966.9481
www.cement.org

Caltrans Research Confirms PLC Performance

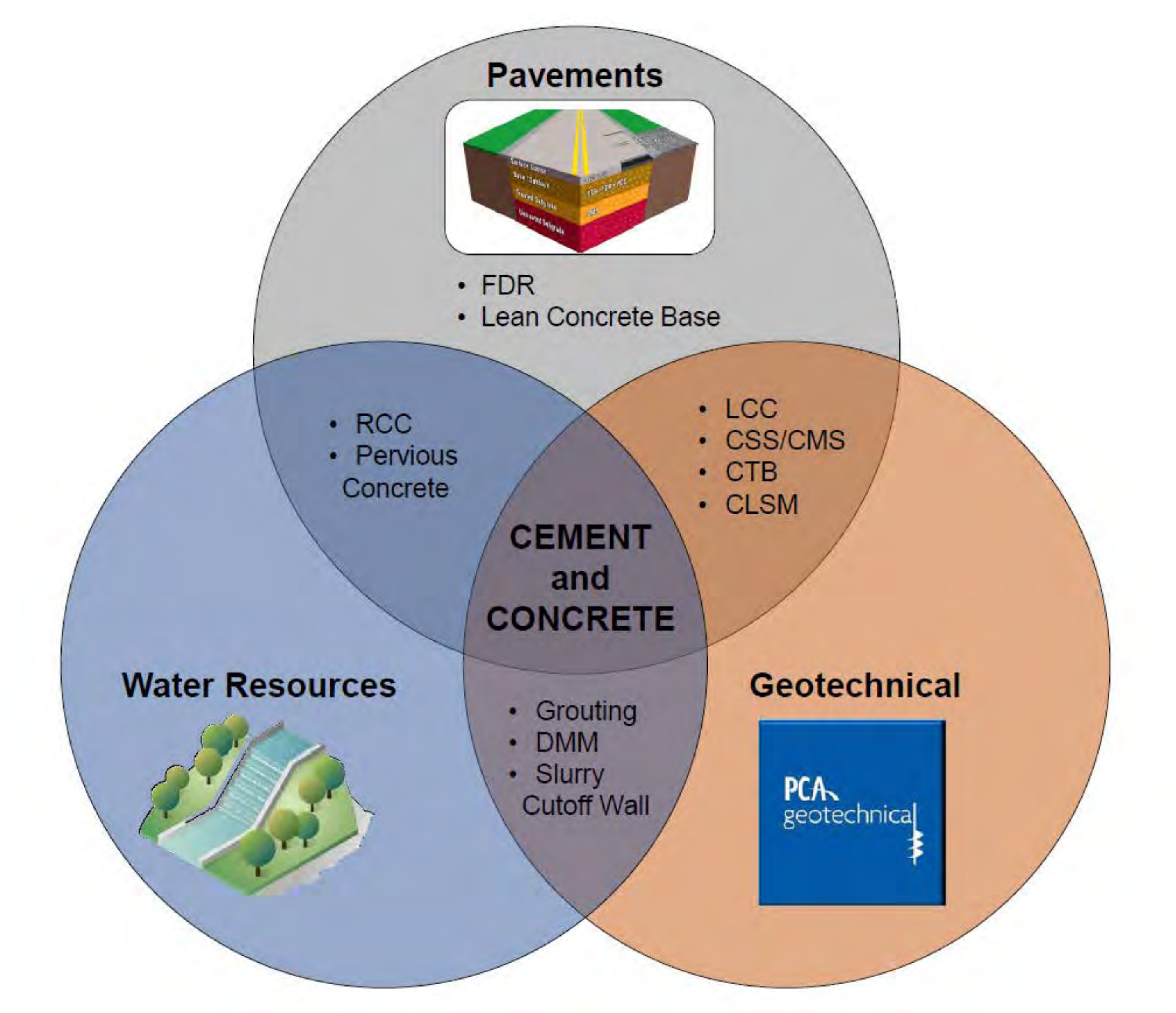
- Provide data to make informed decisions about PLCs
- Oregon State University comprehensive research program on PLC
- "Impact of Use of Portland-limestone Cement on Concrete Performance as Plain or Reinforced Material"
  - Similar set times, shrinkage, bound chloride contents, and time to corrosion 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

Specifying PLC Concrete

Parallel standards for Type IL

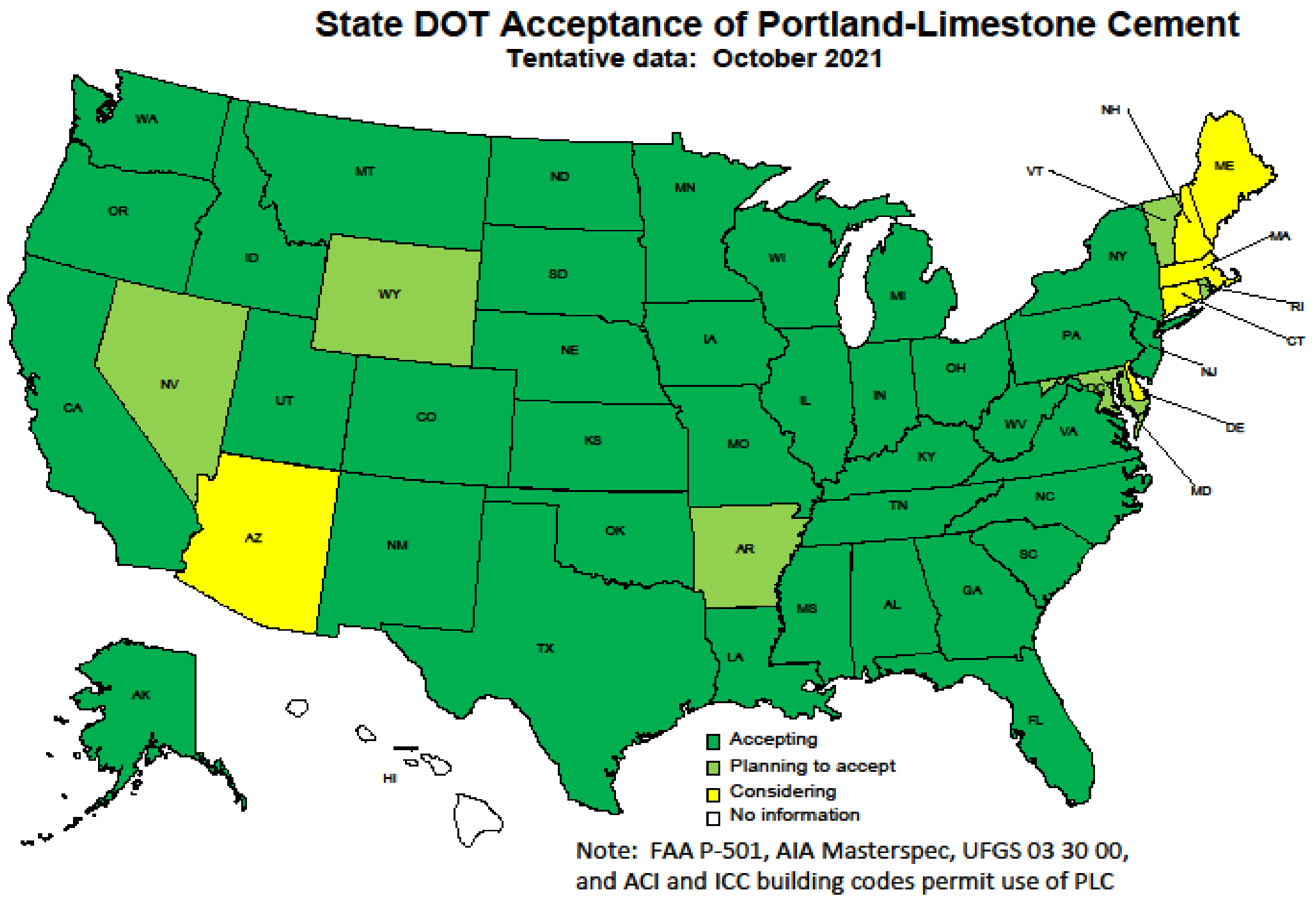
ASTM and AASHTO specifications

Adoption varies by state

ASTM C595 Type IL cement along with ASTM C150 Type I portland cement

Or **AASHTO M 240 Type IL cement** along with M 85 Type I portland cement

In Canada, all cements appear in the **A3000** Cementitious materials compendium: **GUL or GULb** along with GU



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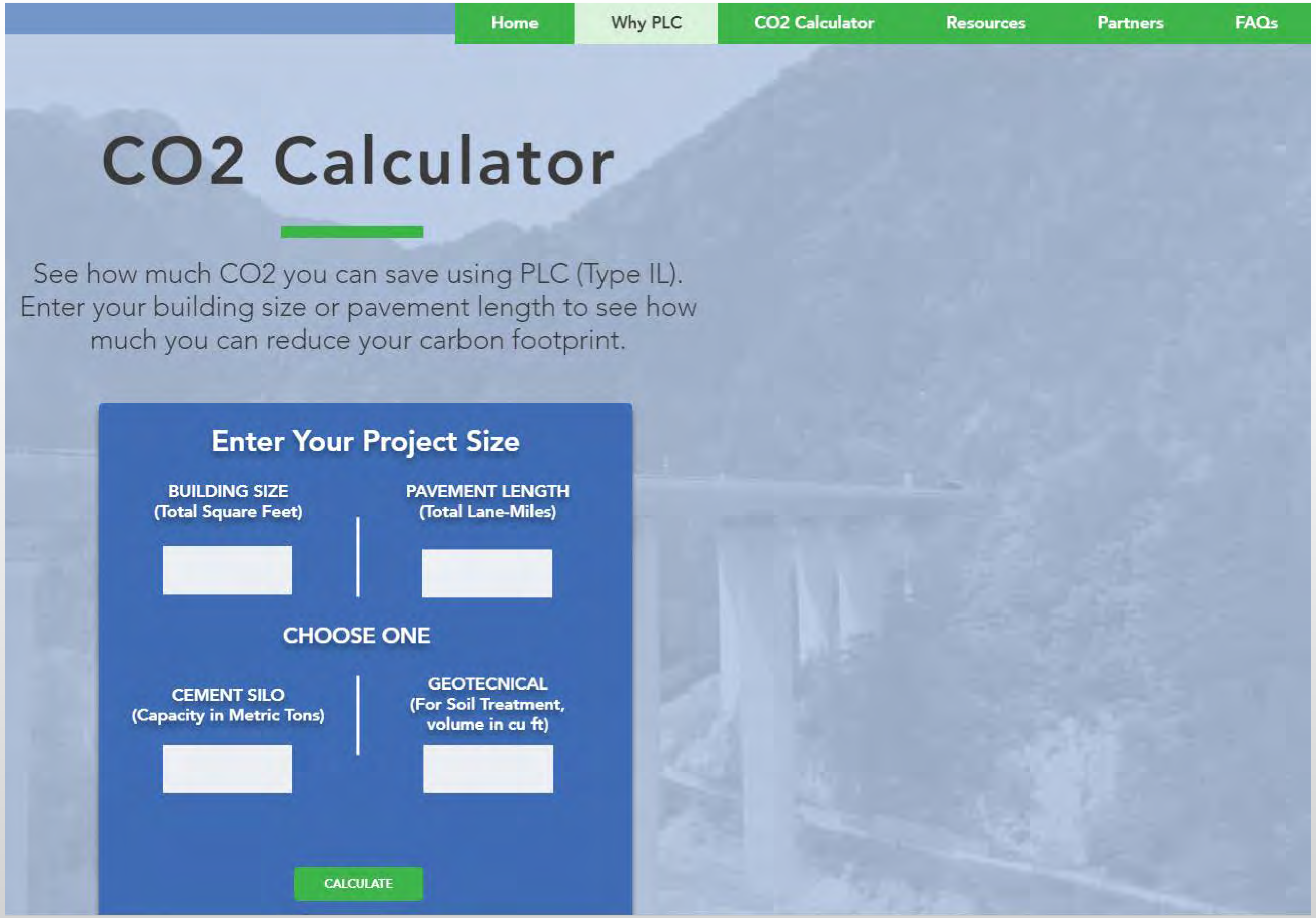
greenercement.com - Your PLC Resource

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



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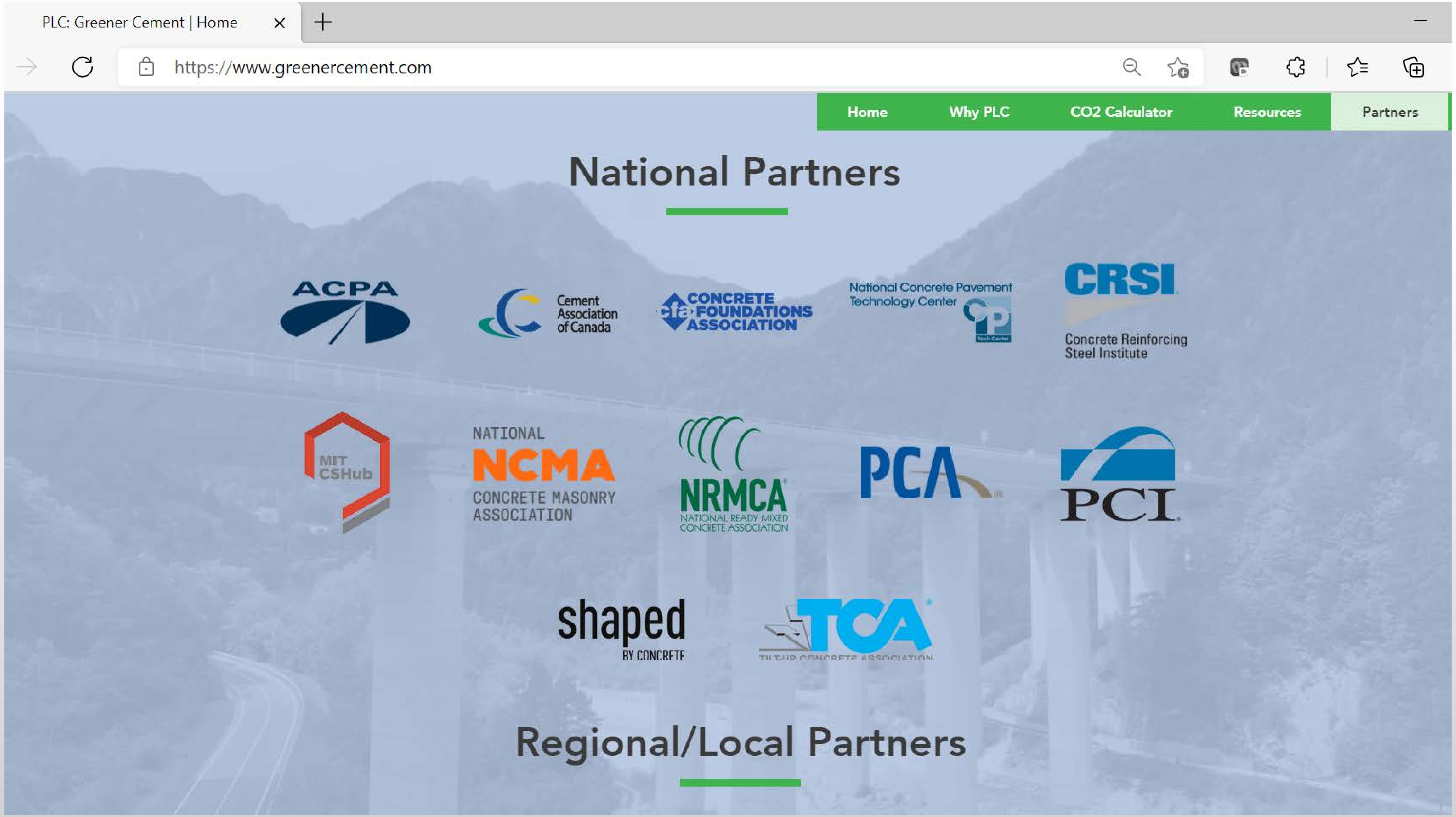

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Partner Resources

- 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)

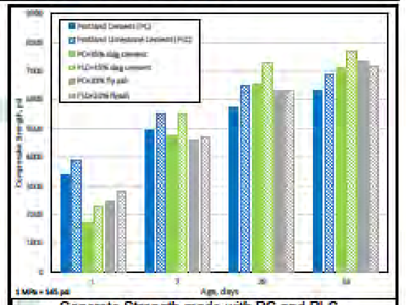
WHAT is Portland Limestone Cement (PLC)

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



Concrete Strength made with PC and PLC

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.

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).

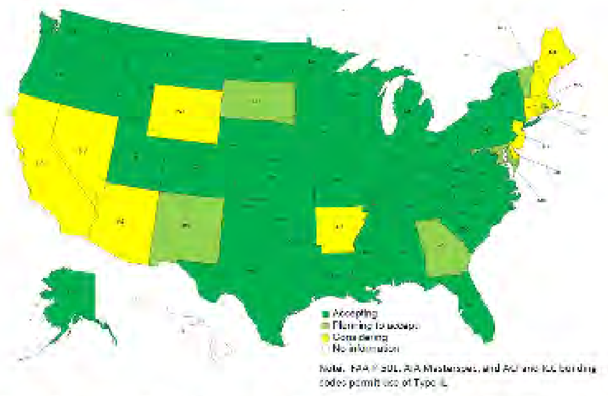


Figure 1 Acceptance of PLC by state DOTs and the FAA as of 2020 (after Innis 2018).
See https://www.cement.org/cement-concrete-applications/cement-and-concrete-basics-faqs

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

One Colorado Example

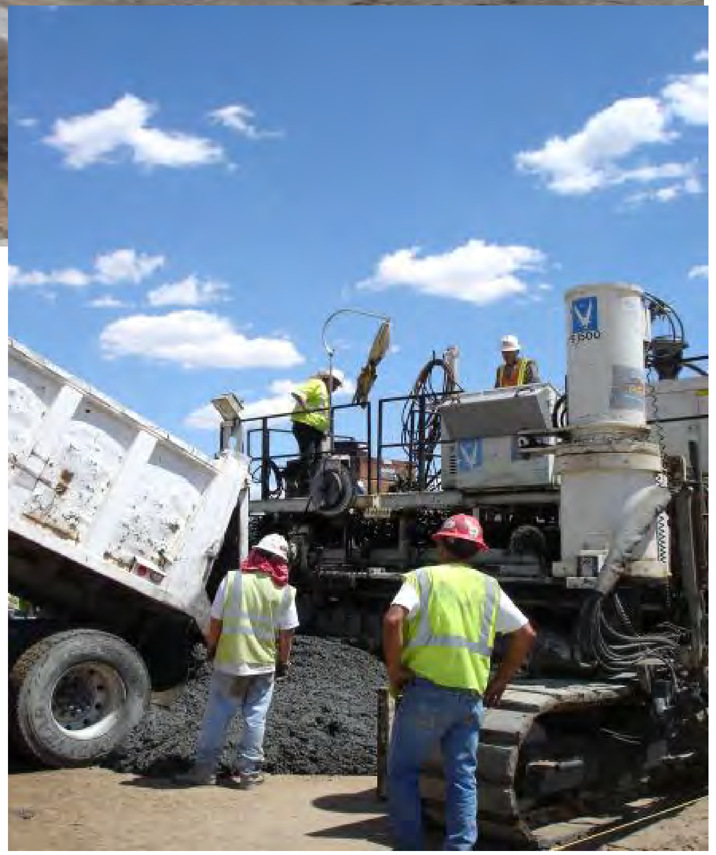
US HWY 287 Near Lamar

Built in 2008 – more than a decade of service

Carries heavy trucking & commerce, US - Mexico

Summertime construction – hot and dry (100°F)

- 7 miles paving and shoulder widening
- PLC (10%L), 20% Class F fly ash
- 695 psi average 28-day flexural strength
- Contractor received quality incentive from CDOT



plc
portland-limestone cement

Soil Stabilization in Florida

Sarasota National residential development

Cement-stabilized soil for road base

Lengthens life of pavement

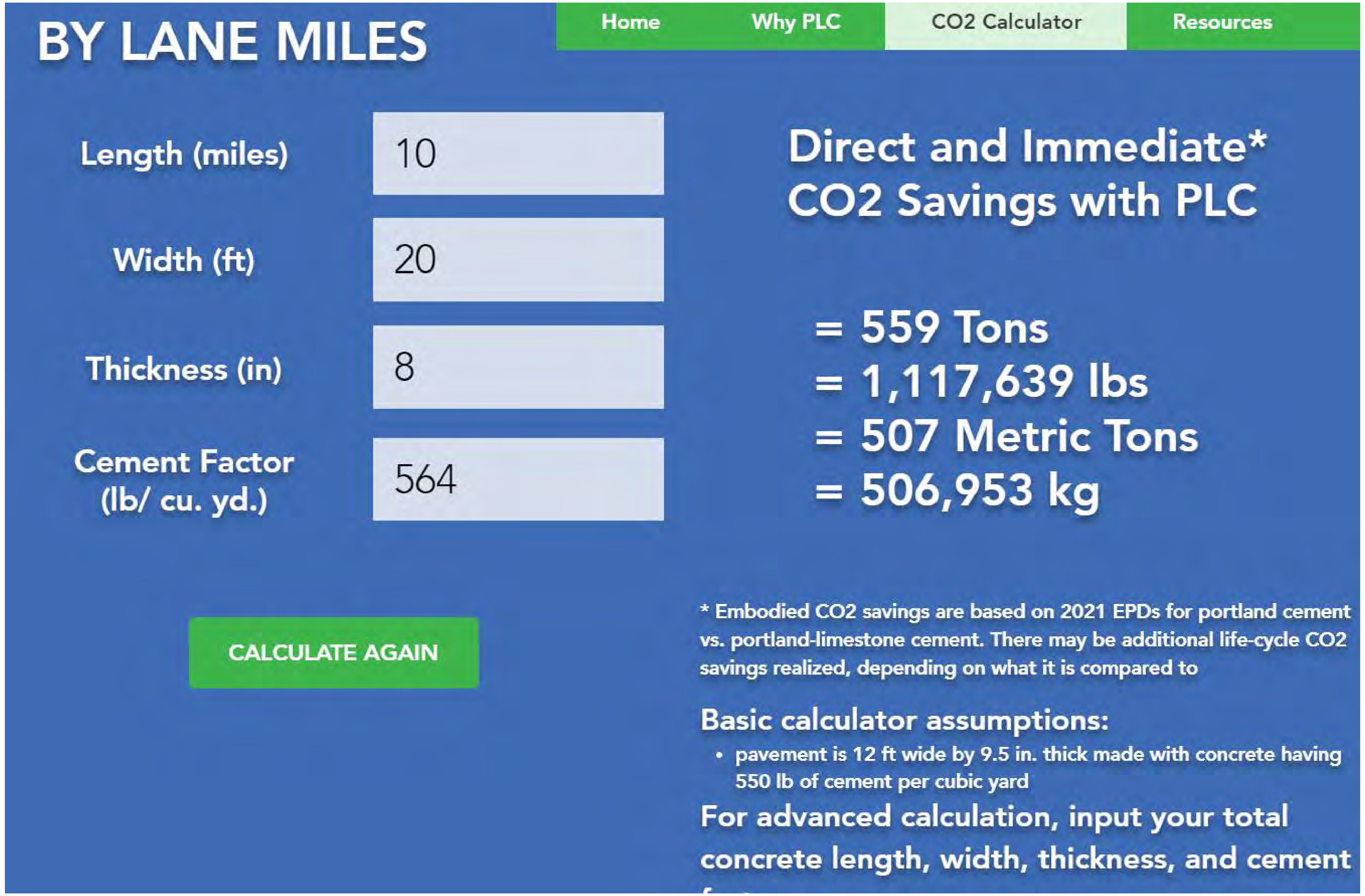
4% PLC dosage by weight of soil

Data on mix designs demonstrated performance

Switch to PLC saved an estimated 76 tons of CO2 on this project

greenercement.com

PLC CO2 savings calculator



IW EPDs for Cement

2016 and 2021 GWP results

L to R

Portland 2016:

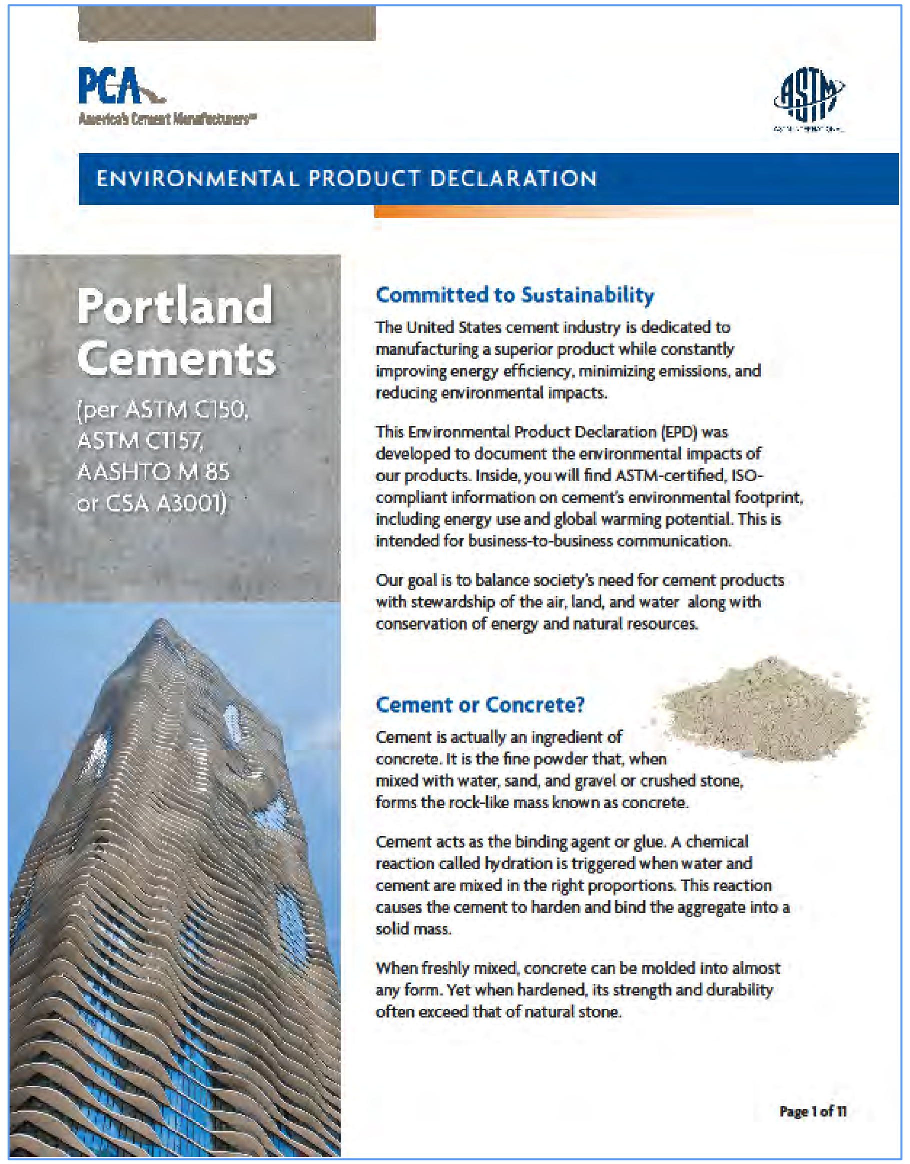
1040 kg CO2eq

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.

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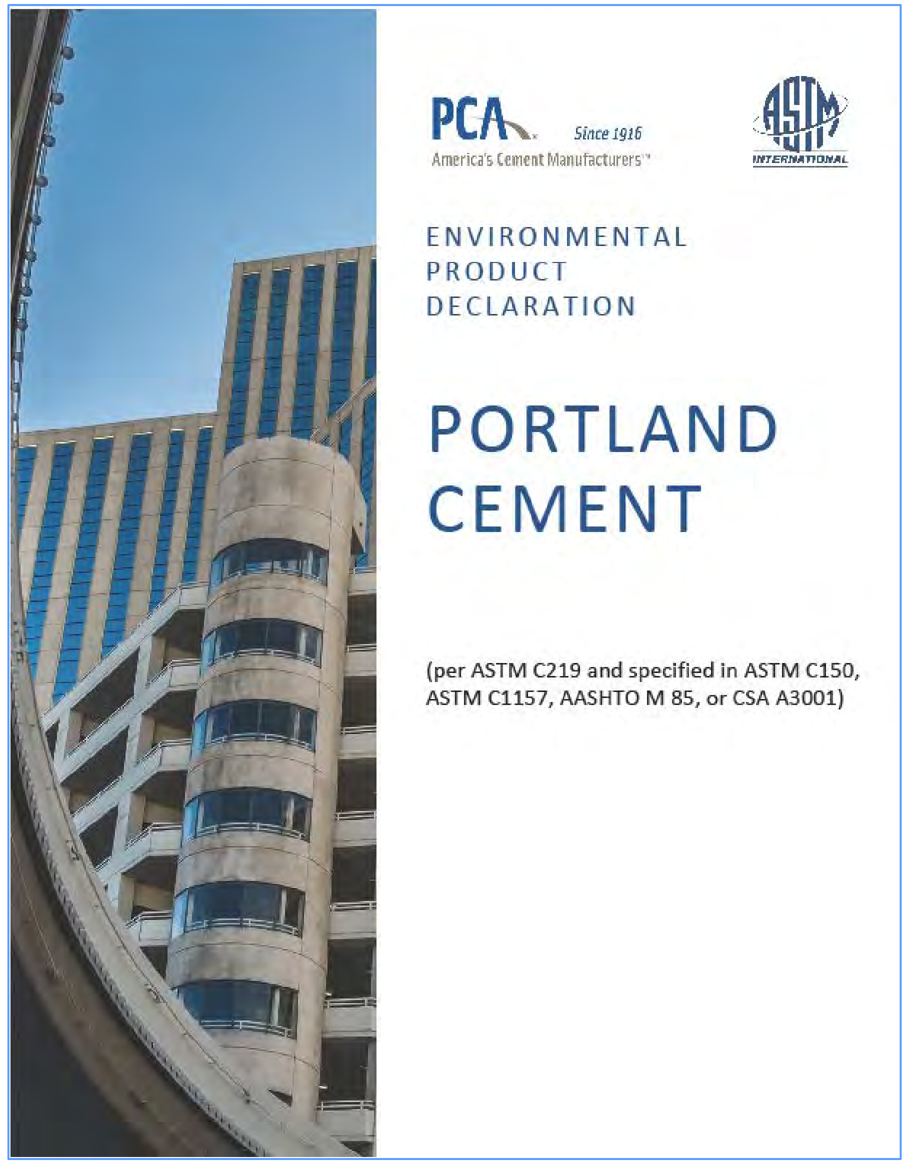
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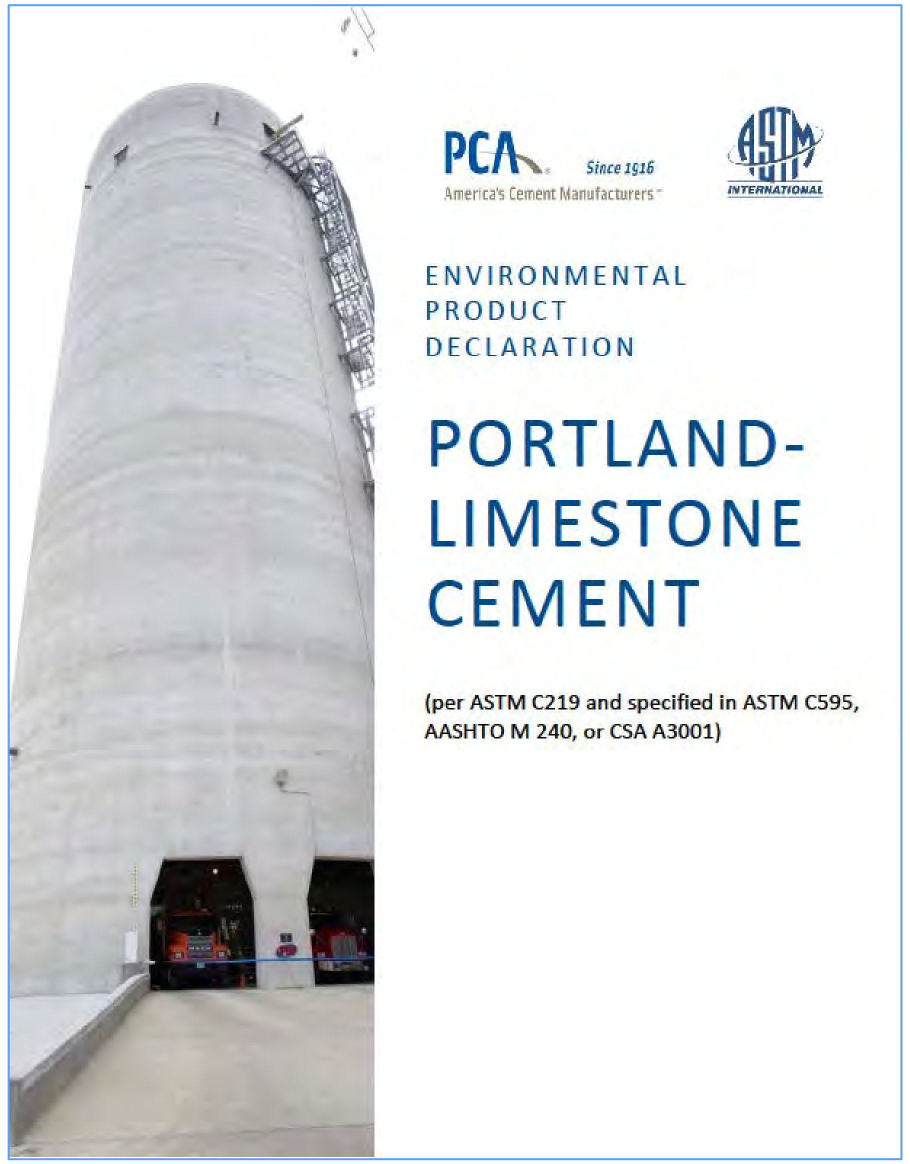
INTERNATIONAL

ENVIRONMENTAL PRODUCT DECLARATION

PORTLAND CEMENT

(per ASTM C219 and specified in ASTM C150, ASTM C1157, AASHTO M 85, or CSA A3001)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INTERNATIONAL

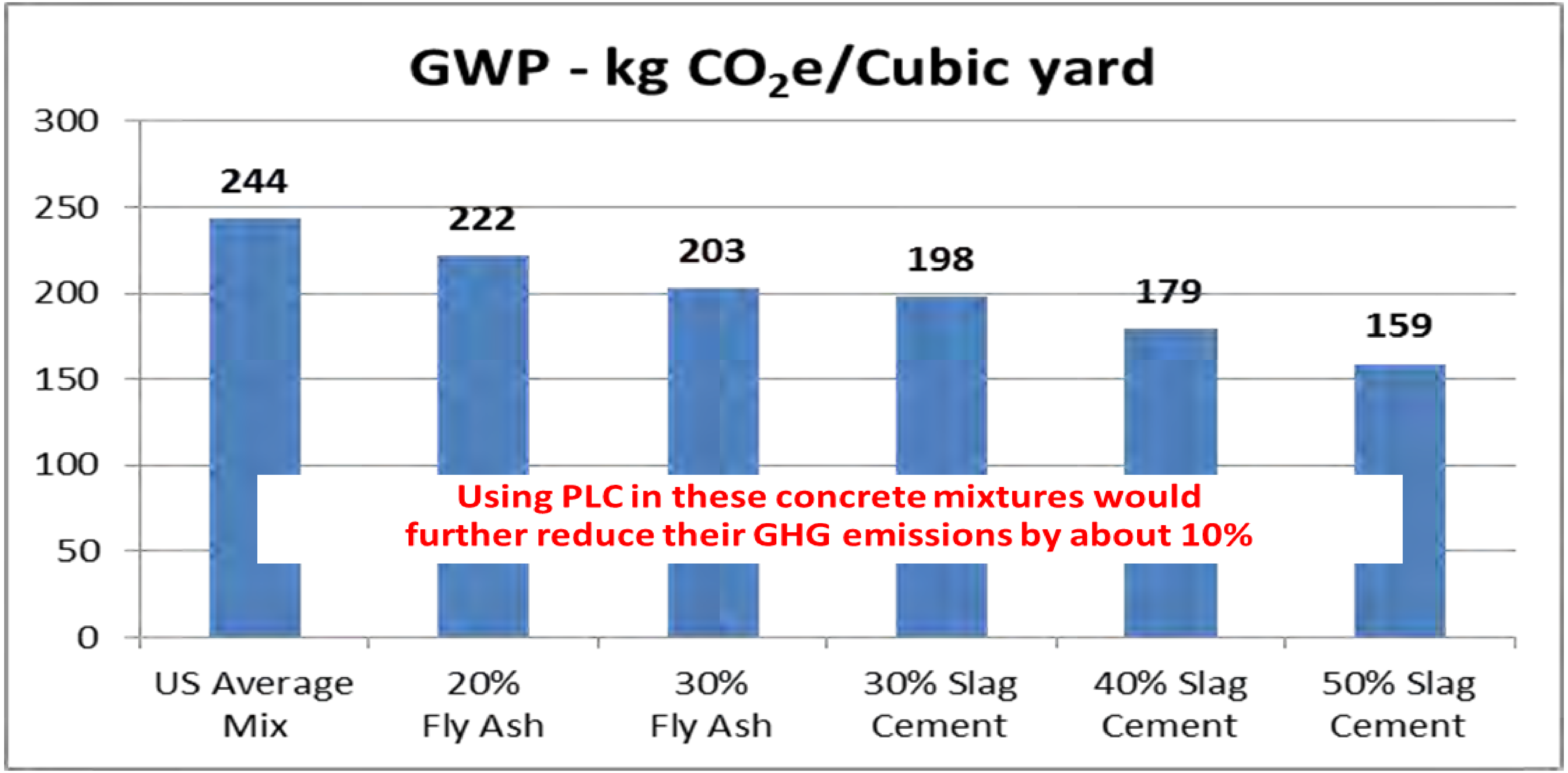
ENVIRONMENTAL PRODUCT DECLARATION

PORTLAND-LIMESTONE CEMENT

(per ASTM C219 and specified in ASTM C595, AASHTO M 240, or CSA A3001)

EPDs -> LCA

Lowering Carbon Footprint of Mixes



3000 psi concrete mixes 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.

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

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

portland-limestone cement

Reducing Concrete's Carbon Footprint with PLCs

NESMEA - October 26, 2021