Portland Limestone Cements (PLC’s)

Why ASTM C150 cements are going away

COLORADO READY MIXED CONCRETE ASSOCIATION

Dave Figurski, PE Holcim
July 27th, 2022
IL Cements - Agenda

- Why the move away from what we’re all used to?
- Cement Manufacturing Process…(and where all this CO$_2$ comes from)
- Where the cement industry is going (Globally & in Colorado)
- Cement Specifications…ASTM C 150’s to C595’s
- Fresh/Hardened property comparison
- CDOT Projects and the cement transition
- Industry research document and online resource review
- Q/A

Note:
Blue Font are Hyperlinks
What’s with this “new” cement?

• This industry doesn’t like change

• IL cements have decades of testing
  • They’re not new
  • Very well vetted
  • ACI 318, 301, FAA, UFGS, AIA (Approved)

Big takeaways...

• Understanding of:
  • Why global cement industry is eliminating C150 cements
  • IL cements are similar to what you’ve been specifying/using
Why the move away from ASTM C150 I/II to ASTM C595 IL?

- Because of CO₂!
- Sustainability push started with the energy sector
- Has moved its way into every other sector of economy

The cement industry produces more CO₂ emissions than most countries. It may not survive.

Concrete needs to lose its colossal carbon footprint
C150 Cement Manufacturing Process

**Raw Materials:**
- Limestone (CaCO$_3$) 65%
- Sandstone (SiO$_2$) 20%
- Clay (Al$_2$O$_3$) 15%
- Mill Scale (Fe$_2$O$_3$) < 2%

The 91-96% clinker is referred to as a cement’s “clinker factor”

**ASTM C150 Cement**

Calcination

$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$

(Heat)

1,500°F

Clinkering in a Kiln

2,500°F

<5% Limestone + Gypsum + 91-96% Clinker

(CaSO$_4$)

35%
C595 Blended Cement Process

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Calcination
1,500°F

Clinkering in a Kiln
2,500°F

Reduction in % clinker is what reduces CO$_2$!

ASTM C595 Cements

C150 = <5% Limestone + Gypsum + 92-95% Clinker

Type IL(10) 10% Limestone + Gypsum + 86% Clinker
Type IP(25) 25% Pozzolan + Gypsum + 71% Clinker

Clinker
- C$_3$S
- C$_2$S
- C$_3$A
- C$_4$AF
Global Cement Industry’s Reaction to Pressure

- Cement company commitments via GCCA:
  - 25% CO\(_2\) reduction by 2030 (from 2020)
  - Net Zero emissions by 2050

- New Terminology:
  - EPD's...Environmental Product Declarations
    - Environmental “Nutrition Label”
  - GWP...Global Warming Potential (CO\(_2\) equiv.)

- Focus now:
  - Reduce clinker contents within cements
  - Minimize cementitious content within concrete

- Future:
  - Renewable Energy additions to cement plants
  - Alternative Fuels
  - More efficient plants
  - Large scale carbon capture

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<th>Metric</th>
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<td>Ozone depletion potential</td>
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State of Colorado’s Reaction to Pressure

Colorado HB21-1303 “Buy Clean Colorado Act” (July 2021):

- Requires CDOT to begin collecting EPDs (eligible materials on eligible projects) (July of 2022)
  - To benchmark GWP levels for each material (cement/concrete, asphalt/asphalt mixes, steel)
  - Facility-specific EPD’s are preferred
  - 2.5 year benchmarking timeframe
- July 2025…Materials used must be below the decided upon GWP threshold for approval
- CDOT will review/adjust this GWP threshold every 4 years (cannot be increased)

More questions?

CDOT EPD Information
- Specifications & Protocols
- Submission Forms
- Form Instructions

CDOT EPD Timeline:

- **July 2022**: EPD Collection
  - Winning bidder to submit EPDs for eligible materials on eligible projects
- **July 2025**: EPD Requirements
  - Winning bidder to submit EPDs for eligible materials as established by policy
- **January 2025**: Policy Creation
  - CDOT to establish policy setting maximum allowable GHG emissions
- **2026**: Reporting
  - CDOT to begin reporting GHG reduction progress to legislature
- **January 2027**: Review & Adjust Policy
  - CDOT to review and adjust policy every 4 years
ASTM C150 Portland Cements (1904)

- Types are based on physical and/or chemical characteristics
  
  • **Type I** – no special properties req’d
  
  • **Type II** – moderate sulfate resistance ($C_3A < 8\%$)
  
  • **Type III** – higher early strengths
    - Typically a I or II cement with a finer grind
    - Becoming less common
  
  • **Type IV** – for lower heat of hydration
    - No longer readily available…utilize higher % replacements of SCMs to achieve heat reduction
  
  • **Type V** – high sulfate resistance ($C_3A < 5\%$)
    - % replacement of a Type II cement with an effective SCM is much more efficient than a Type V

Cements can meet both specs:

- A cement meeting a Type V, automatically meets a Type II
**C595 Blended Cements (1967)**

- Types are based on what else is blended in with clinker/gypsum
- Included in Colorado DOT specifications (2011)

**Type IP(x)** – Portland-pozzolan cement
- Fly Ash @ 25% replacement = IP(25)

**Type IS(x)** – Portland-slag cement
- Slag 40% replacement = IS(40)

**Type IT (x)(x)** – Ternary blended cement
- 20% Pozz/10% Limestone = Type IT (P20)(L10)

**Type IL(x)** – Portland-Limestone Cement (≤ 15%) (added in 2013)
- Ground slightly finer to compensate for 5-10% less clinker
- Provides CO₂ reduction with similar strength/durability to C150’s
- Can/should be used with added SCM’s

This cement will be the predominant cement in the Colorado market by EOY 2022. C150’s won’t be available.
Quick history of limestone in cement

- Limestone commonly used in Europe since the 1970’s, growing since 2000
  - 4 Types of IL cements, between 6-35% limestone
- Canadian specs permitted up to 5% limestone in 1983
  - United States in 2004 (C150)
- Canadian specs permitted limestone cements (<15%) in 2008
  - US specs permitted limestone additions in 2013 in C595

Colorado
- Used on CDOT pavements since 2008
- To Date: >1,500 lane miles of concrete pavement w/PLC’s
How to use C595 IL cements

- Allowed by ACI, ASTM C94, FAA, Army Corp, Master Spec, etc.
- Designed for 1:1 replacement for a C150 cement with similar performance
- Use IL’s with SCM’s as is typically done with C150 cements
- SG ~ 3.10 (slightly less than a C150)

**IL cements are ground finer to offset the loss in reactive material (clinker) to maintain similar performance**

Added limestone has benefits…not just a filler:

- Particle Packing due to smaller limestone particles (similar to optimized agg gradations)
- Limestone particles serve as nucleation sites for hydration products (slight hydration acceleration)
- Limestone will react w/alumina in SCM’s to form hydration products (minor extent)
Performance of IL cements (Fresh Properties)

- **Workability**
  - Added cement fineness can have an effect on water demand (particle packing might offset)
  - Similar water demand to a I/II...I have seen some IL cements show ½” – 1” reduced slump

- **Set/Heat of Hydration**
  - If any change, typically a reduced time of set with IL cements b/c of finer grind
  - Added limestone should decrease...increased fineness should increase... (should balance out)
  - Nucleation site development can increase early (< 48 hrs) heat of hydration...less Δ later on
Performance of IL cements (Hardened Properties)

- **Strength**
  - Reduced clinker content is offset by higher fineness of overall cementitious blend
  - Early-age strengths are typically higher with IL’s
  - Later-age strengths are typically in line with C150’s

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**Figure 2**: PLC compressive strength plotted versus each mixture’s reference OPC. The dashed line indicates a 1:1 relationship, while the solid lines indicate ± 10%.

**Figure 3**: Strength Development of PC and PLC Mixes with and without SCM at W/CM = 0.45.

Buchner et al, 2008

Barrett, Sun, Weis 2007
Performance of IL cements (Hardened Properties)

- **Drying Shrinkage**
  - Reports showing either similar or improved shrinkage performance
  - Could be attributed to particle size distribution and particle packing (densified matrix)

- Other factors are still **much more important**:
  - Water Content
  - Paste Content
  - Coarse aggregate content/type

*Bucher et al, 2008*
Performance of IL cements (Hardened Properties)

- **Durability/RCPT/Surface Resistivity**
  - PCA R&D SN3142..Durability of Concrete Produced with PLC (Thomas/Hooton)
  - PLC’s with up to 15% limestone can be produced with equivalent performance as OPC’s

![Graph](image1)

**Figure 5. “Rapid Chloride Permeability” – ASTM C1202.**

M. Thomas, D. Hooton 2010
Performance of IL cements (Hardened Properties)

- **Alkali Silica Reaction (ASR)**
  - Cement alkali levels shouldn’t be affected by limestone addition
  - No testing difference between expansions of OPC’s and PLC’s (PCA R&D SN3142)
  - Reminder:
    - C150 eliminated <0.60% in 2019 (encouraging ASTM C1778)
    - Levels found to be outdated and potentially misleading

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M. Thomas, D. Hooton 2010
Performance of IL cements (Hardened Properties)

- **Sulfate Resistance**
  - “Concretes made with ASTM C595 IL cements blended with appropriate levels of SCMs are performing as well or better than ASTM C150 Type V’s. (PCA R&D SN3285b (Hooton/Thomas 2016))

- C150 cements mainly rely on % C₃A for sulfate resistance protection
- **C595 cements rely on C1012 sulfate test (6 to 18-month test)**
  - For CDOT Class 2 or 3, C1012 data is necessary.

- The most effective method of reducing the risk of sulfate issues is to use an appropriate amount of an effective SCM.
  - Reducing overall C₃A content
  - Reducing permeability of the mix
CDOT Construction Bulletin Highlights

• All CO supplied cement suppliers by EOY 2022 will be ceasing production of C150 cements, and moving to C595 IL’s as their base products

• CDOT Construction Bulletin on PLC’s (7/14/22):
  1) Approved mixes w/C150 cements expiring in 2022 will be extended until EOY 2022
  2) Approved mixes w/C150 cements may switch pound-for-pound to a C595 IL as long as:
     • C595 IL cement must be from same source as C150 cement
     • Any required ASR mitigative measures must be tested and pass ASTM C1567 w/C595 IL
     • The sulfate resistance requirements in 601.04 have been met for the class on the project
  3) Mix designs making a change to Type IL will expire at their natural expiration date after 12/31/22
  4) Mix designs expiring after 12/31/22 will require a new mix design upon expiring if the producer hasn’t already changed over to IL.
Industry Resources

- Greenercement.org
- NRMCA CIP #45 – Portland Limestone Cements
- Performance of Portland Limestone Cements (JTRP…Barrett, Sun, Weiss)
- State-of-the-art report on use of limestone in cements at levels up to 15% (PCA R&D SN3148) (Tennis, Thomas, Weiss)

Add ASTM C595 blended cements to your specifications!

Questions…feel free to email: Dave Figurski
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