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

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

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

Charge Passed (Coulombs)

28 days

56 days

No SCM  No SCM  35% Slag  20% Fly Ash  No SCM  No SCM  35% Slag  20% Fly Ash

W/CM = 0.40  W/CM = 0.45  W/CM = 0.40  W/CM = 0.45

PC  PLC

Thomas and Hooton 2010
Performance of PLC Concrete

Scaling resistance (ASTM C672)

- Mass Loss (g/m²)
- Supplementary Cement Materials (w/cm)

- PC
- PLC - 12%

Cement compositions:
- No SCM (0.40)
- No SCM (0.45)
- 35% Slag (0.45)
- 20% Fly Ash (0.45)

Thomas et al. 2010
Performance of PLC Concrete

Freeze-Thaw Resistance (ASTM C666)

![Bar chart showing the performance of PLC concrete with different supplementary cementing materials.](image)

<table>
<thead>
<tr>
<th>Supplementary Cementing Materials (w/cm)</th>
<th>Durability Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SCM (0.40)</td>
<td>100</td>
</tr>
<tr>
<td>No SCM (0.45)</td>
<td>100</td>
</tr>
<tr>
<td>35% Slag (0.45)</td>
<td>100</td>
</tr>
<tr>
<td>20% Fly Ash (0.45)</td>
<td>100</td>
</tr>
</tbody>
</table>

Thomas et al. 2010
Performance of PLC Concrete

Field Trials: Pavement slab after one winter
Performance of PLC Concrete

ASR resistance

Test (age when expansion reported)

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

Fly Ash Mixes

- Standard C1012
- 23C

Exposure, weeks

Expansion, %

Blair and Delagrave 2012
Hardened Properties

- Summary in PCA Report SN3148 at [www.cement.org](http://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)
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
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
greenercement.com - Partners

- National
- Regional
- Unified messages for all users
Partner Resources

• NRMCA CIP on PLC
• Build With Strength
• ACPA Position Paper on PLC
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
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
<table>
<thead>
<tr>
<th>BY LANE MILES</th>
<th>CO2 Savings with PLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (miles)</td>
<td>10</td>
</tr>
<tr>
<td>Width (ft)</td>
<td>20</td>
</tr>
<tr>
<td>Thickness (in)</td>
<td>8</td>
</tr>
<tr>
<td>Cement Factor (lb/ cu. yd.)</td>
<td>564</td>
</tr>
</tbody>
</table>

* Embodied CO2 savings are based on 2021 EPDs for portland cement vs. portland limestone cement. There may be additional life-cycle CO2 savings realized, depending on what it is compared to.

**Basic calculator assumptions:**
- pavement is 12 ft wide by 9.5 in. thick made with concrete having 550 lb of cement per cubic yard
- For advanced calculation, input your total concrete length, width, thickness, and cement factor.
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)

EPDs -> LCA
Lowering Carbon Footprint of Mixes

GWP - kg CO$_2$e/Cubic yard

Using PLC in these concrete mixtures would further reduce their GHG emissions by about 10%

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>
<thead>
<tr>
<th>Report Type</th>
<th>Reference Document(s) for the Optimization Report</th>
<th>Report Verification</th>
<th>Valuation</th>
</tr>
</thead>
<tbody>
<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>Baseline: Product-specific LCA, Product-specific Type III EPD, or Industry-wide Type III EPD</td>
<td>Comparator 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>Optimized: Product-specific LCA or product-specific Type III EPD</td>
<td>Comparator analysis is verified by an independent party</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>Comparator analysis is verified by an independent party</td>
<td>2 products</td>
</tr>
</tbody>
</table>

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