plc portland-limestone cement

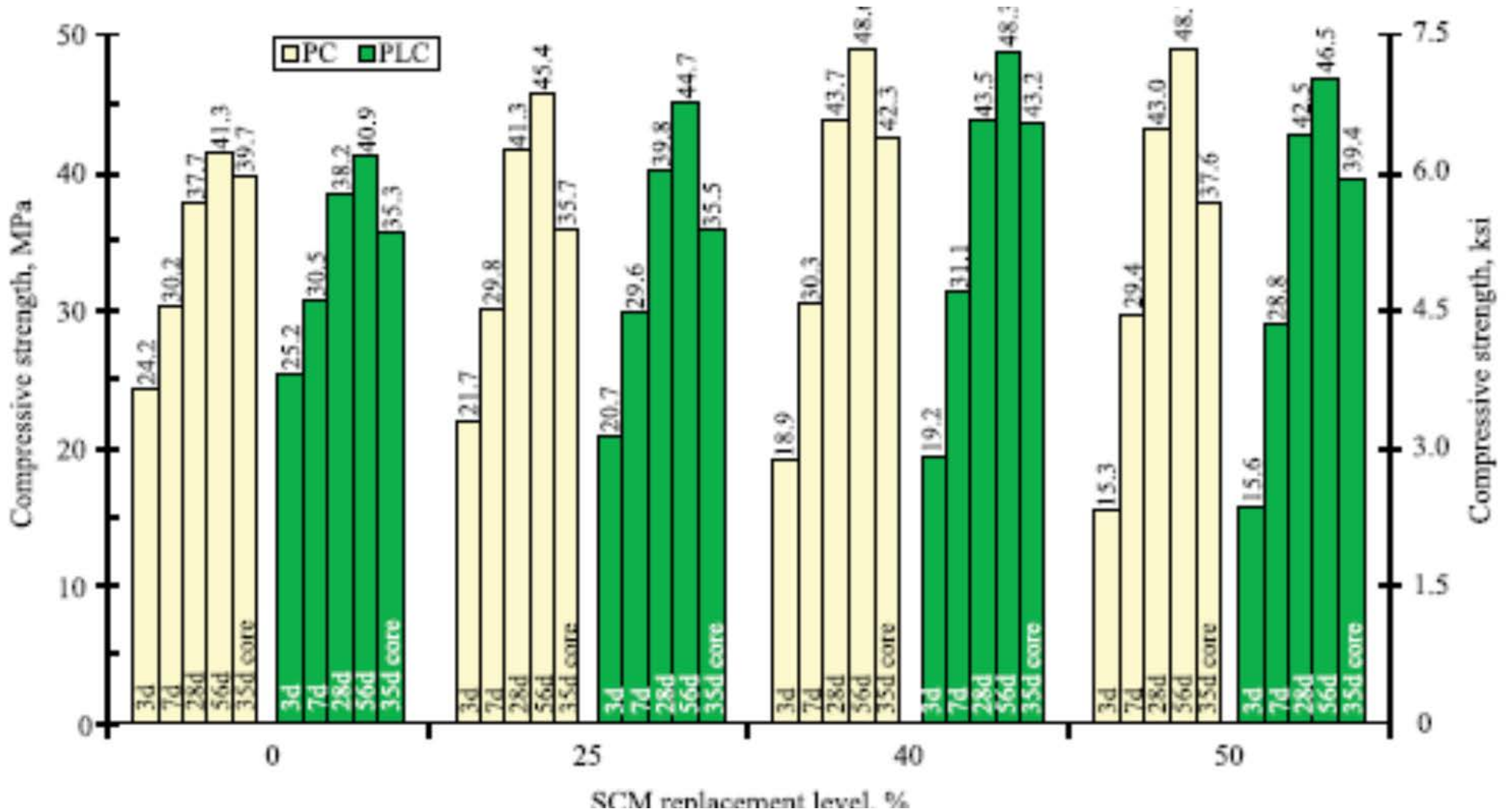
Portland-Limestone Cement and New Industry Initiatives

Sustainable Structures Webinar Series - January 26, 2022

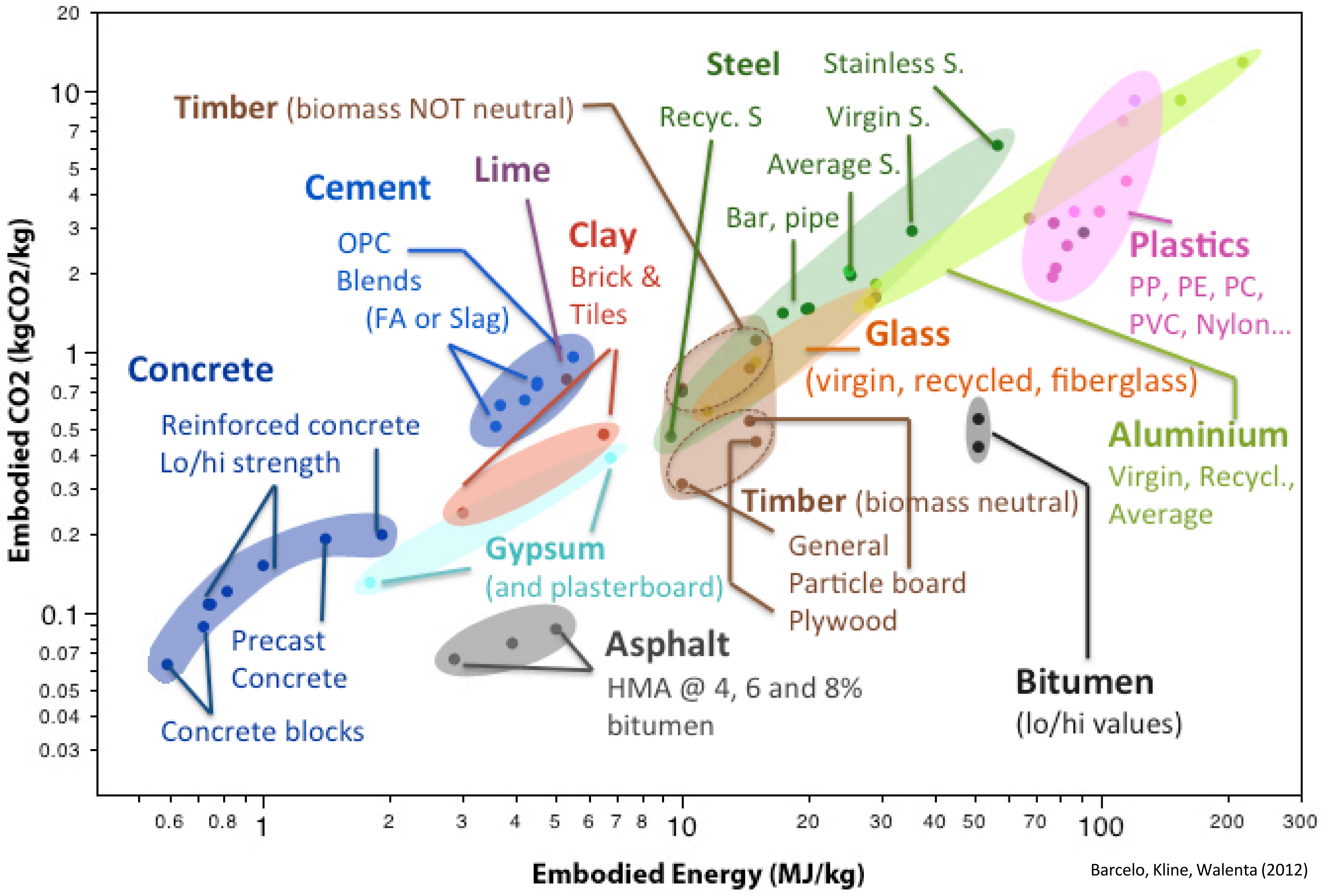
Learning Objectives

Learning how to work with PLC

1. Understand the potential savings in CO_2 footprint when using PLC to make concrete and explain how that is achieved.
2. State the replacement level and how to modify mix designs when swapping in PLC for OPC.
3. State how supplementary cementitious materials (SCMs) contents are affected by using PLC.
4. Describe how PLC affects fresh and hardened concrete properties relative to OPC concrete.



Concrete is Environmentally Friendly



Barcelo, Kline, Walenta (2012)

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America's Cement Manufacturers™

Shaped by Concrete Campaign

shaped
BY CONCRETE

ABOUT | CONCRETE SHAPING OUR WORLD | ROADMAP TO CARBON NEUTRALITY | NEWS

Modern society has been built using cement and concrete.

These materials are used throughout our daily lives to shape the world around us. Our roadways, homes, schools, communities and cities have all been shaped by cement and concrete. In fact, the only other material consumed more than concrete is water.

Concrete Shaping Our World

Enhancing Sustainability

The cement and concrete industry continues to be committed to a sustainable future, improving and innovating in a variety of ways and reducing energy associated with waste and maintenance. Our industry also supports policies and initiatives that enable the reduction of our carbon footprint.

Creating a Resilient Nation

Our nation and economy are sustained by safe, strong and durable infrastructure built with concrete, which allows us to better withstand natural disasters - enabling our lives and economy to function without interruption – and better address the realities of our changing climate.

Industry Leadership

Cement and concrete manufacturers play a major role in our communities, and we are committed to maintaining the health, safety and vitality of our workforce and local communities.

Foundation of Our Society

Cement and concrete are essential to our progress and development, enabling our society to be safer, stronger and more productive.

ABOUT | CONCRETE SHAPING OUR WORLD | ROADMAP TO CARBON NEUTRALITY

Roadmap to Carbon Neutrality

Cement and concrete are the foundation of a resilient, durable and sustainable built environment

America's cement manufacturers have committed to the goal of reaching carbon neutrality throughout the cement-concrete-construction value chain by 2050.

Cement is the first – and critical – ingredient in concrete infrastructure. Concrete provides the foundation for the nation's built environment through structures that can withstand the extreme weather events that accompany climate change. This includes the roads, runways, bridges, buildings, waterways and more that we rely on every day.

Currently, based on U.S. Environmental Protection Agency (EPA) carbon emissions data, the manufacture of cement accounts for 1.25% of U.S. CO_2 emissions – with demand projected to increase, we have a once-in-a-generation opportunity to set a global example on building sustainably, utilizing new approaches and advocating for updated technology.

The cement and concrete industry have developed a Roadmap outlining the opportunities and actions to reach carbon neutrality. The Roadmap involves the entire value chain, starting at the cement plant and extending through the entire life cycle of the built environment to incorporate the circular economy. This approach to carbon neutrality leverages relationships at each step of the value chain, demonstrating to the world that this industry can address climate change.

[PCA 2050 Roadmap to Carbon Neutrality]

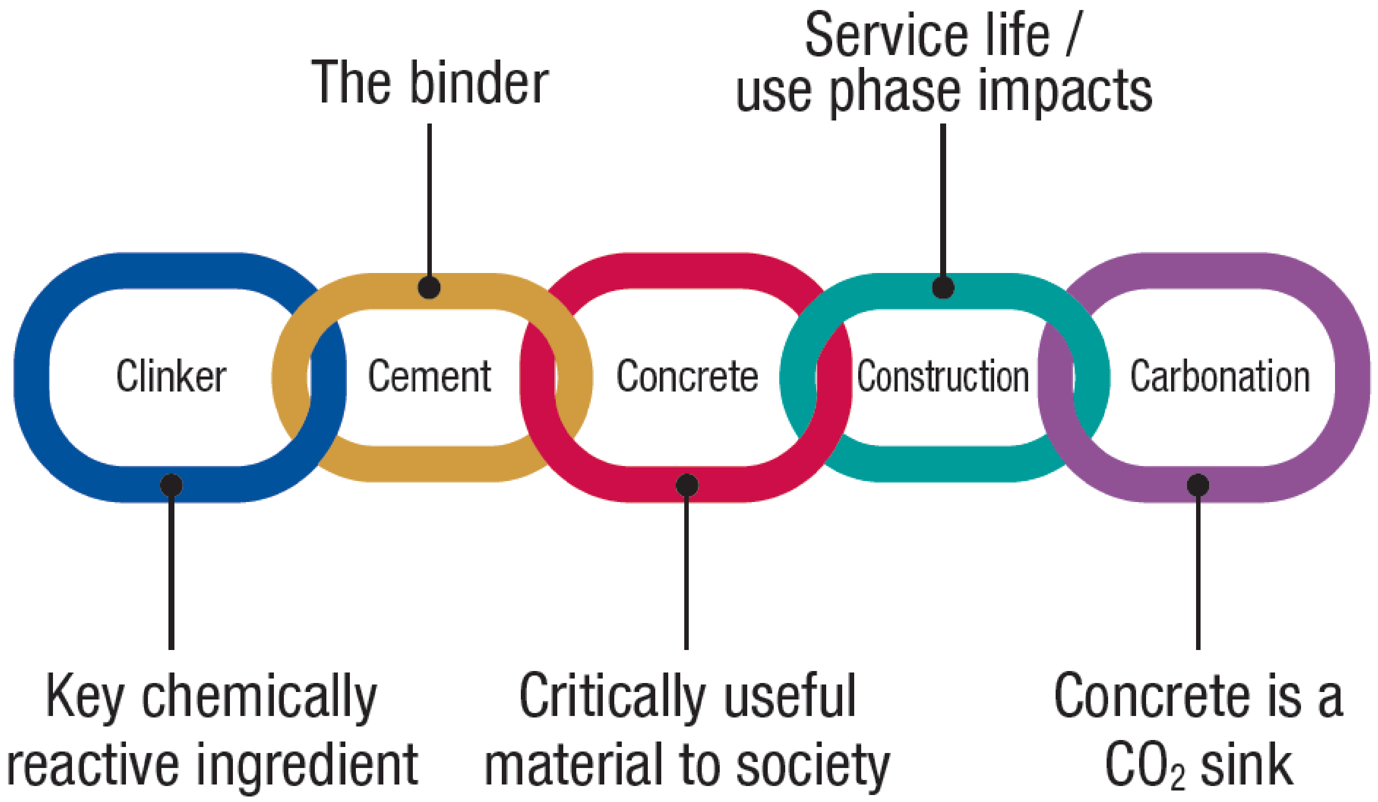
CO2 and Sustainability

Increasing interest in reducing environmental impact of building materials 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]



2050: PCA Attains Carbon Neutrality

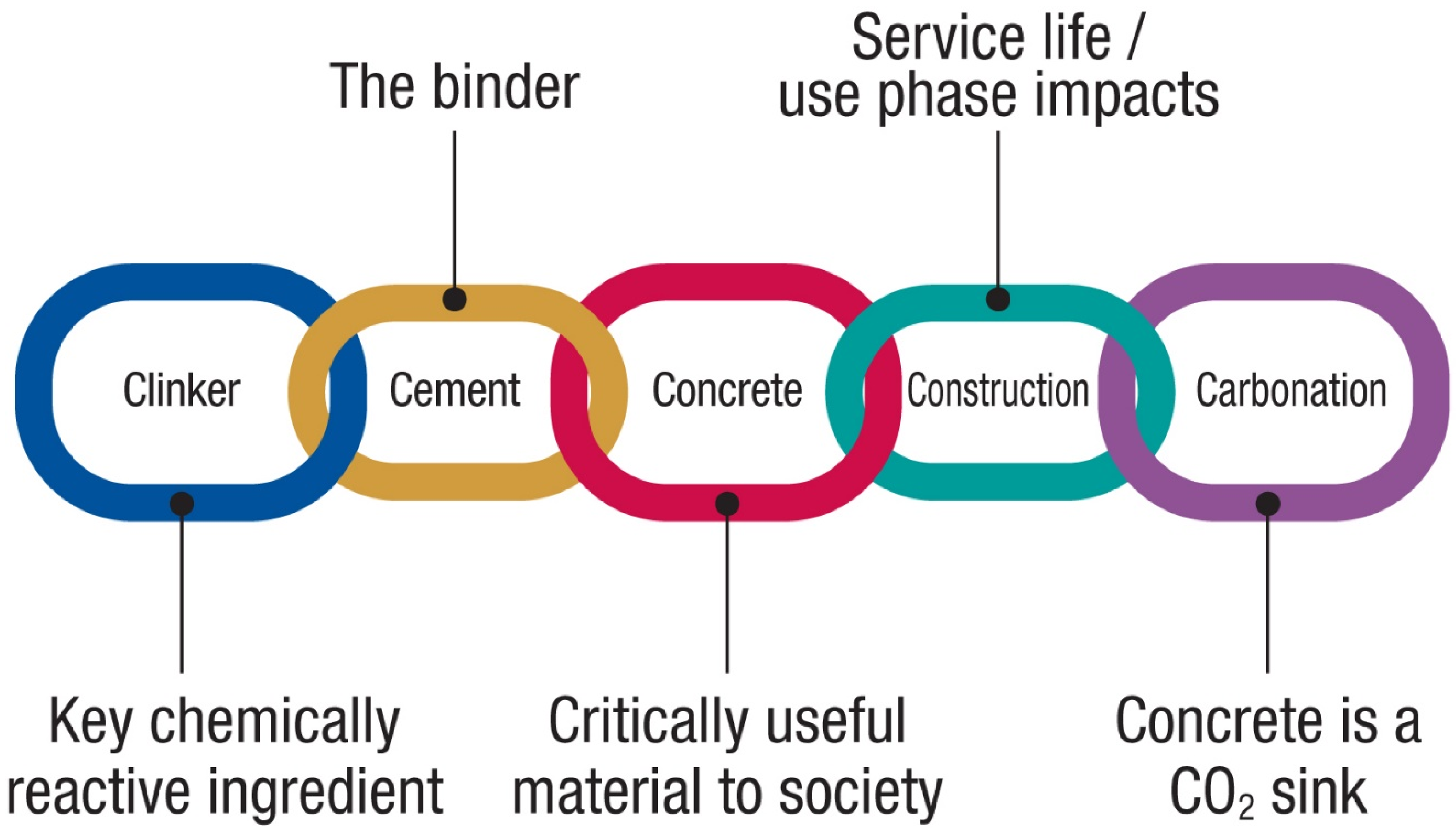
5 Cs approach to getting there

Clinker and Cement – more decarbonated materials, alternative fuels, improve manufacturing efficiency, CCUS, new cement formulations

Concrete – optimized mixes, more recycled materials and SCMs, performance specs

Construction – optimization in design, delivery, handling, zero waste

Carbonation – quantify natural process



PLC is a Key Lever for the Roadmap

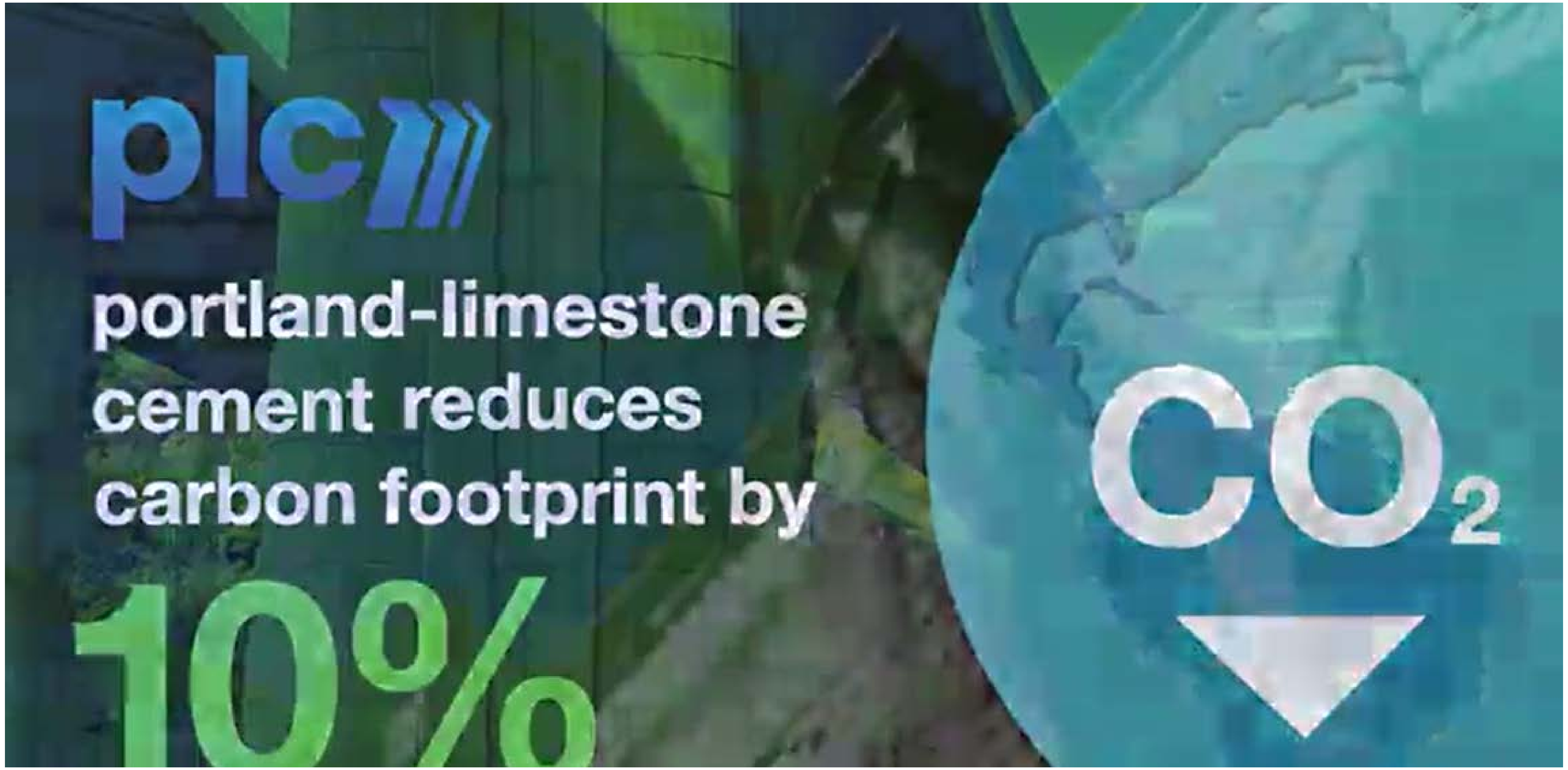
CO2 Footprint of Construction

CO2 problem?

CO2 opportunity!

PLC is proven technology

PLC can help position concrete as more sustainable



Portland-limestone cements

Embracing their use to reduce concrete’s carbon footprint

What is PLC?

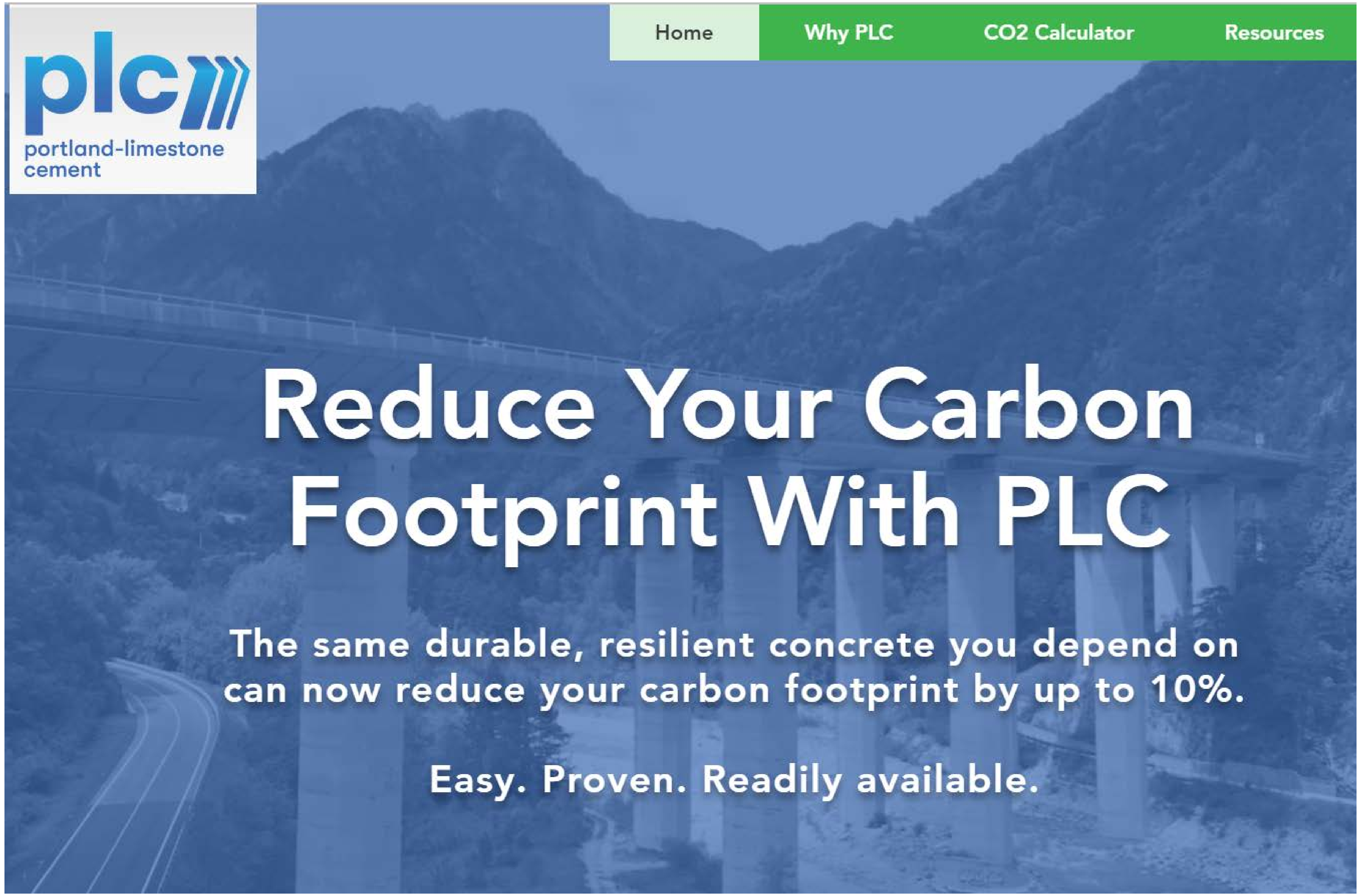
A greener cement option

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 C150
- Limestone (2004, 2007)
- Inorganic processing additions (2009)

Blended cements C595
- Nomenclature (2006)
- Type IT (2009)
- **Type IL (2012)**

U.S. Standards

Cementitious Materials and Concrete 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

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

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

C476 grout for masonry – equal recognition of C150, C595, and C1157 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 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)
General use	I	IL
moderate sulfate resistance	II, II(MS)	IL(MS)
moderate heat of hydration	II(MH)	IL(MH)
high sulfate resistance	V	IL(HS)
low heat of hydration	IV	IL(LH)
high-early strength	III	IL(HE)

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

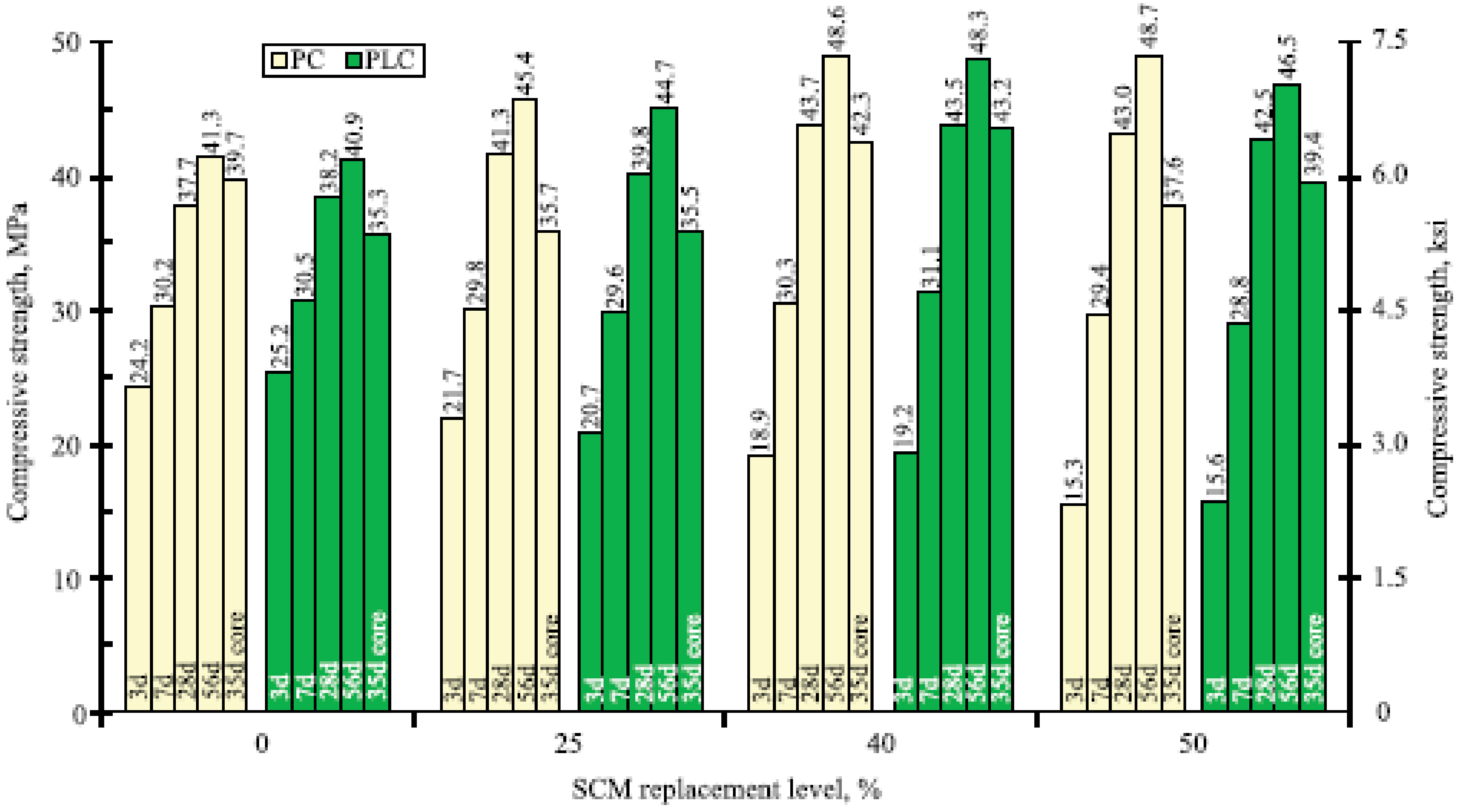
Virtually the same handling and performance as OPC

Performance of PLC Concrete

A look at hardened properties

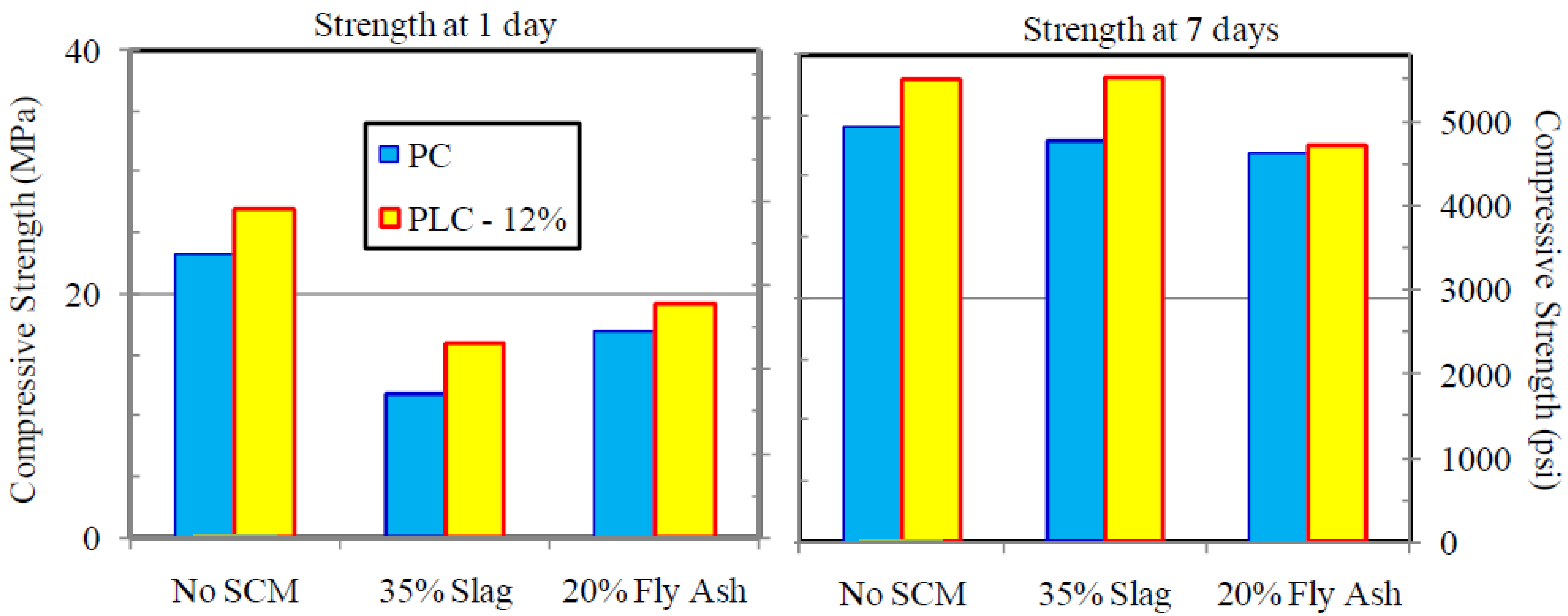
Strength
- OPC to PLC comparisons
- With and without SCMs

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



Performance of PLC Concrete

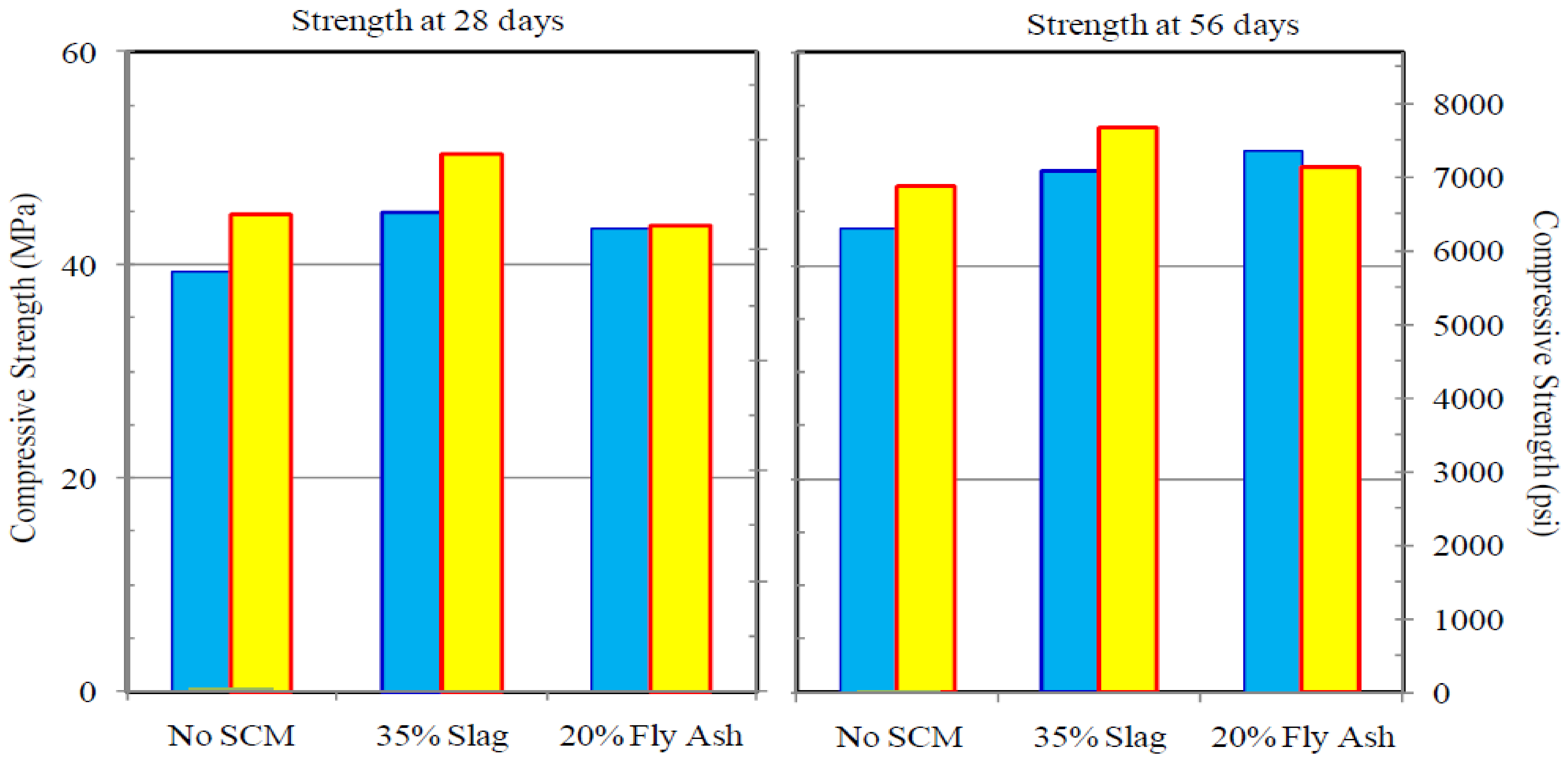
Early age strength development with and without SCMs



Thomas and Hooton 2010

Performance of PLC Concrete

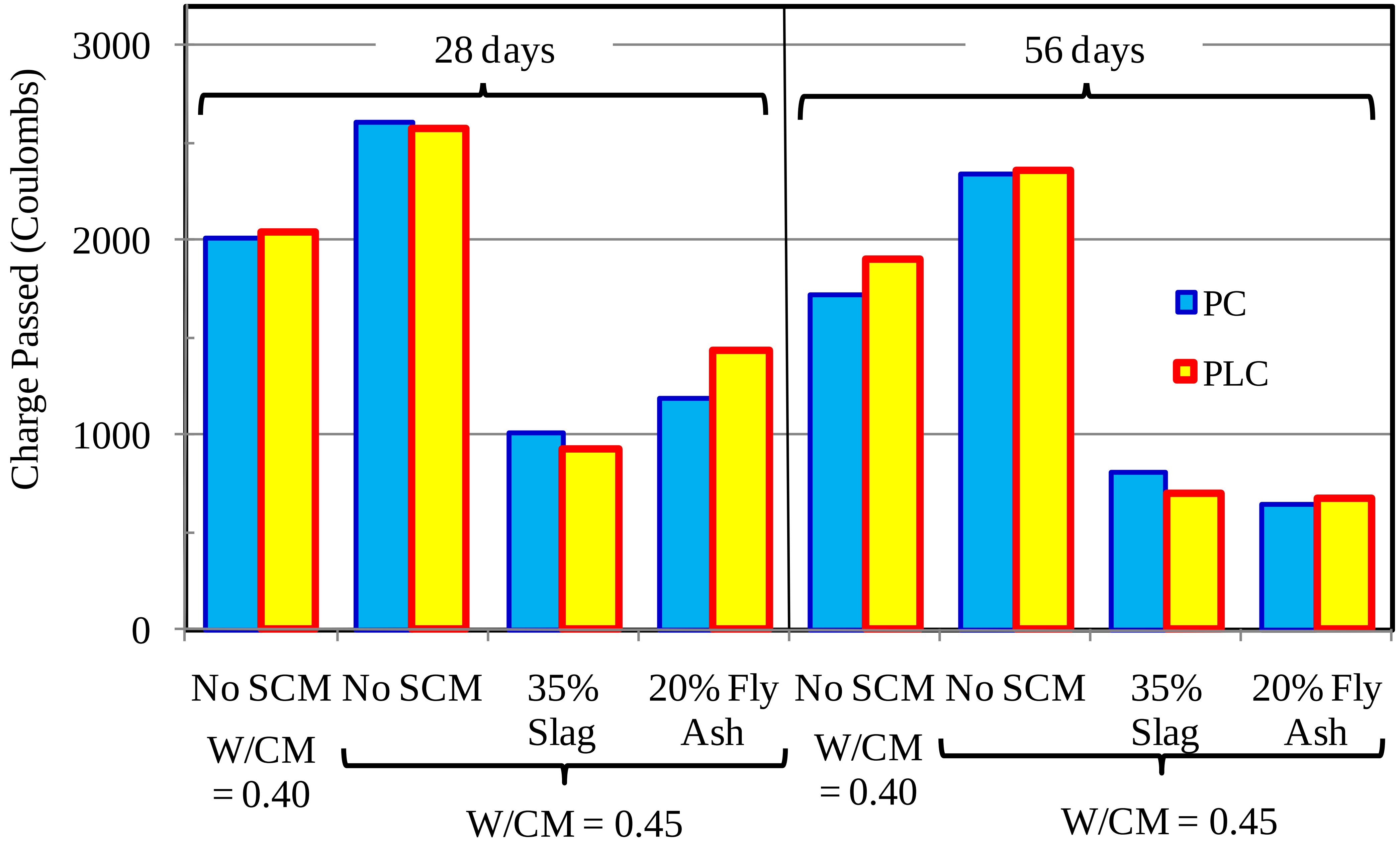
Later age strength development with and without SCMs



Thomas and Hooton 2010

Performance of PLC Concrete

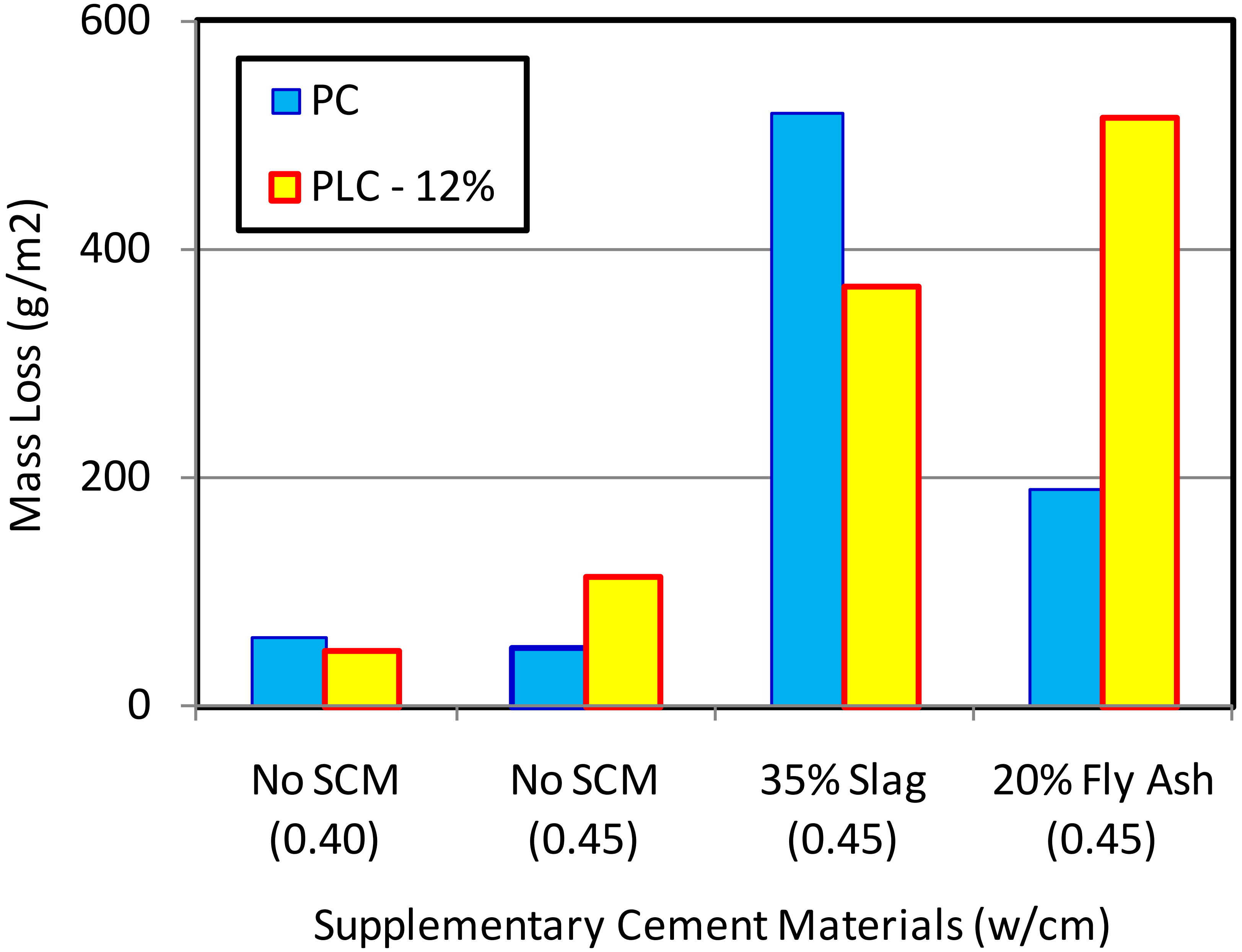
“Permeability” T277/C1202



Thomas and Hooton 2010

Performance of PLC Concrete

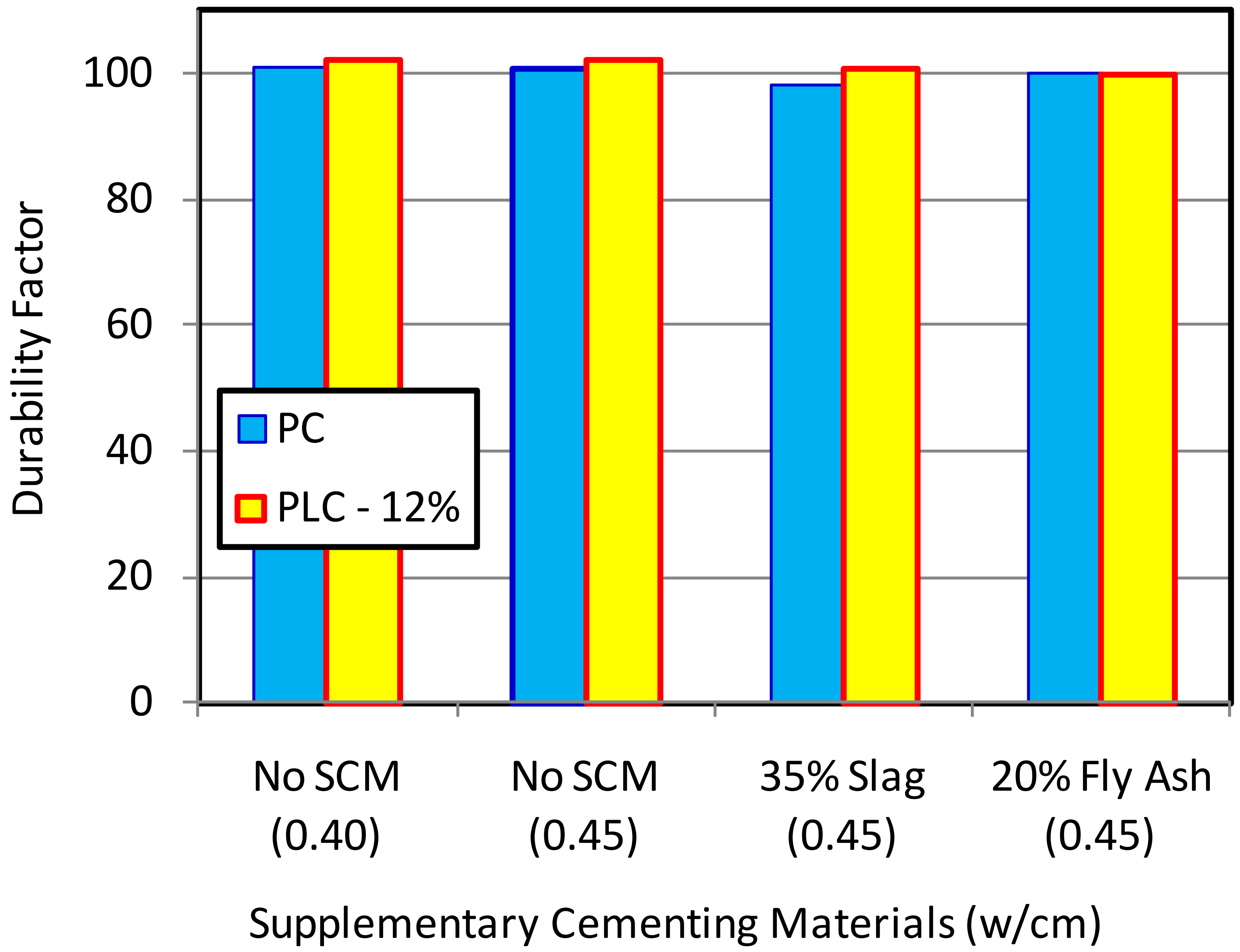
Scaling resistance (ASTM C672)



Thomas et al. 2010

Performance of PLC Concrete

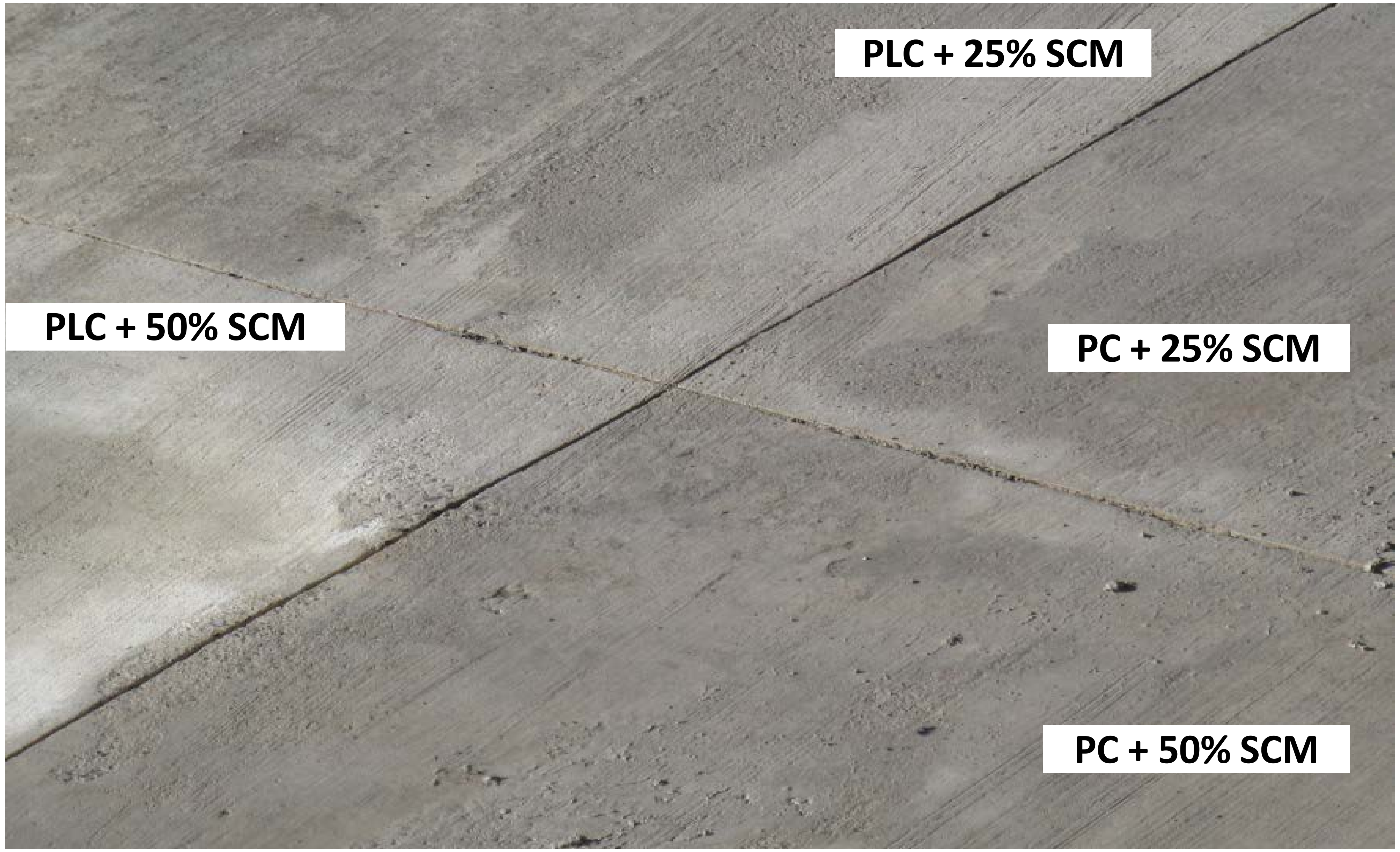
Freeze-Thaw Resistance (ASTM C666)



Thomas et al. 2010

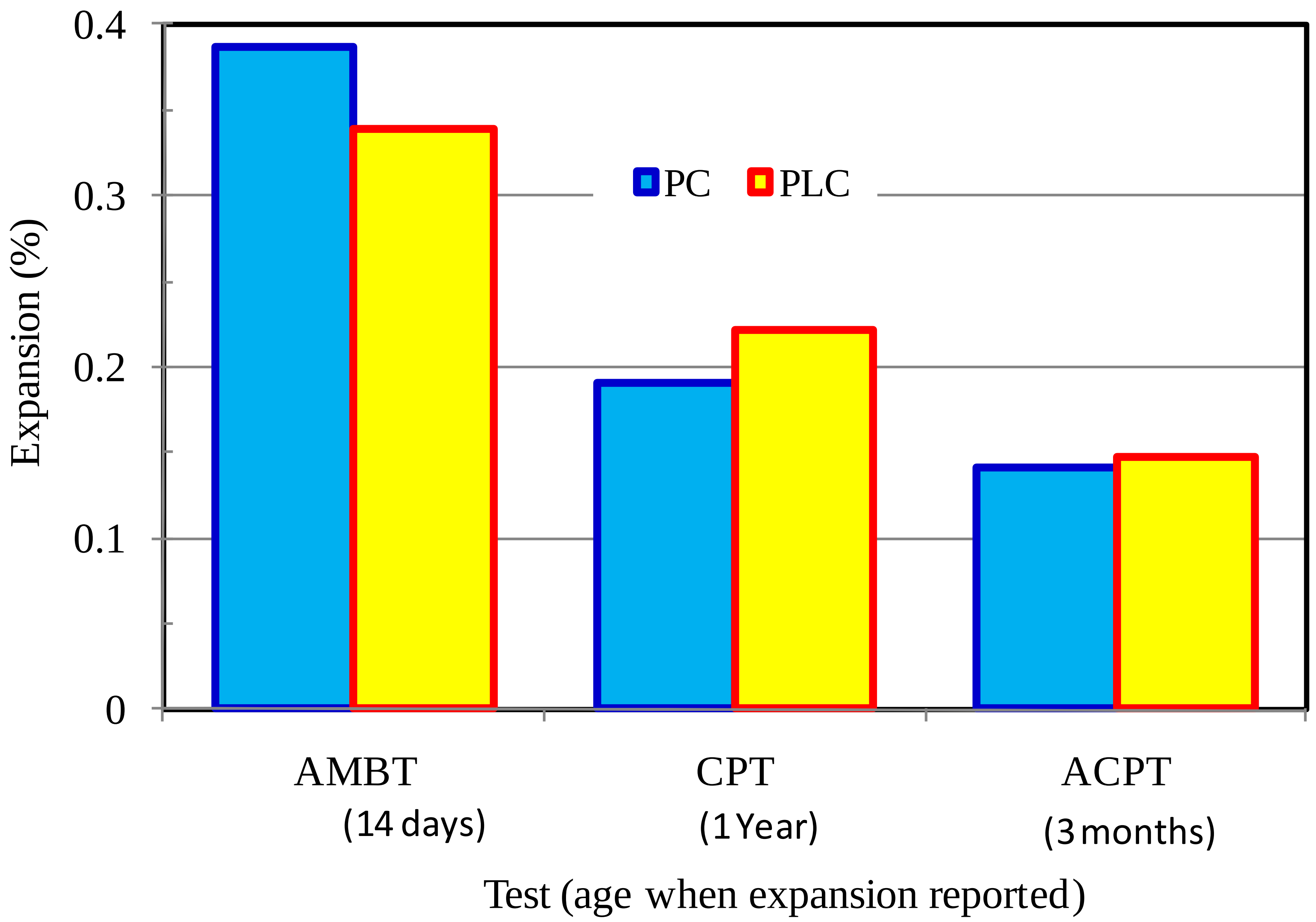
Performance of PLC Concrete

Field Trials: Pavement slab after one winter



Performance of PLC Concrete

ASR resistance



Thomas et al. 2010

PLC and Sulfate Resistance

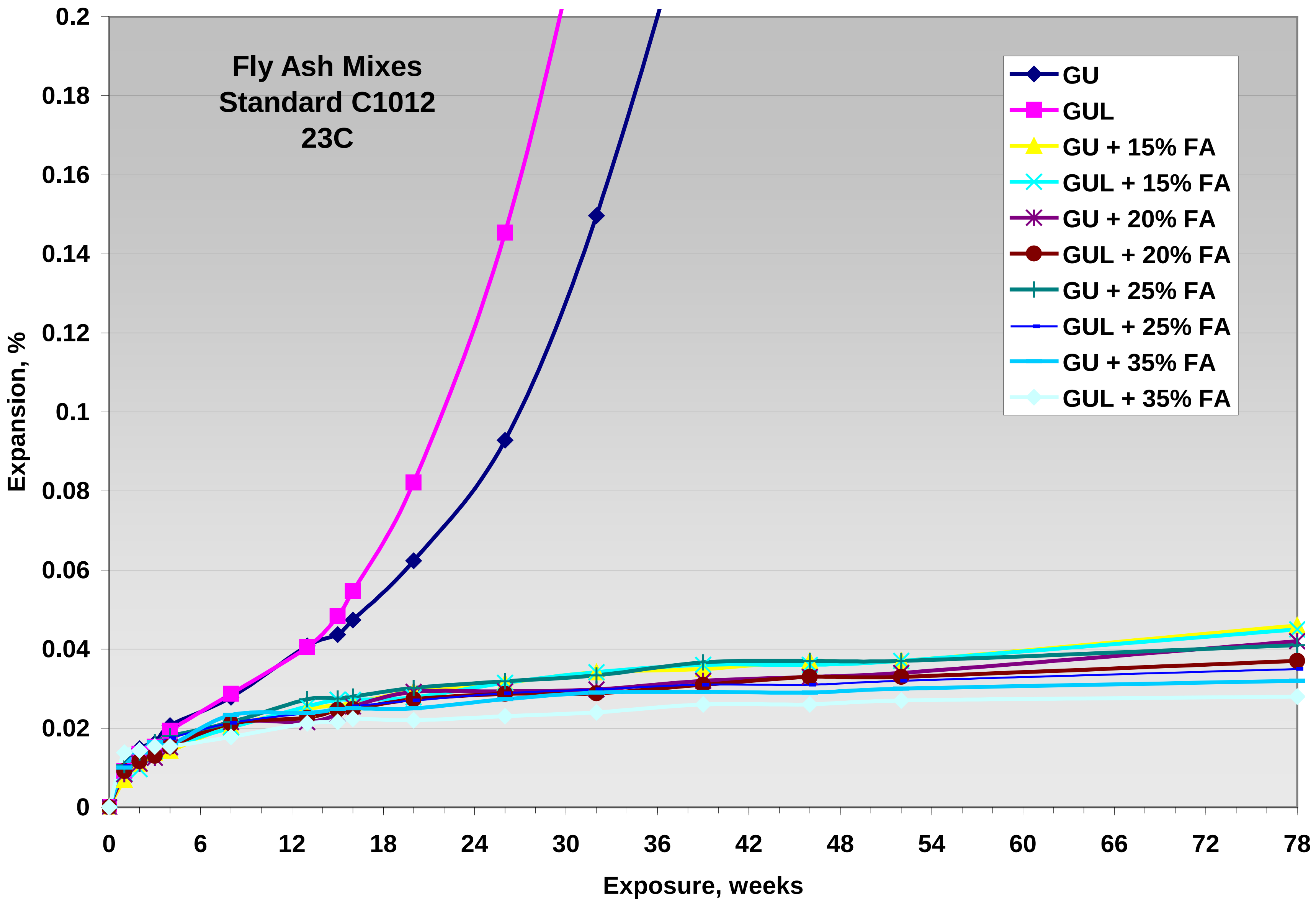
Same approach as for other blended cements

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

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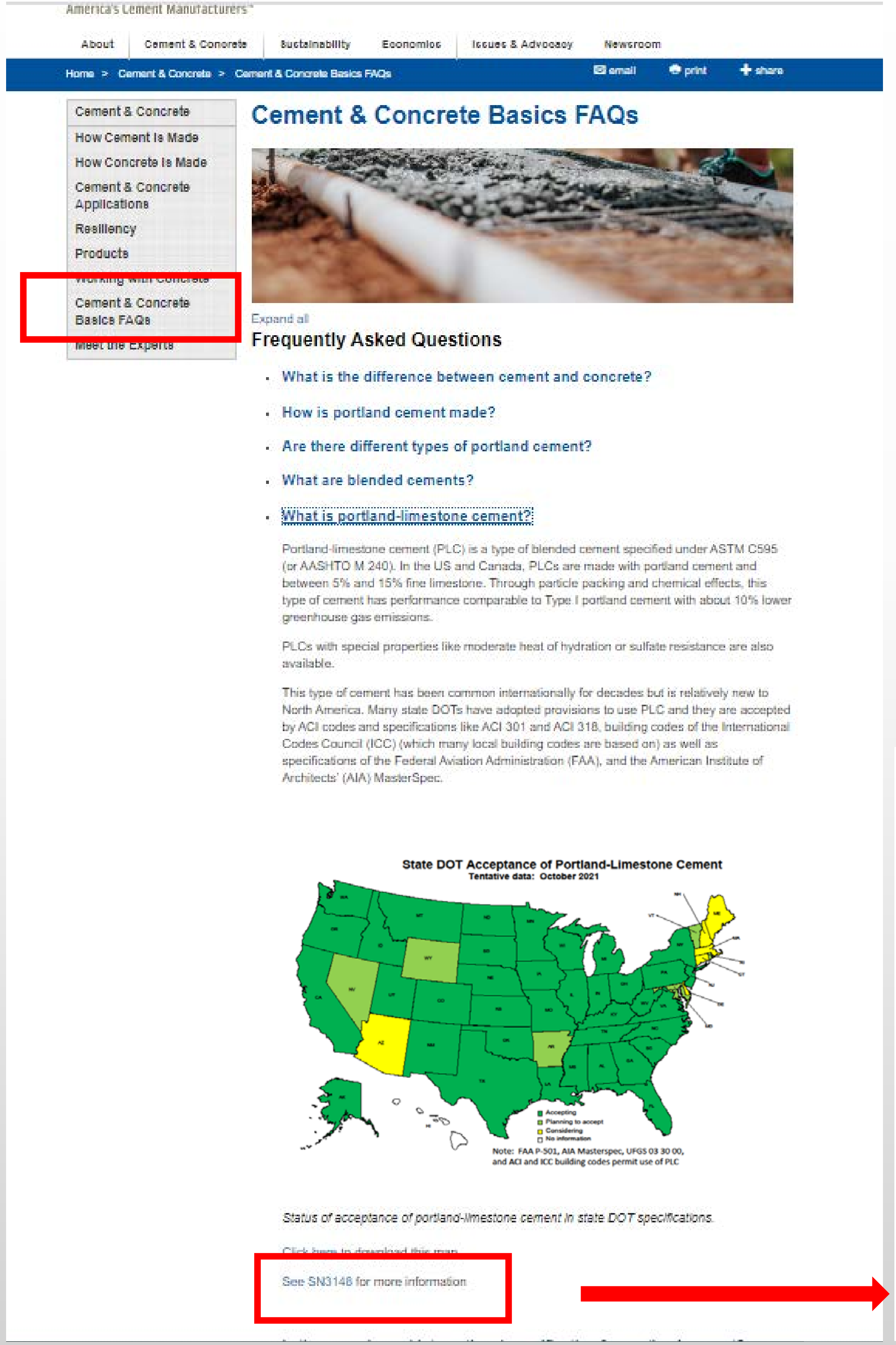
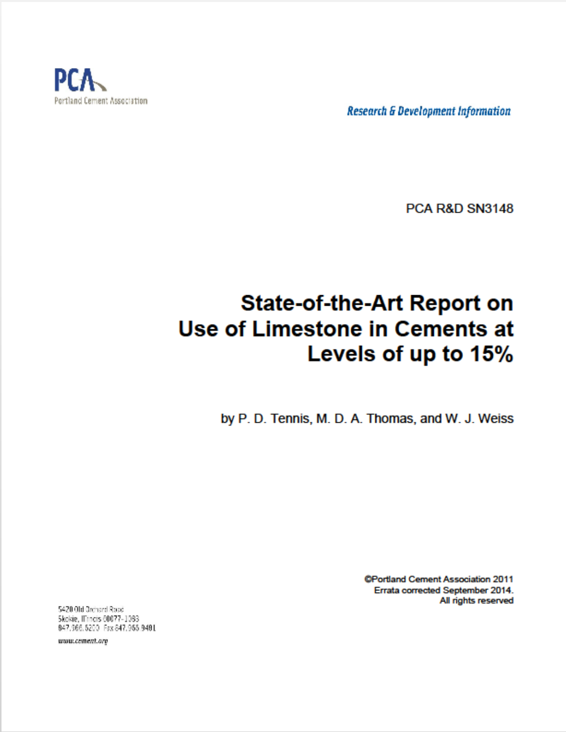
Documented Performance

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



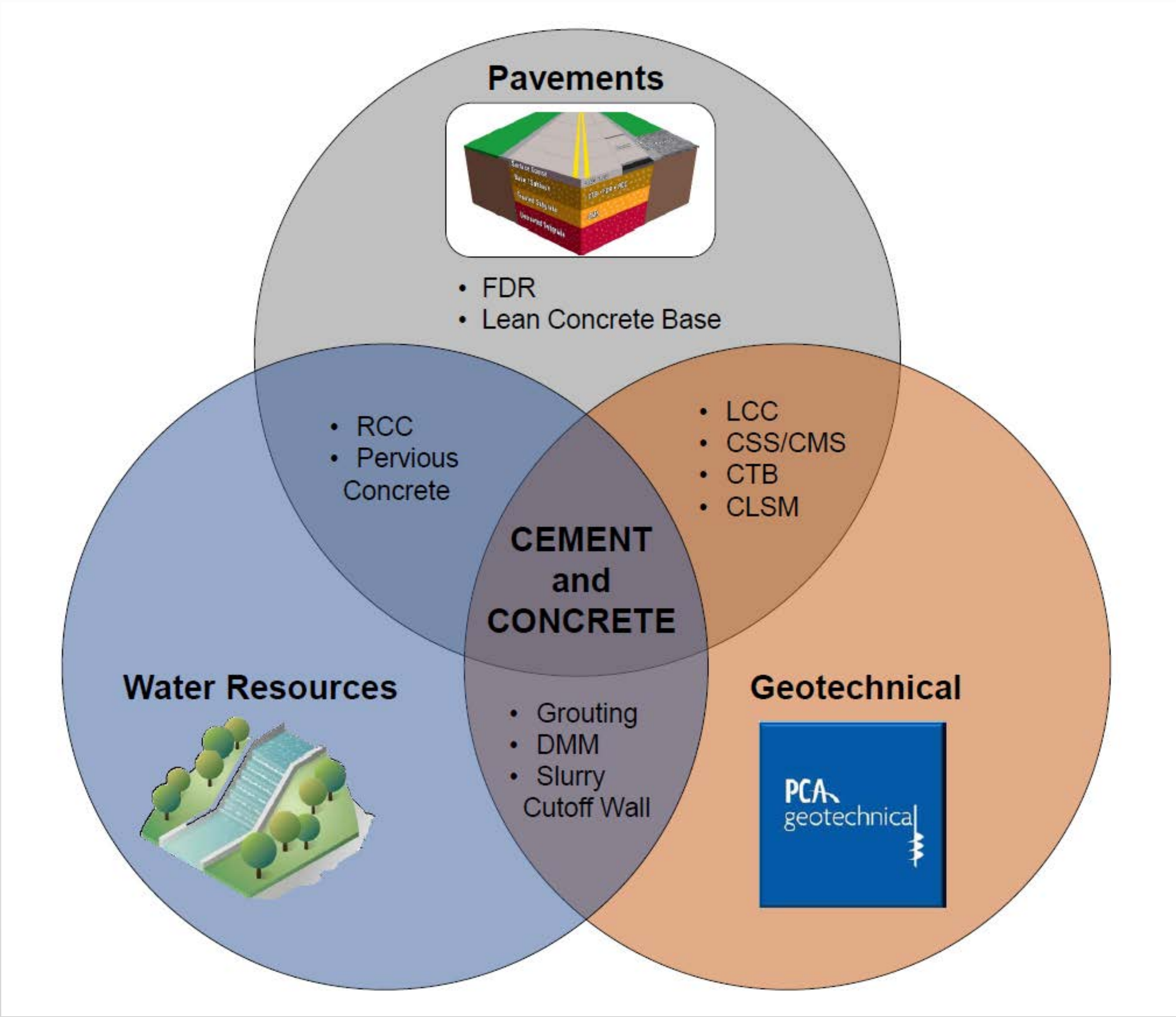


Caltrans Research Confirms PLC Performance

- 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)

Research into PLC Soil-Cement

- Research needed on the efficacy of PLC in soil-cement applications
- Supports all 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
- Preliminary results look promising



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

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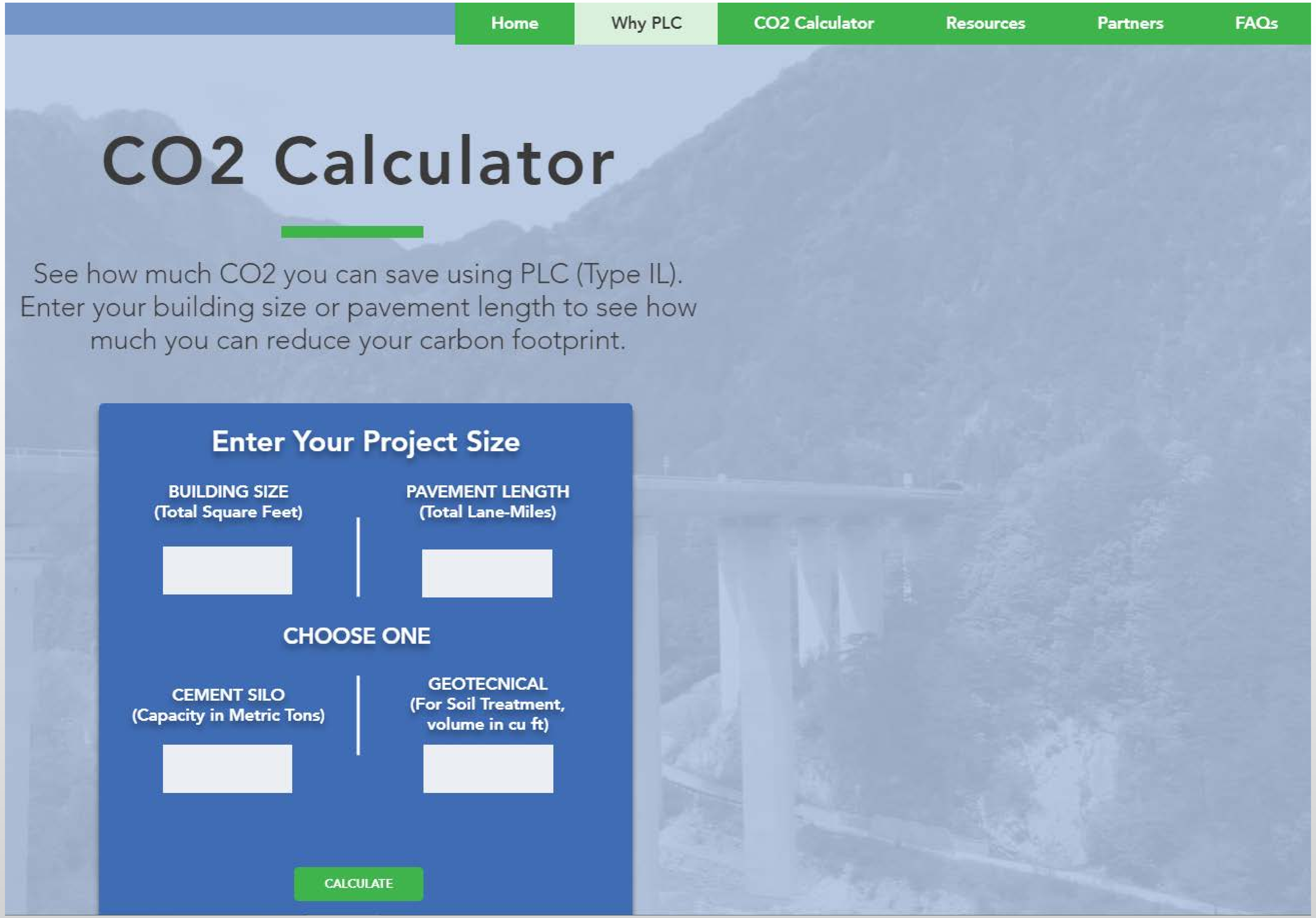
America's Cement Manufacturers™

greenercement.com - The 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



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

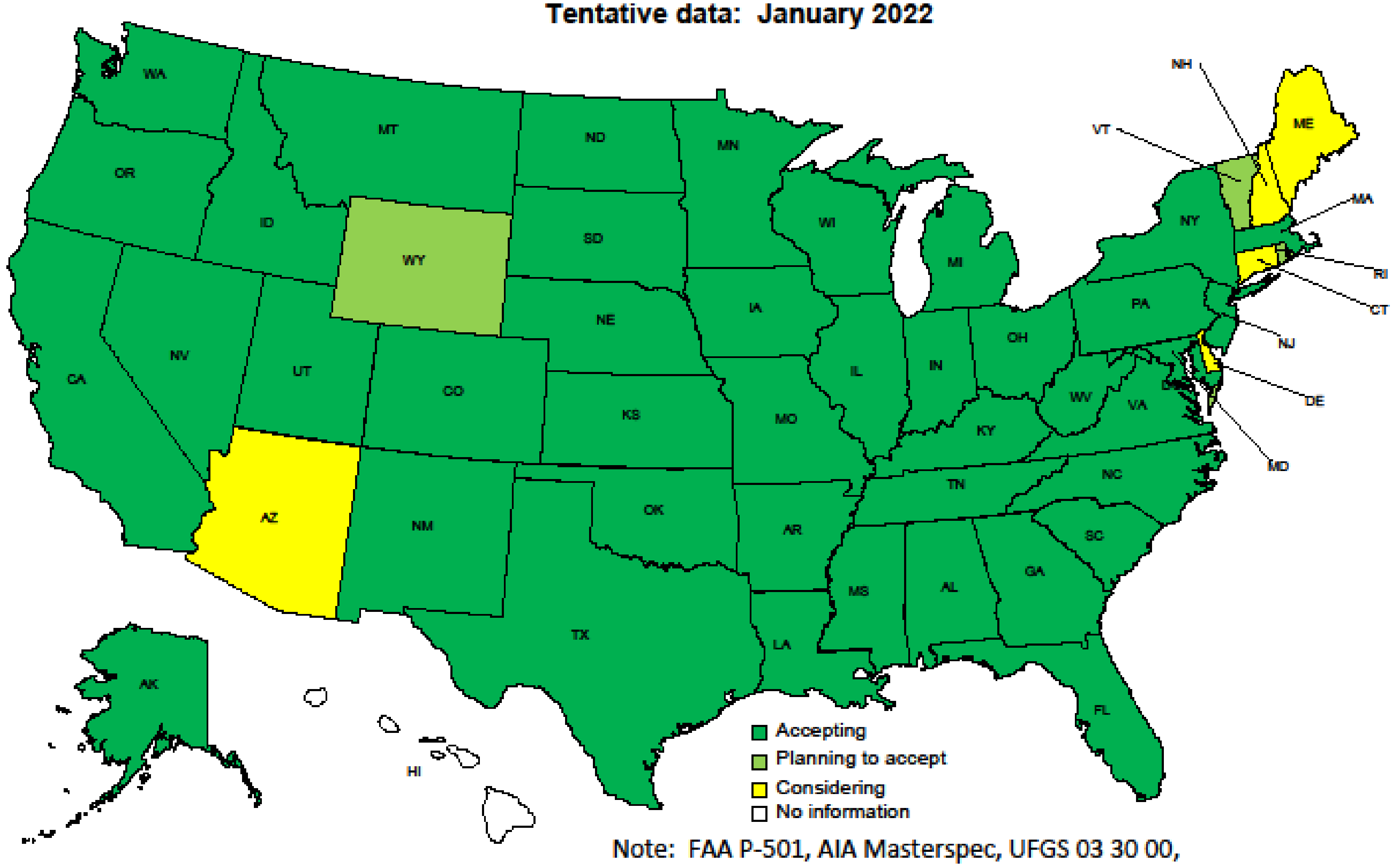
Or **AASHTO M 240 Type IL cement** along with M 85 Type I portland cement

ACI 318 (building code) and 301 (specification)

ICC codes

AIA, FAA specifications

State DOT Acceptance of Portland-Limestone Cement
Tentative data: January 2022



Note: FAA P-501, AIA Masterspec, UFGS 03 30 00, and ACI and ICC building codes permit use of PLC

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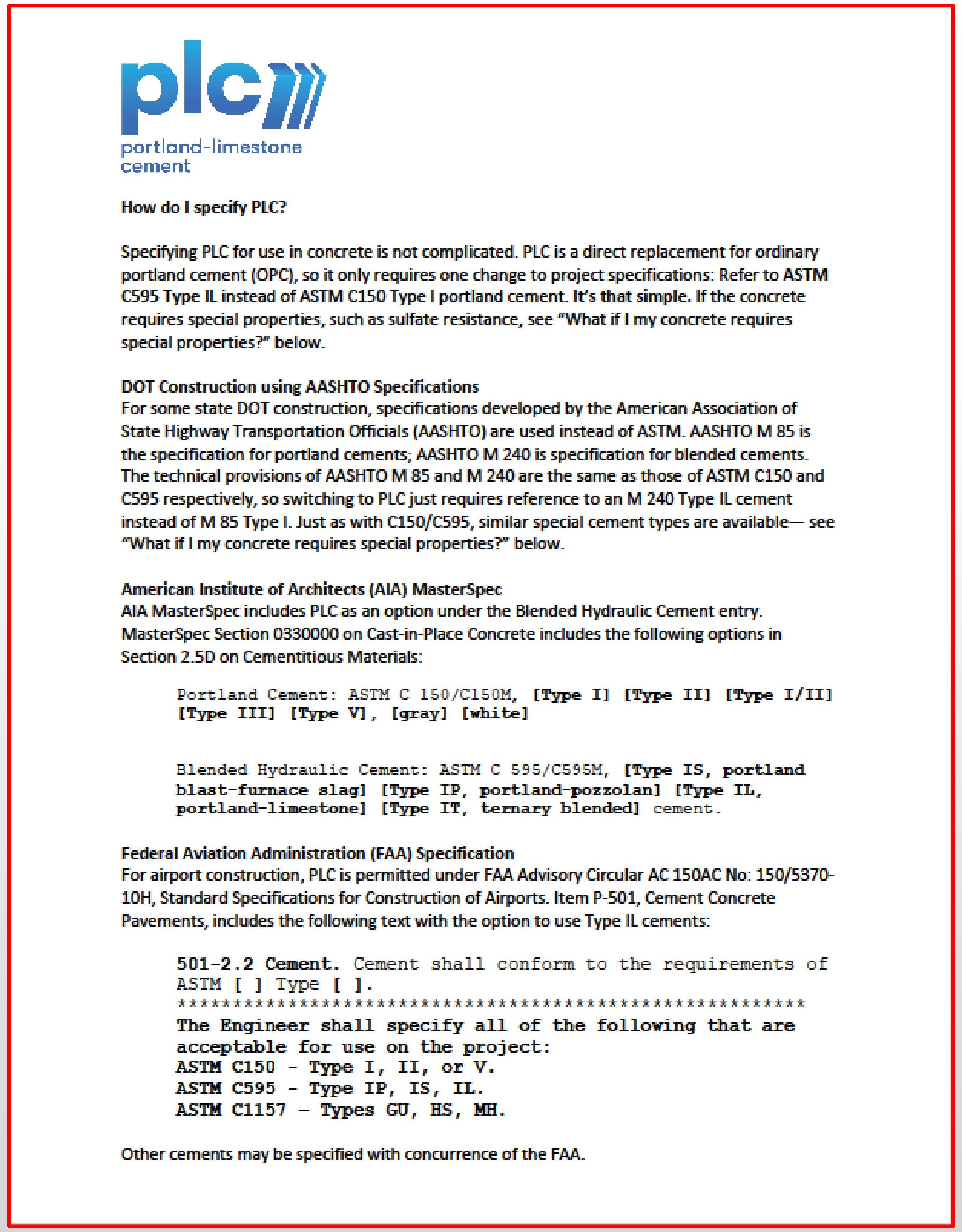
greenercement.com – Spec language



plc portland-limestone cement

How do I specify PLC?

Specifying PLC for use in concrete is not complicated. PLC is a direct replacement for ordinary portland cement (OPC), so it only requires one change to project specifications: Refer to ASTM C595 Type IL instead of ASTM C150 Type I portland cement. It's that simple. If the concrete requires special properties, such as sulfate resistance, see "What if I my concrete requires special properties?" below.

DOT Construction using AASHTO Specifications

For some state DOT construction, specifications developed by the American Association of State Highway Transportation Officials (AASHTO) are used instead of ASTM. AASHTO M 85 is the specification for portland cements; AASHTO M 240 is specification for blended cements. The technical provisions of AASHTO M 85 and M 240 are the same as those of ASTM C150 and C595 respectively, so switching to PLC just requires reference to an M 240 Type IL cement instead of M 85 Type I. Just as with C150/C595, similar special cement types are available— see "What if I my concrete requires special properties?" below.

American Institute of Architects (AIA) MasterSpec

AIA MasterSpec includes PLC as an option under the Blended Hydraulic Cement entry. MasterSpec Section 0330000 on Cast-in-Place Concrete includes the following options in Section 2.5D on Cementitious Materials:

> Portland Cement: ASTM C 150/C150M, **[Type I] [Type II] [Type I/II] [Type III] [Type V]**, **[gray] [white]**

> Blended Hydraulic Cement: ASTM C 595/C595M, **[Type IS, portland blast-furnace slag] [Type IP, portland-pozzolan] [Type IL, portland-limestone] [Type IT, ternary blended]** cement.

Federal Aviation Administration (FAA) Specification

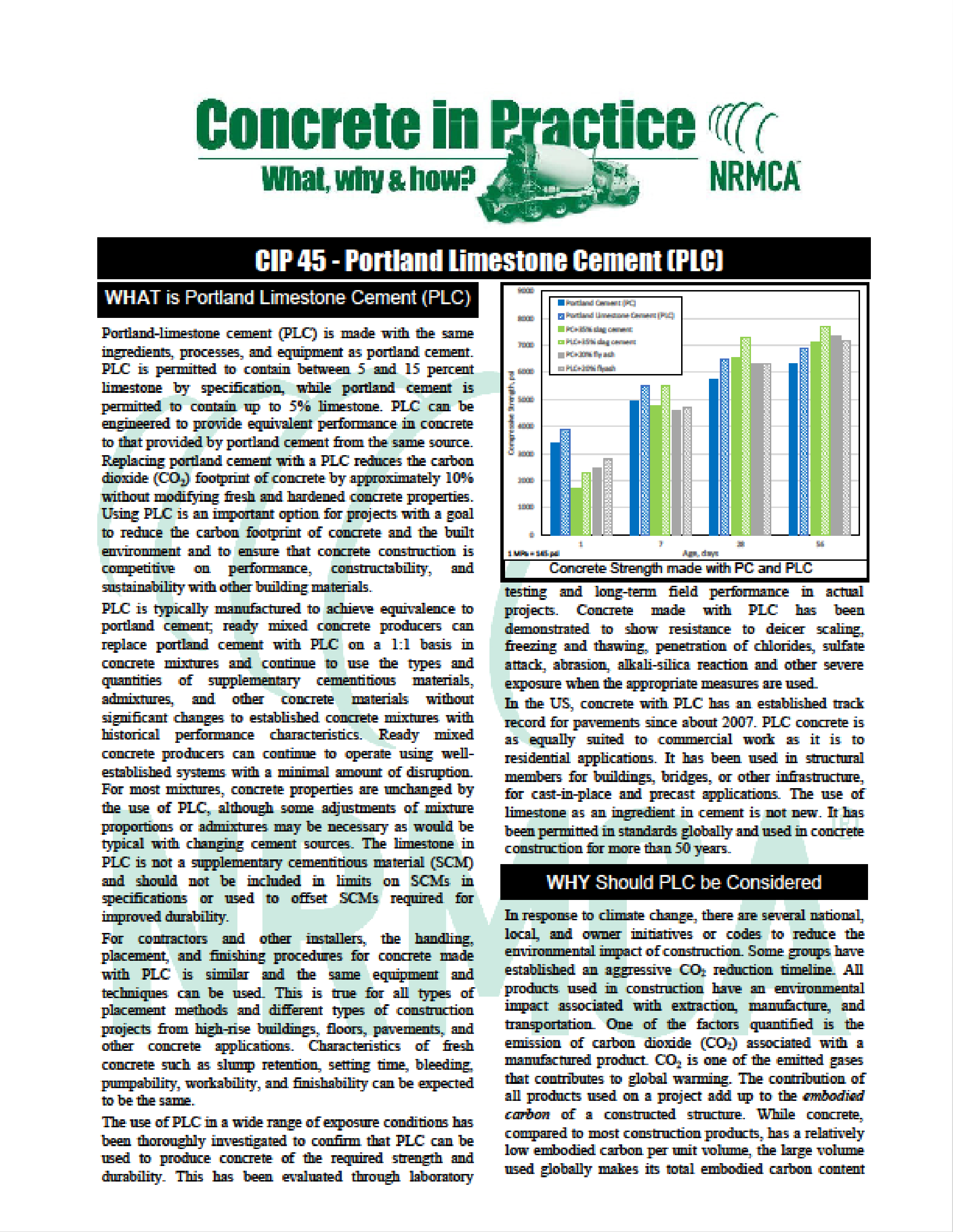
For airport construction, PLC is permitted under FAA Advisory Circular AC 150AC No: 150/5370-10H, Standard Specifications for Construction of Airports. Item P-501, Cement Concrete Pavements, includes the following text with the option to use Type IL cements:

> **501-2.2 Cement.** Cement shall conform to the requirements of ASTM [ ] Type [ ].
> **
> **The Engineer shall specify all of the following that are acceptable for use on the project:**
> **ASTM C150 – Type I, II, or V.**
> **ASTM C595 – Type IP, IS, IL.**
> **ASTM C1157 – Types GU, HS, MH.**

Other cements may be specified with concurrence of the FAA.

greenercement.com - 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.

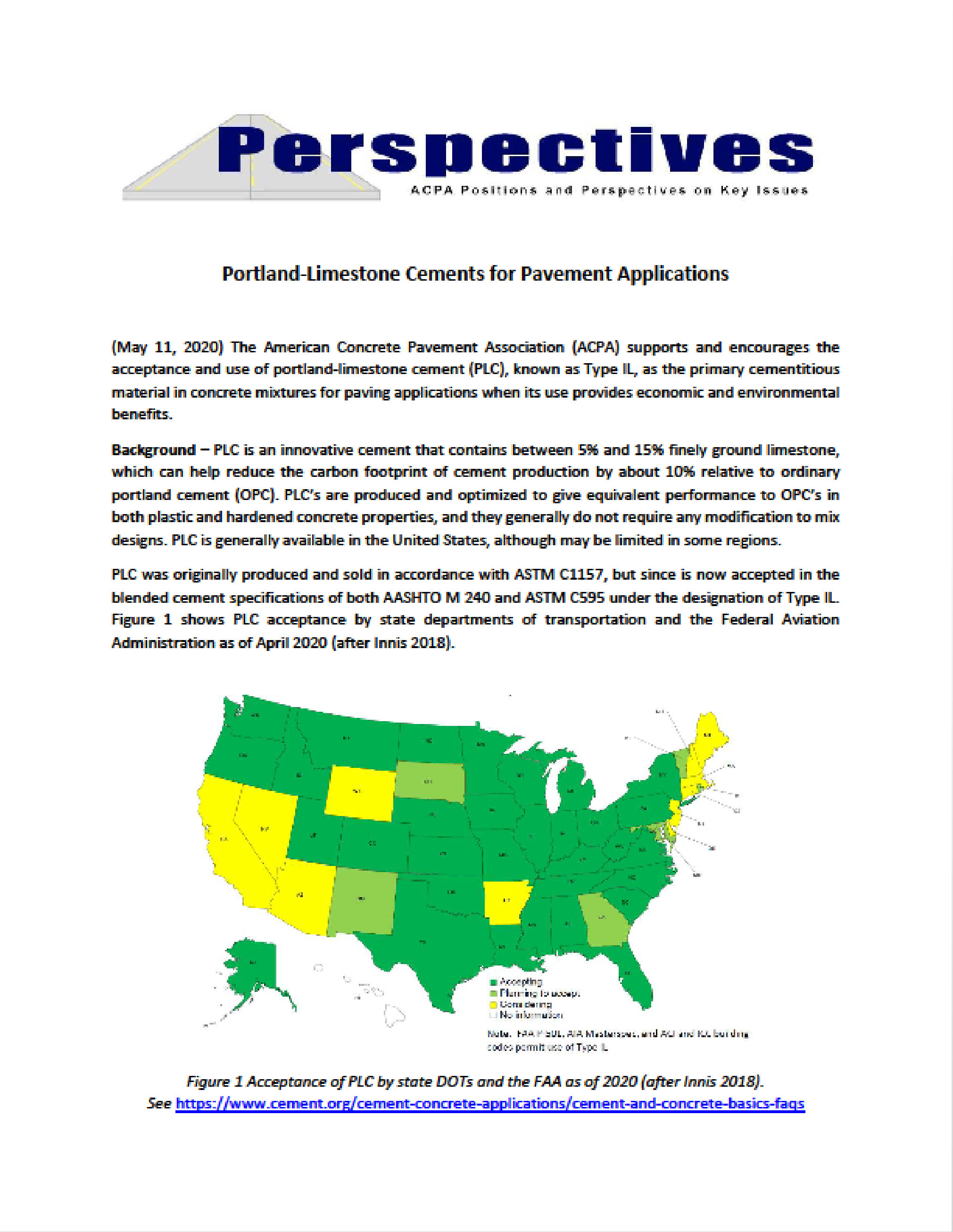
The use of PLC in a wide range of exposure conditions has been thoroughly investigated to confirm that PLC can be used to produce concrete of the required strength and durability. This has been evaluated through laboratory testing and long-term field performance in actual projects. Concrete made with 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

NRMCA P2P Initiative (Prescriptive to Performance)

- Performance specs:
- Describe the end product
- Do not describe how to achieve the result
- Allow contractors to choose products, equipment, and construction procedures from various alternatives
- Can lead to innovation, improved quality, and optimized products and construction procedures

P2P INITIATIVE

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

plc portland-limestone cement

One Colorado Example

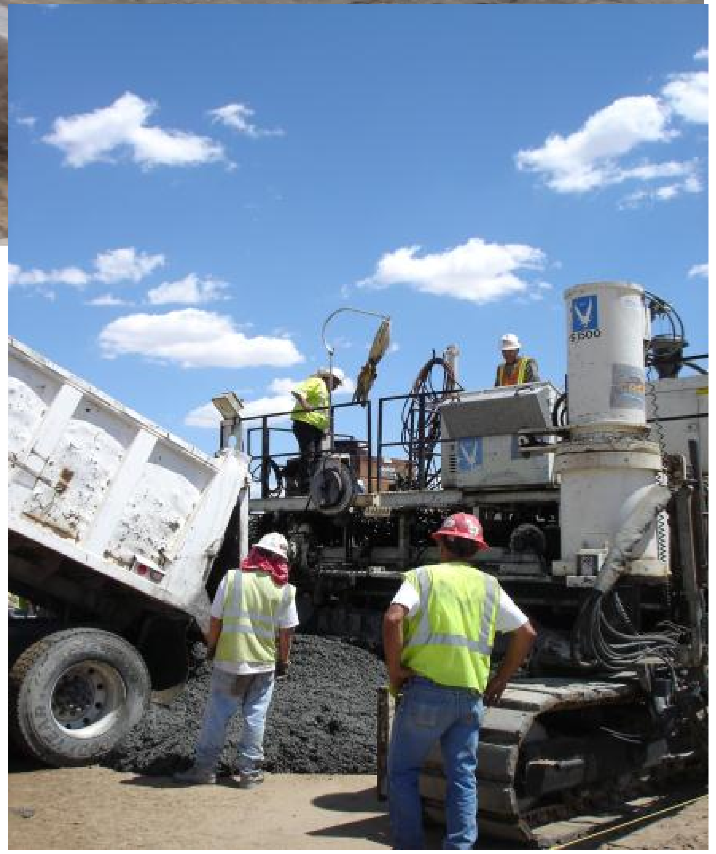
US HWY 287 Near Lamar

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



Soil Stabilization in Florida

Sarasota National residential development

Cement-stabilized soil for road base

Lengthens life of pavement

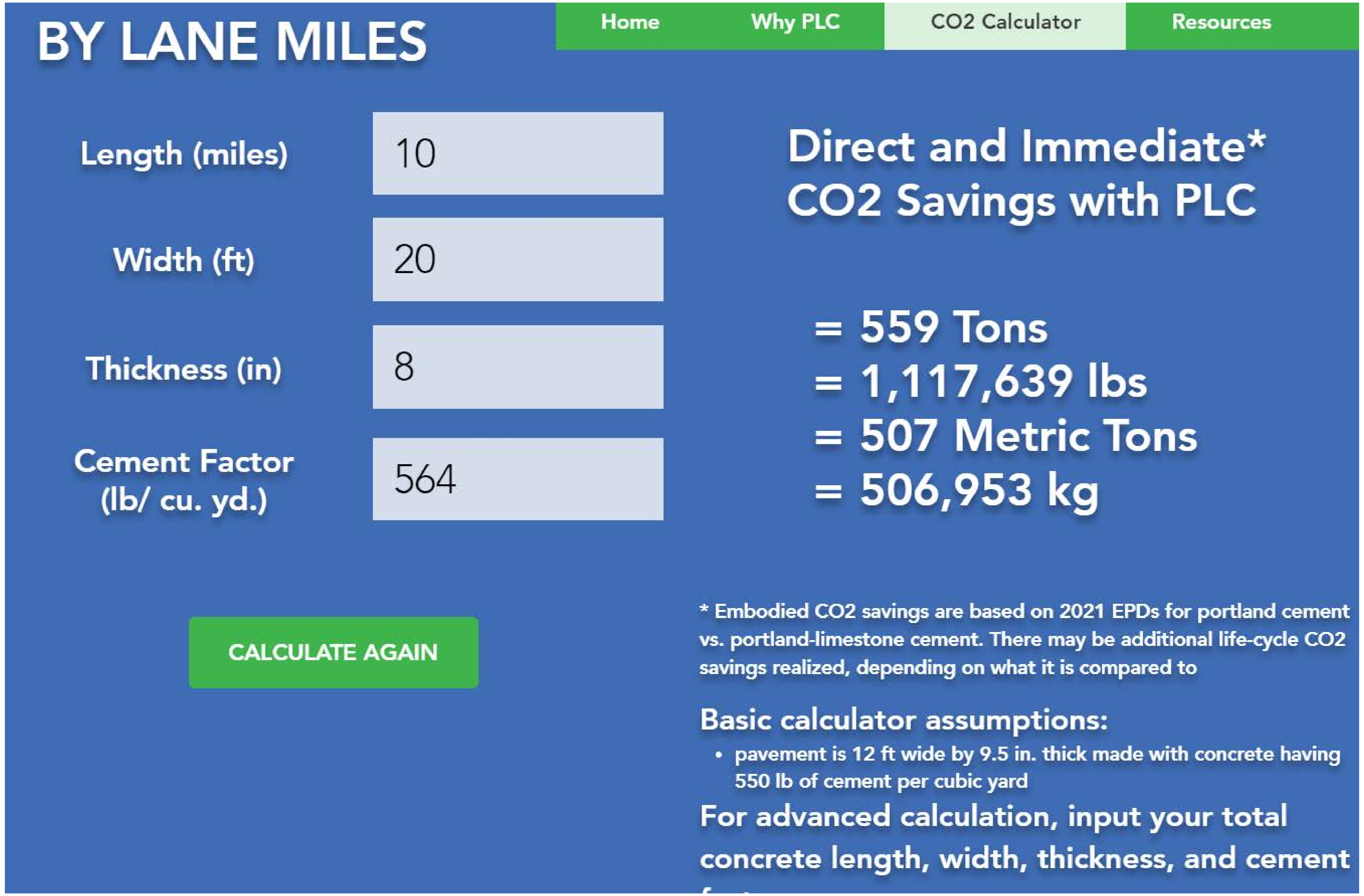
4% PLC dosage by weight of soil

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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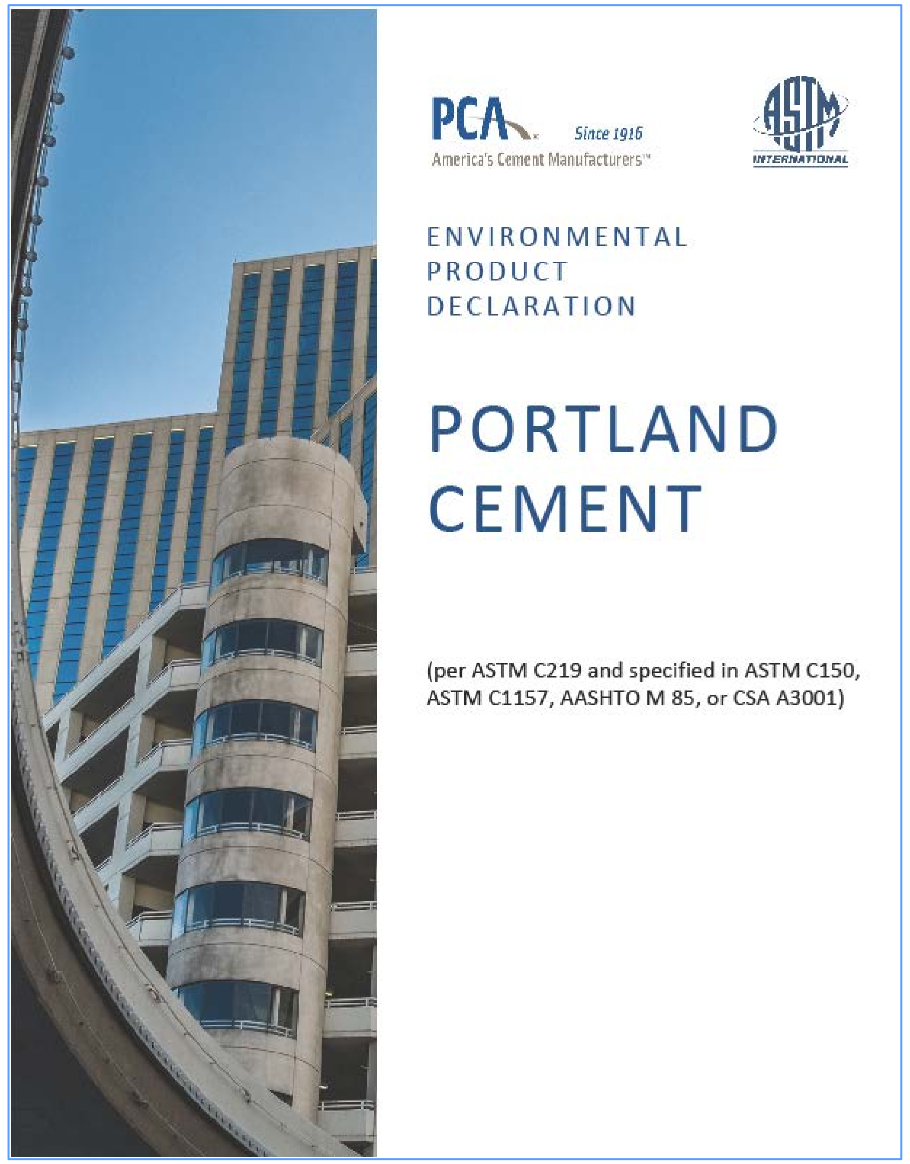
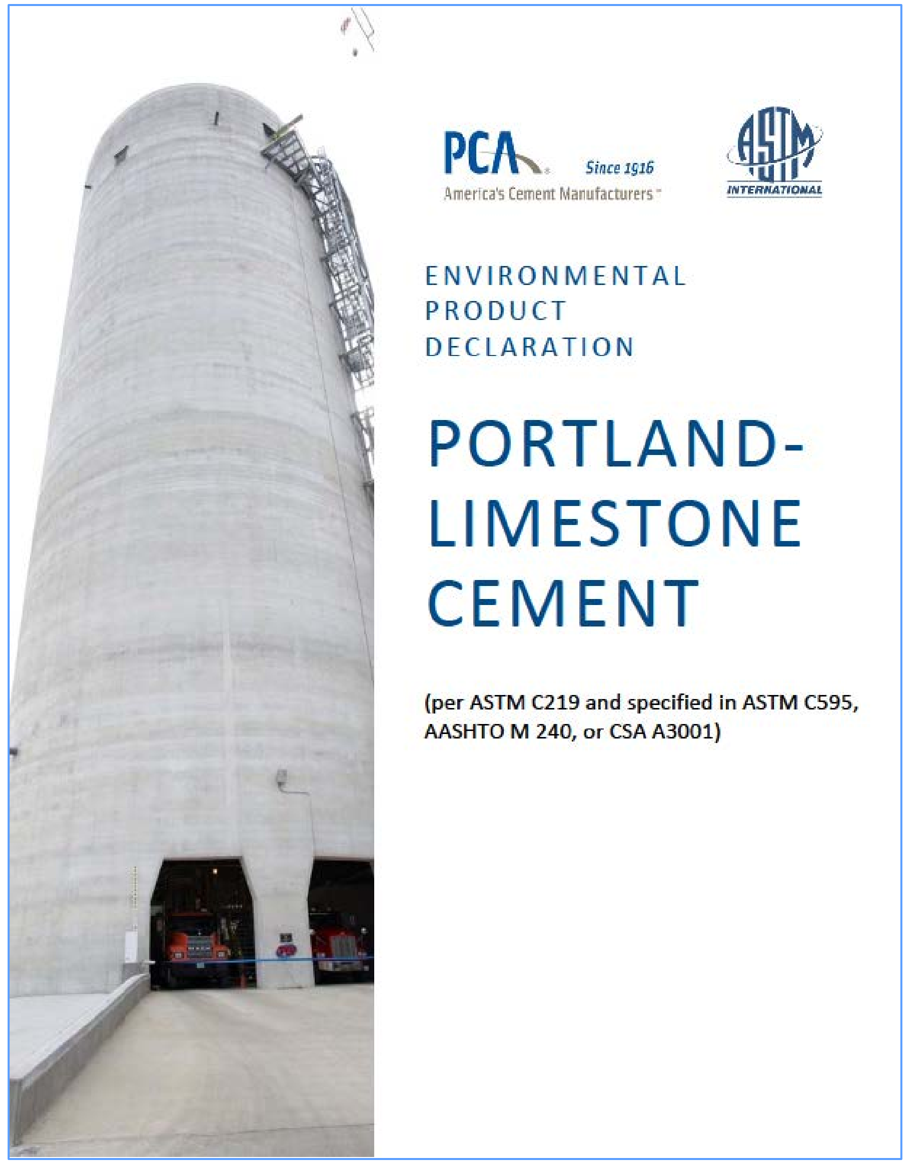
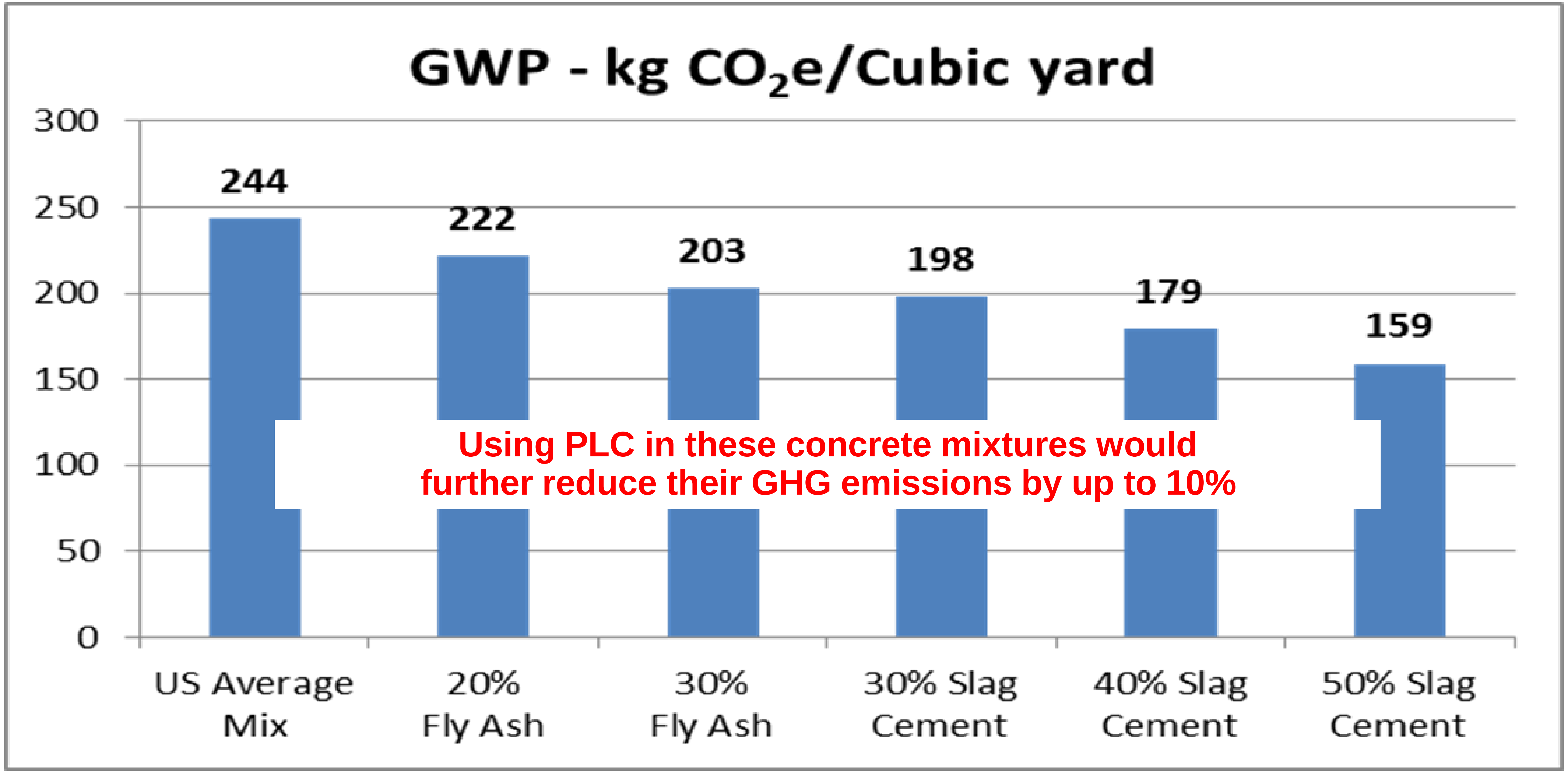




EPDs -> LCA

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.

<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.

Reviewing Learning Objectives

Helping you transition to using PLC

1. Save up to 10% CO_2, the difference in allowable limestone content between OPC and PLC (currently, 8.2% average in the US)
2. 1:1 replacement for OPC makes it easy to use
3. Start with the same dosage of SCMs, test to understand effects
4. Minor differences in both fresh and hardened properties, may or may not need to adjust admixture dosages

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
portland-limestone cement

Portland-Limestone Cement and New Industry Initiatives

Sustainable Structures Webinar Series – January 26, 2022