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

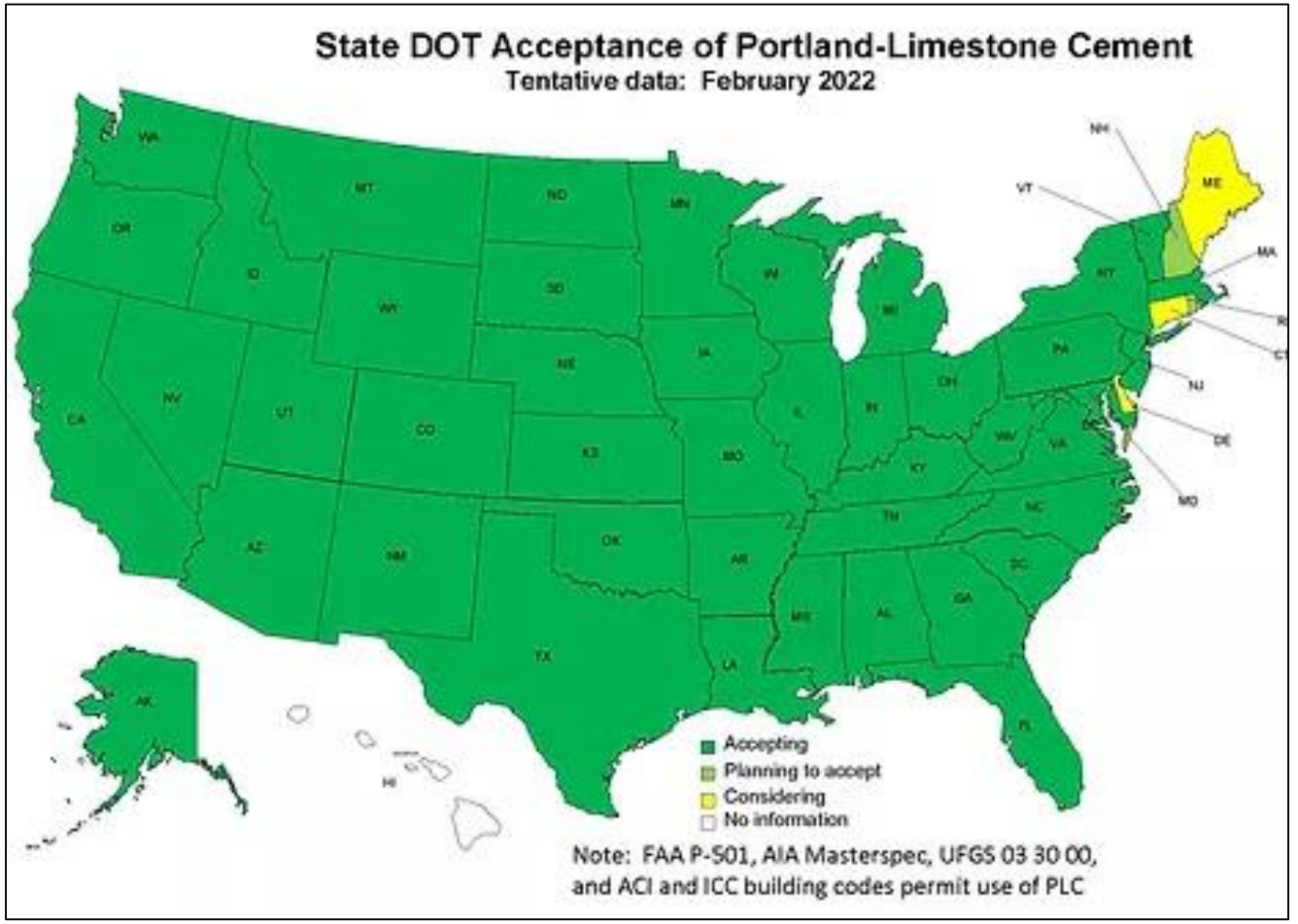
- Why the move away from what we're all used to?
- Cement Manufacturing Process…(and where all this CO_2 comes from)
- Where the cement industry is going (Globally & in Colorado)
- Cement Specifications…ASTM C 150's to C595's
- Fresh/Hardened property comparison
- CDOT Projects and the cement transition
- 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)



greenercement.org

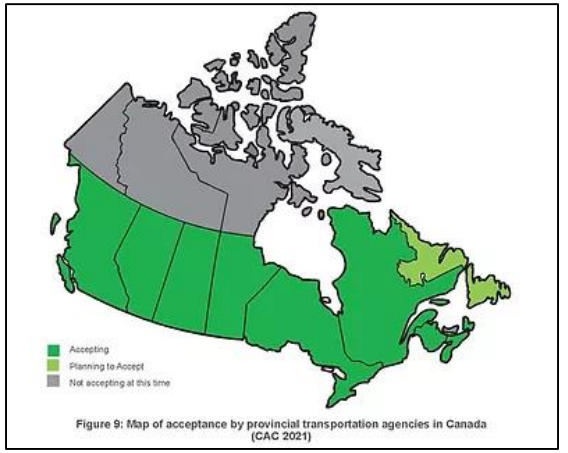


Figure 9: Map of acceptance by provincial transportation agencies in Canada (CAC 2021)

Big takeaways…

- Understanding of:
  - Why global cement industry is eliminating C150 cements
  - IL cements are similar to what you've been specifying/using

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Why the move away from ASTM C150 I/II to ASTM C595 IL?

- Because of CO_2!
- Sustainability push started with the energy sector
- Has moved its way into every other sector of economy

Cement makers across world pledge large cut in emissions by 2030

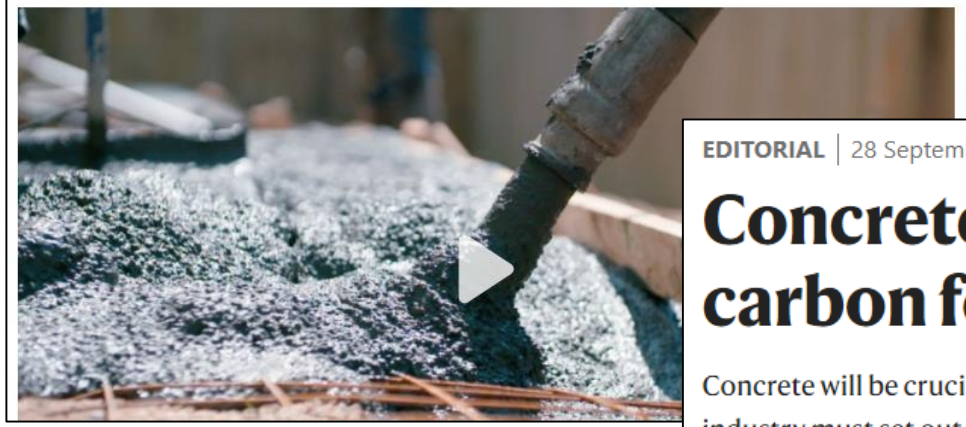
Industry responsible for about 8% of CO2 emissions commits to reaching net zero by 2050 without offsetting

THE GLOBAL ENERGY CHALLENGE

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

By Charles Riley, CNN Business

Updated 12:49 PM EDT, Mon July 22, 2019



CNN travel DESTINATIONS FOOD & DRINK NEWS STAY

Airbus to test hydrogen-fueled engine on A380 jet

Tamara Hardingham-Gill, CNN • Published 25th February 2022

[No Title]

EDITORIAL | 28 September 2021

Concrete needs to lose its colossal carbon footprint

Concrete will be crucial for much-needed climate-resilient construction. But the cement industry must set out its plan for decarbonization.

C150 Cement Manufacturing Process

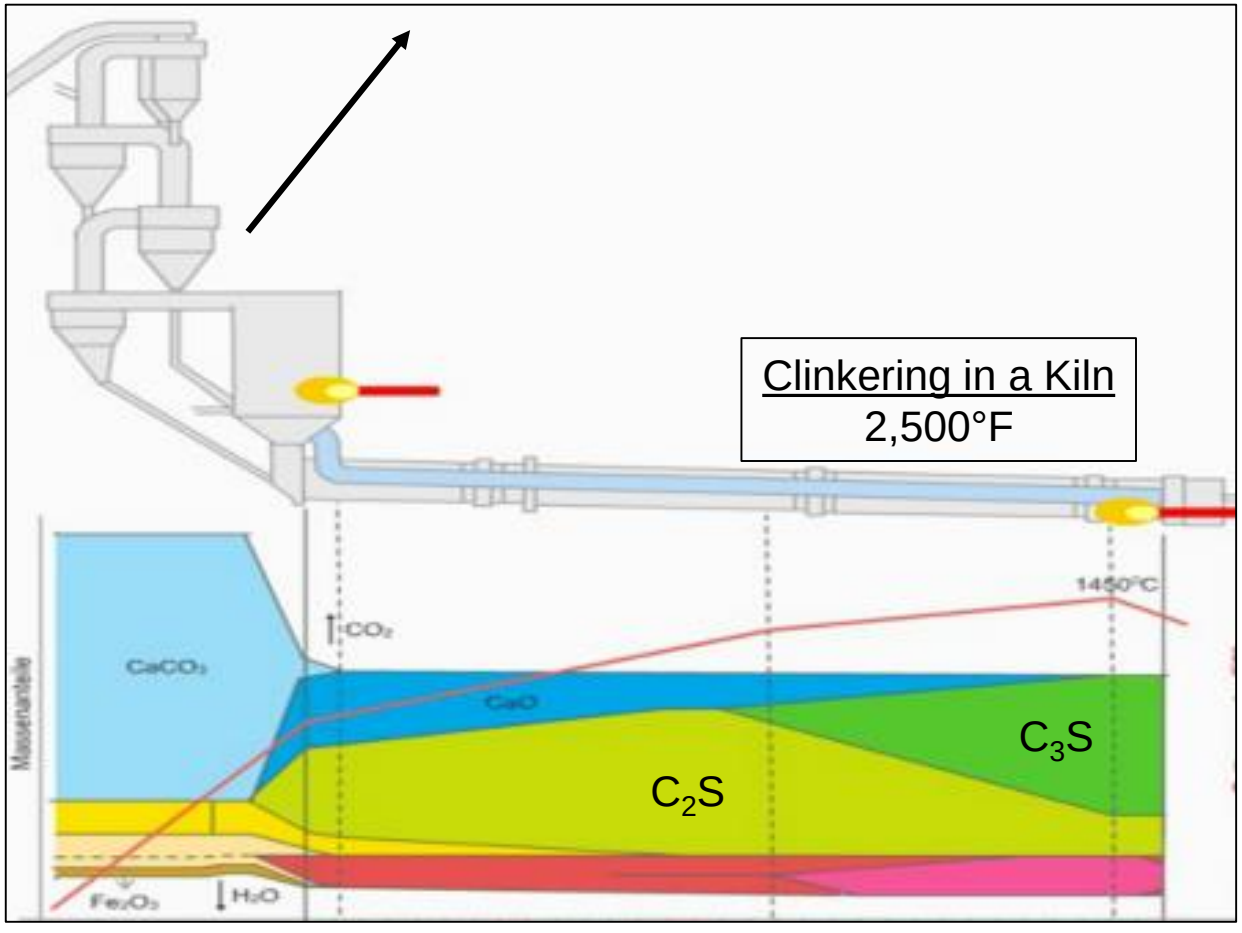
Raw Materials:

- Limestone ($CaCO_3$) 65%
- Sandstone (SiO_2) 20%
- Clay (Al_2O_3) 15%
- Mill Scale (Fe_2O_3) < 2%

Calcination
1,500°F

$CaCO_3 \rightarrow CaO + CO_2$ (Heat)

35%



Clinkering in a Kiln
2,500°F

Clinker
- C_2S
- C_3S
- C_3A
- C_4AF

<5% Limestone + Gypsum ($CaSO_4$) + 91-96% Clinker

The 91-96% clinker is referred to as a cement's "clinker factor"

ASTM C150 Cement

C595 Blended Cement Process

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- Sandstone (SiO_2) 20%
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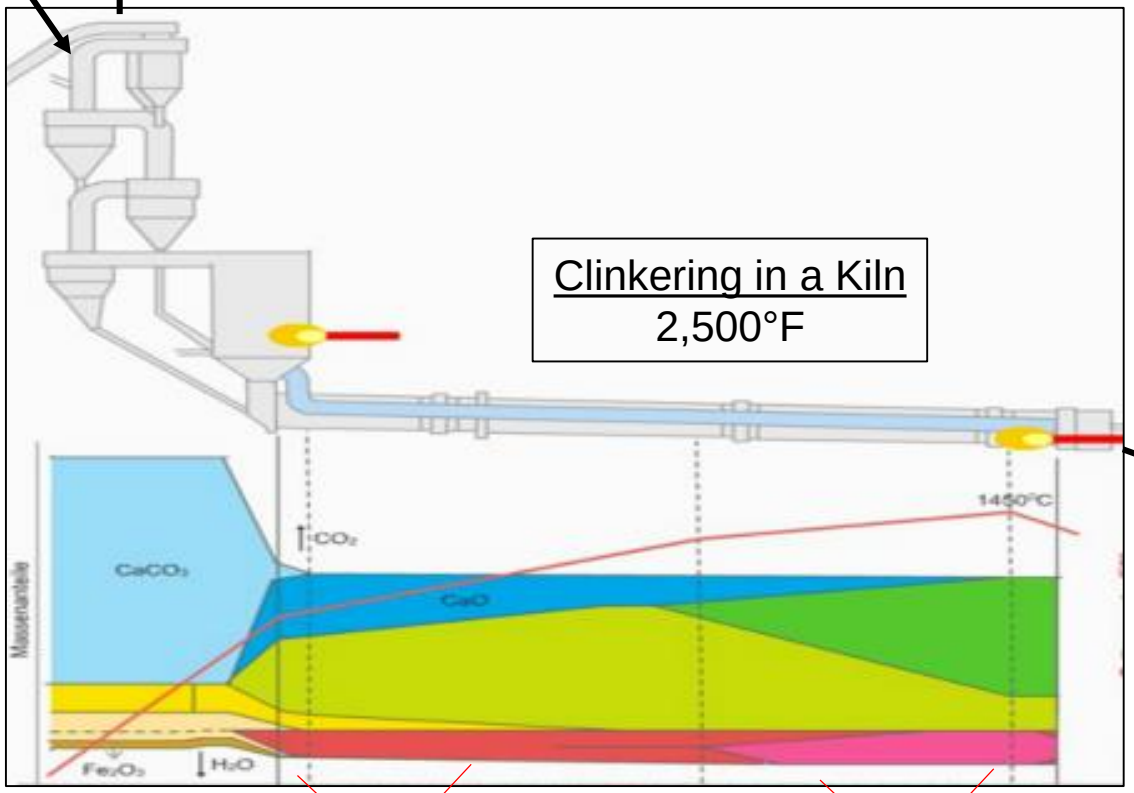
CO_2

Calcination
1,500°F



Clinker
- C_3S
- C_2S
- C_3A
- C_4AF

Reduction in % clinker is what reduces CO_2!

ASTM C595 Cements

C150 = <5% Limestone + Gypsum ($CaSO_4$) + 92-95% Clinker

Type IL(10) ← 10% Limestone + Gypsum + 86% Clinker

Type IP(25) ← 25% Pozzolan + Gypsum + 71% Clinker

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

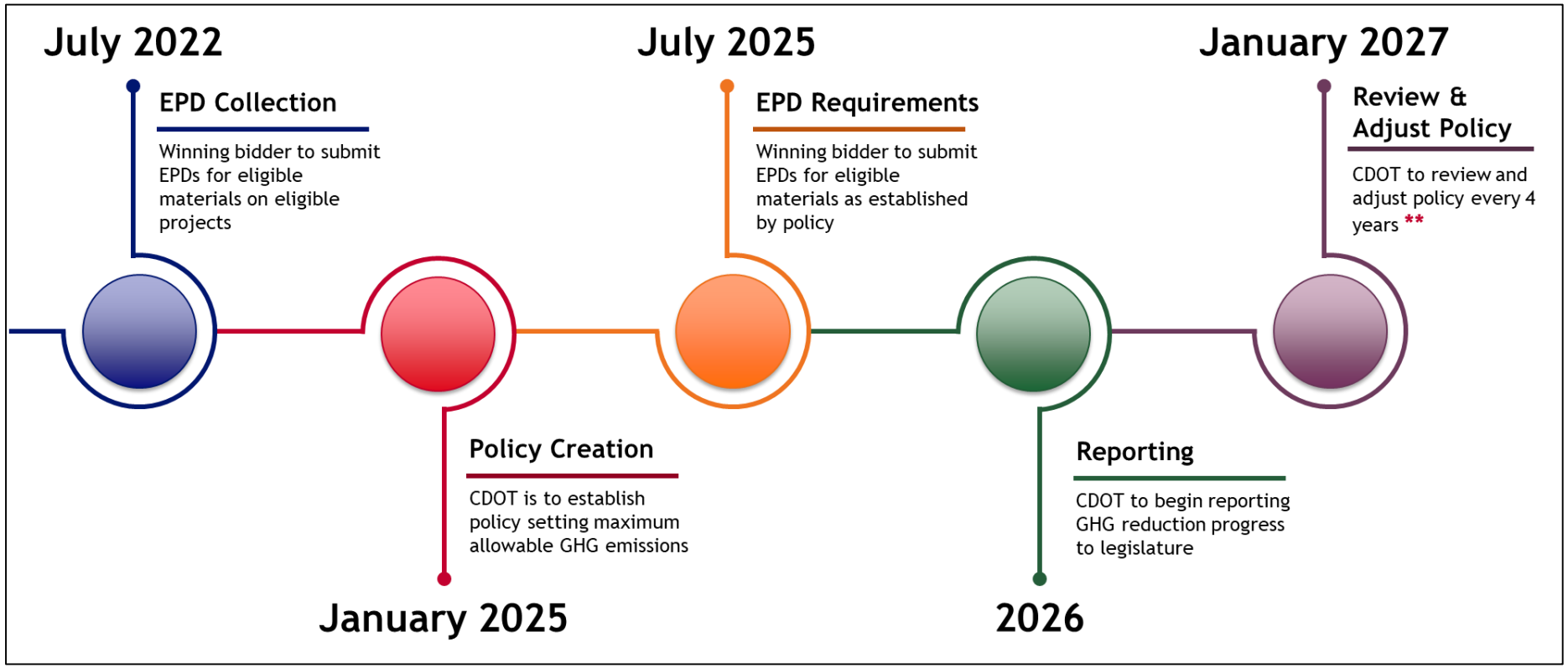
Metric	Cradle-to-gate total per metric tonne of production	Unit
Environmental impact		
Global warming potential (100 years)	1040	kg CO2-eq.
Acidification potential	2.45	kg SO2-eq.
Eutrophication potential	1.22	kg N-eq.
Formation potential of tropospheric ozone	48.8	kg O3-eq
Ozone depletion potential	2.61E-05	kg CFC 11-eq.

PCA Portland Cement Industry Average EPD

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)



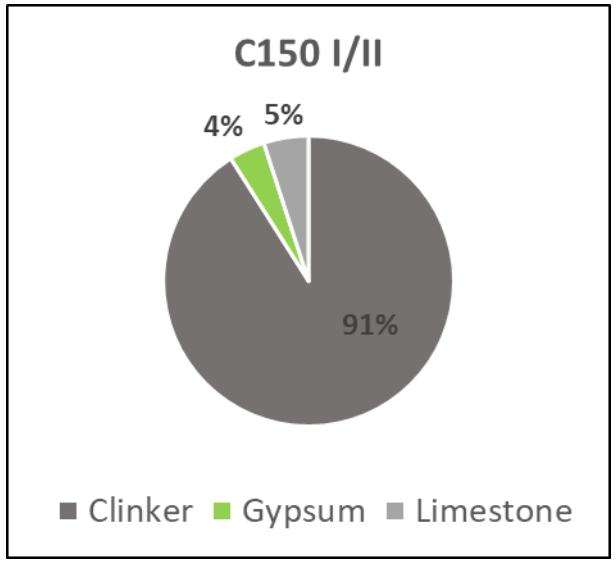
More questions?

CDOT EPD Information

- Specifications & Protocols
- Submission Forms
- Form Instructions

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)

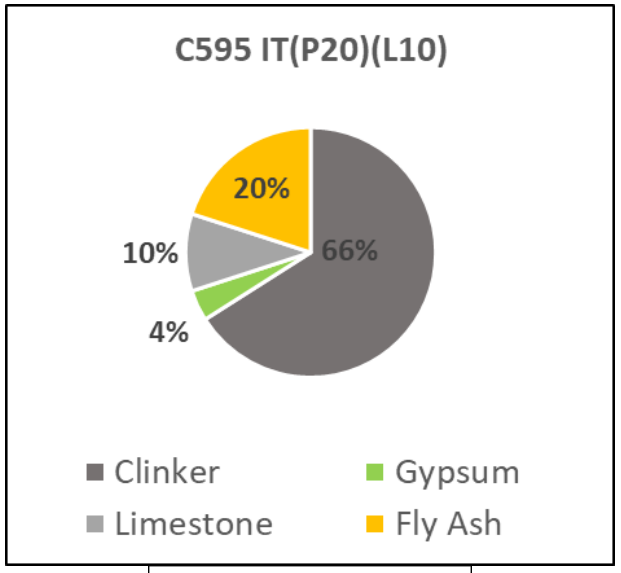
- **Type IP(x)** – Portland-pozzolan cement
  - Fly Ash @ 25% replacement = IP(25)

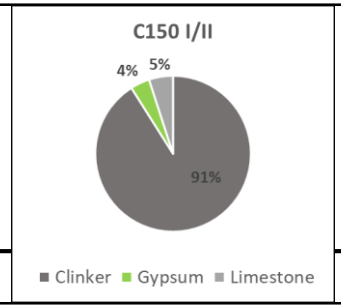
- **Type IS(x)** – Portland-slag cement
  - Slag 40% replacement = IS(40)

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

(cpexecutive.com)

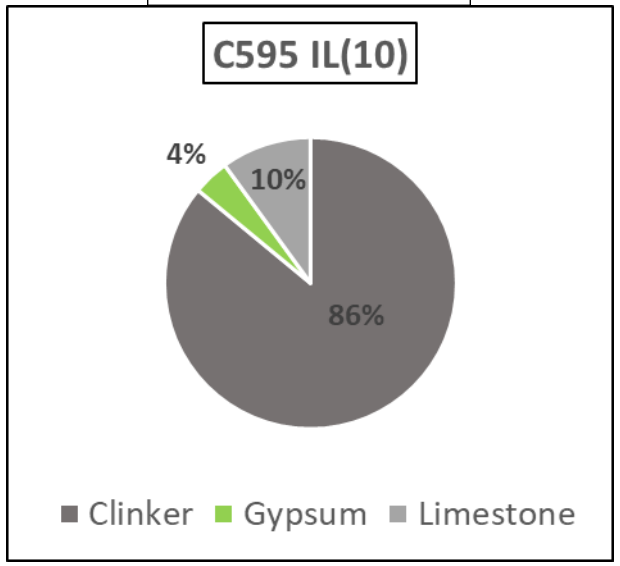
10 Hudson Yards NYC (2016)
- 30% Portland Cement
- 65% Slag
- 5% Silica Fume
  - 16,000 psi





- **Type IL(x)** – Portland-Limestone Cement (≤ 15%) (added in 2013)
  - Ground slightly finer to compensate for 5-10% less clinker
  - Provides CO_2 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

1st CDOT Paving Project w/ PLC
US 287 (SE CO)

C470 in SW Denver

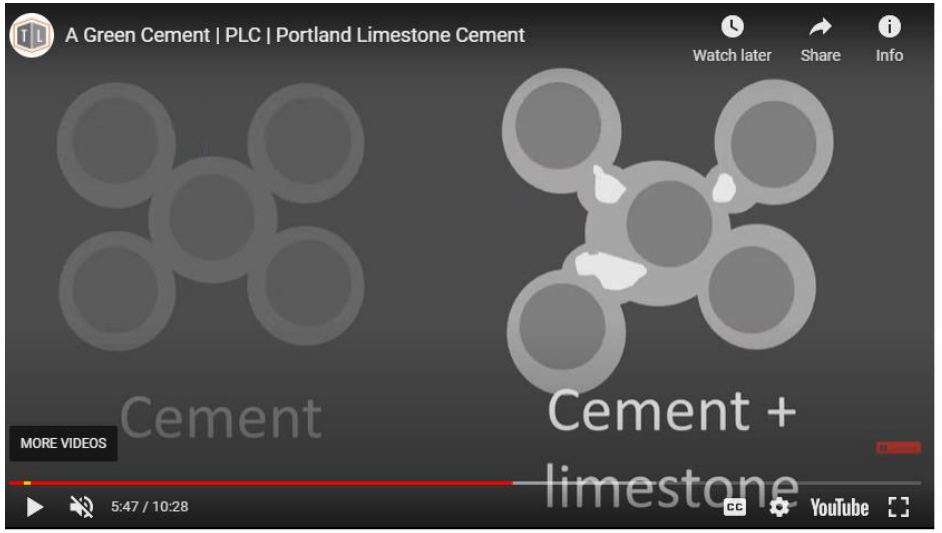
Pena Blvd to DIA

US 36 - Denver to Boulder

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



PCA/Ley, T. greenercement.org

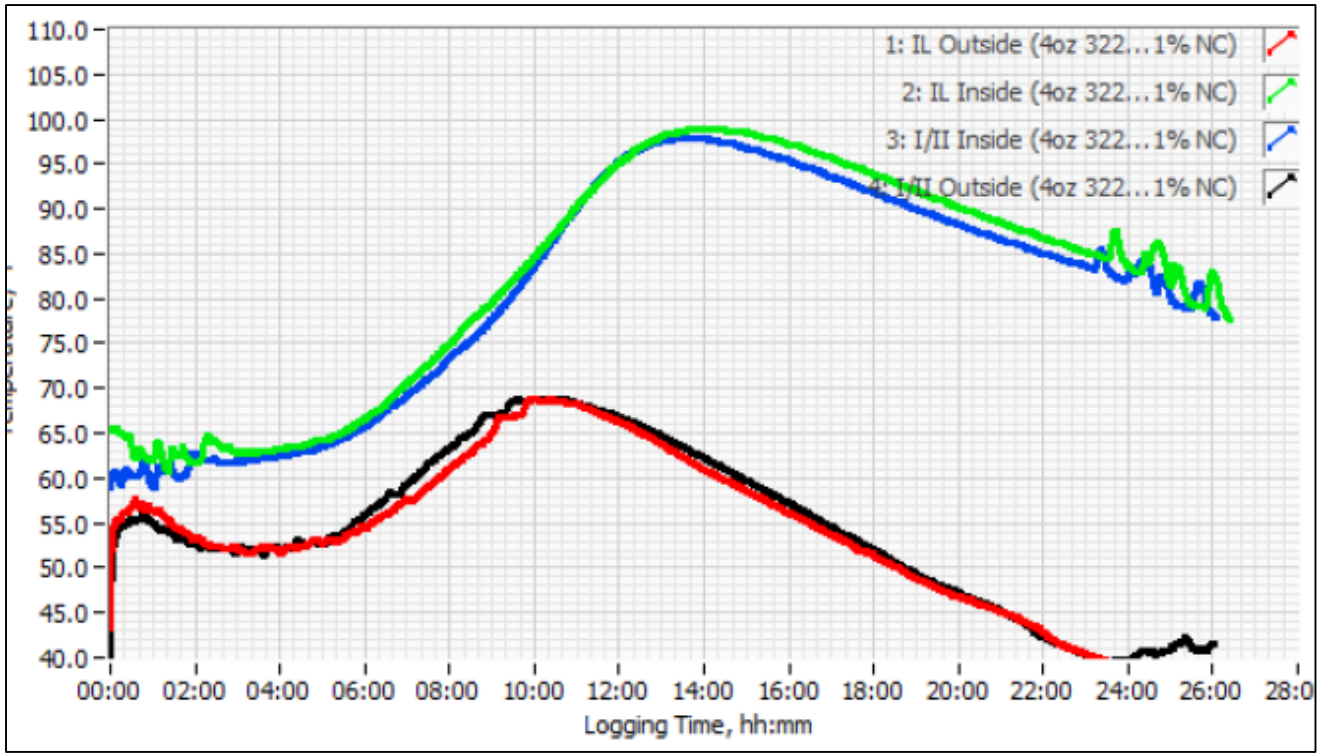
Added limestone has benefits…not just a filler:

- 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 a affect 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

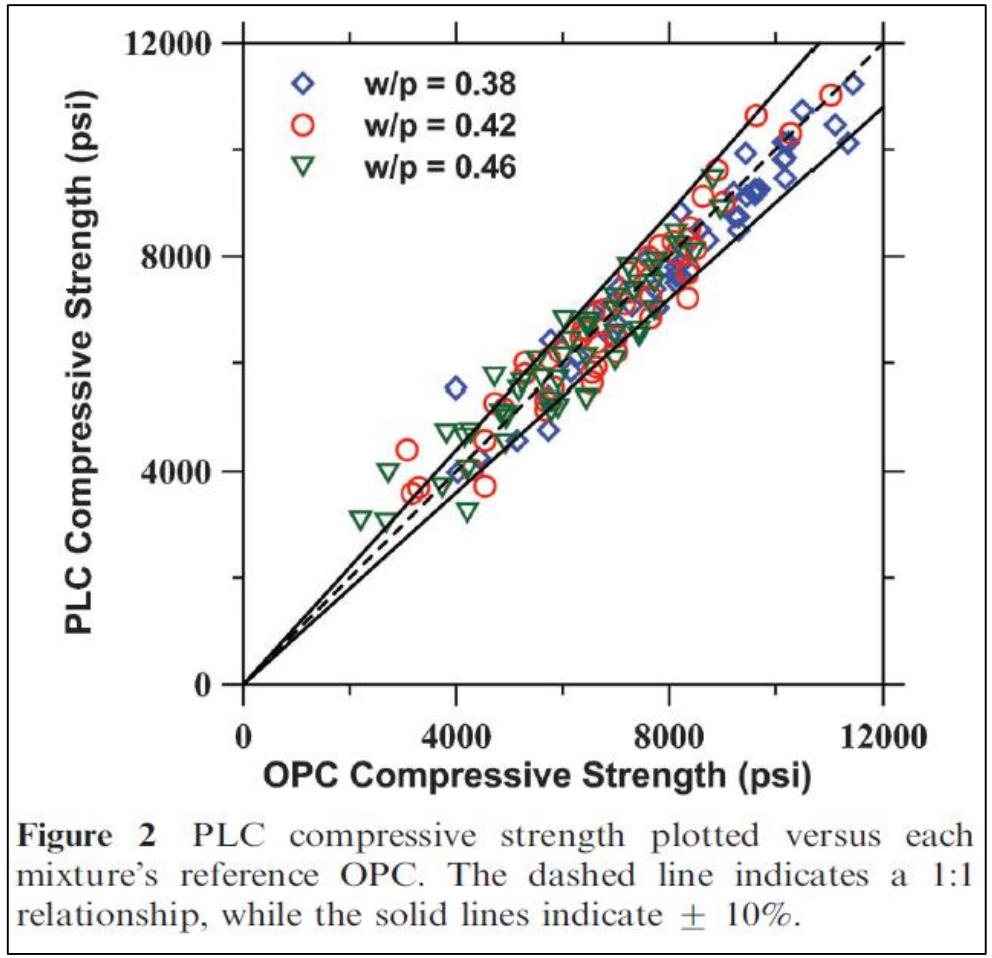


Figure 2 PLC compressive strength plotted versus each mixture's reference OPC. The dashed line indicates a 1:1 relationship, while the solid lines indicate ± 10%.

Barrett, Sun, Weis 2007

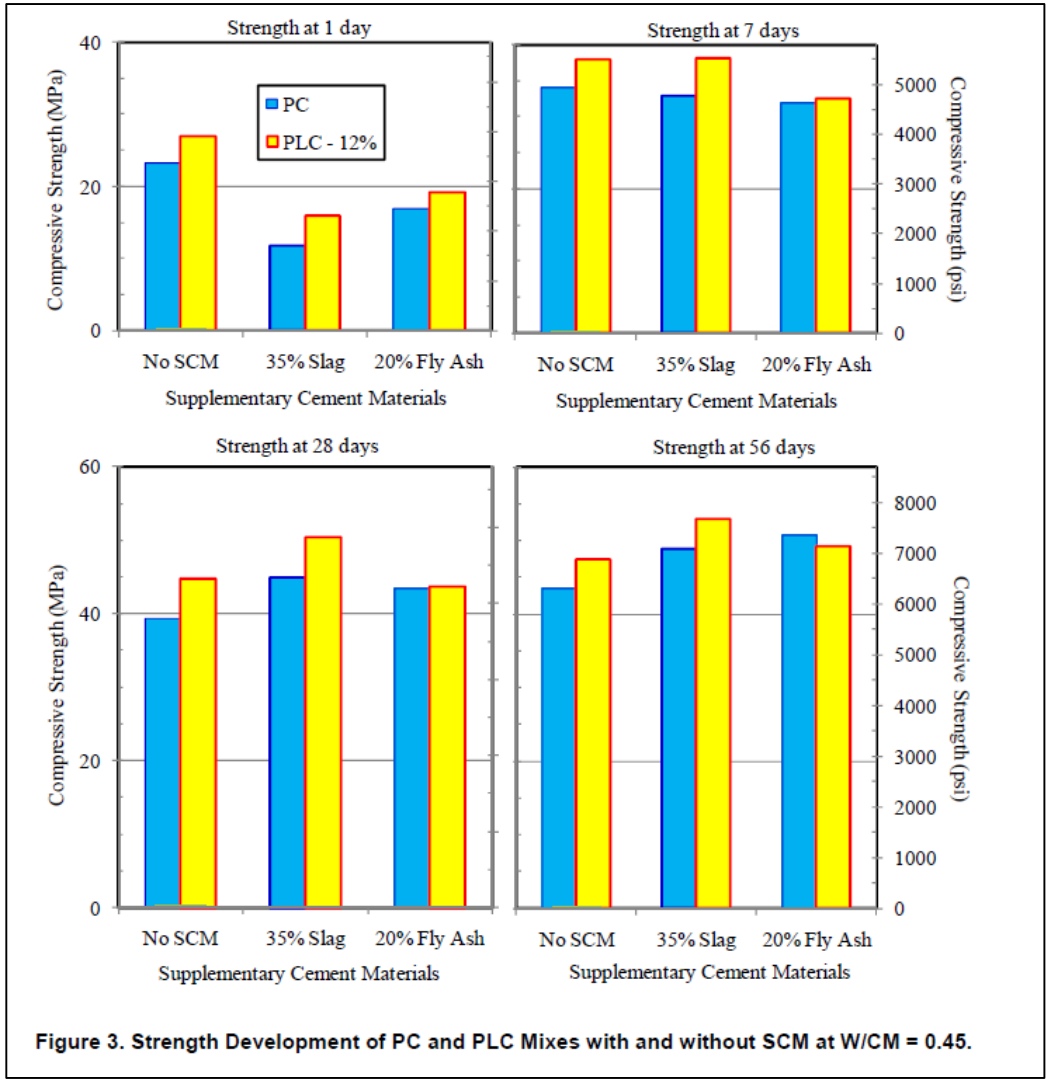


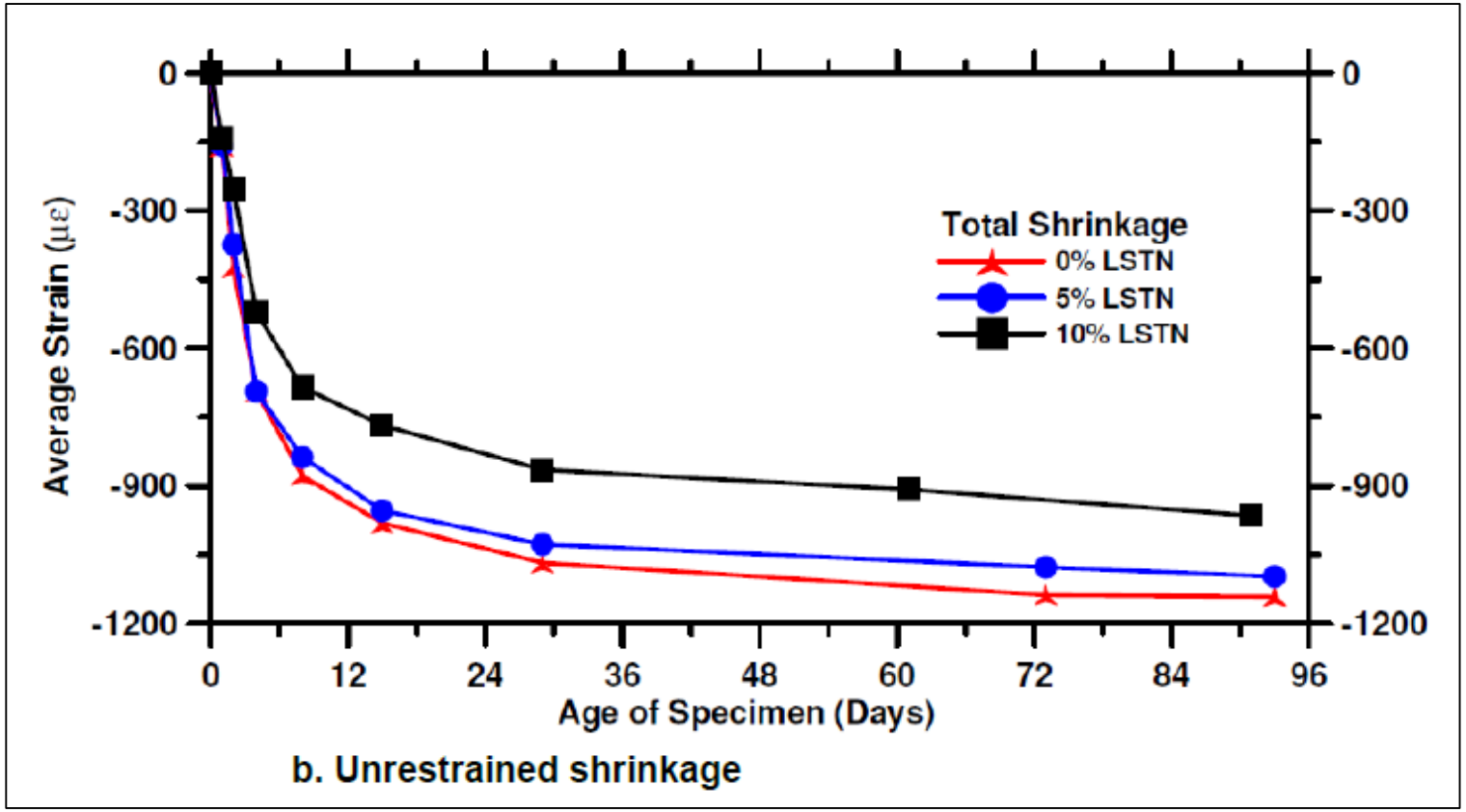
Figure 3. Strength Development of PC and PLC Mixes with and without SCM at W/CM = 0.45.

Bucher et al, 2008

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

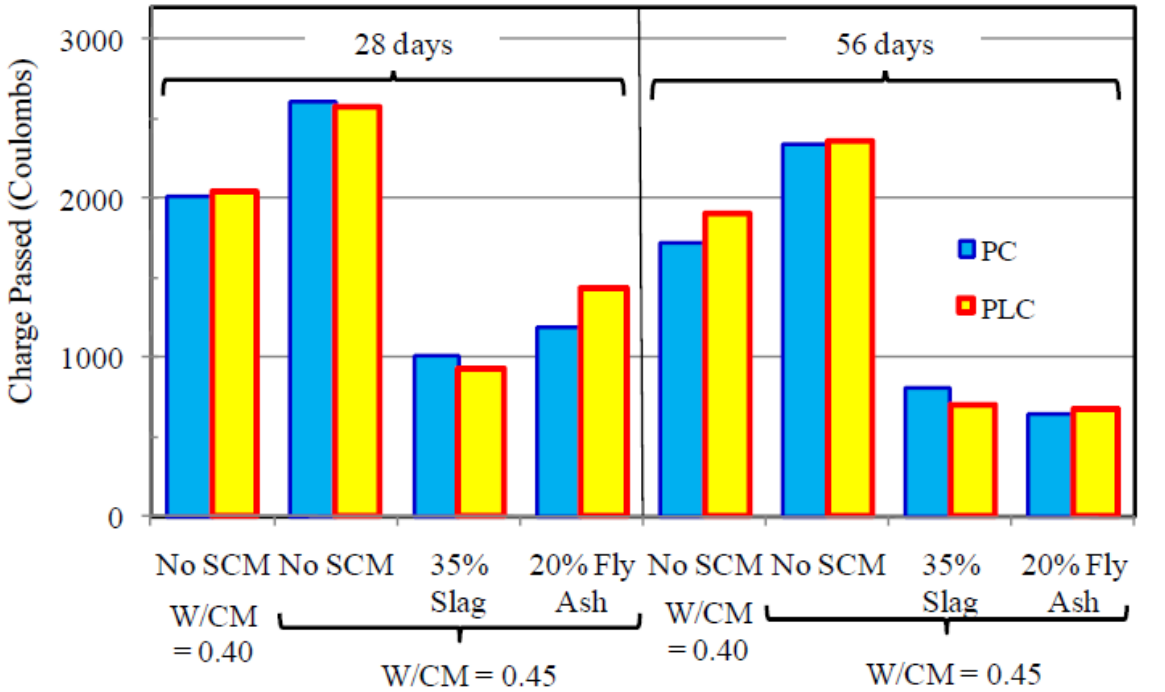
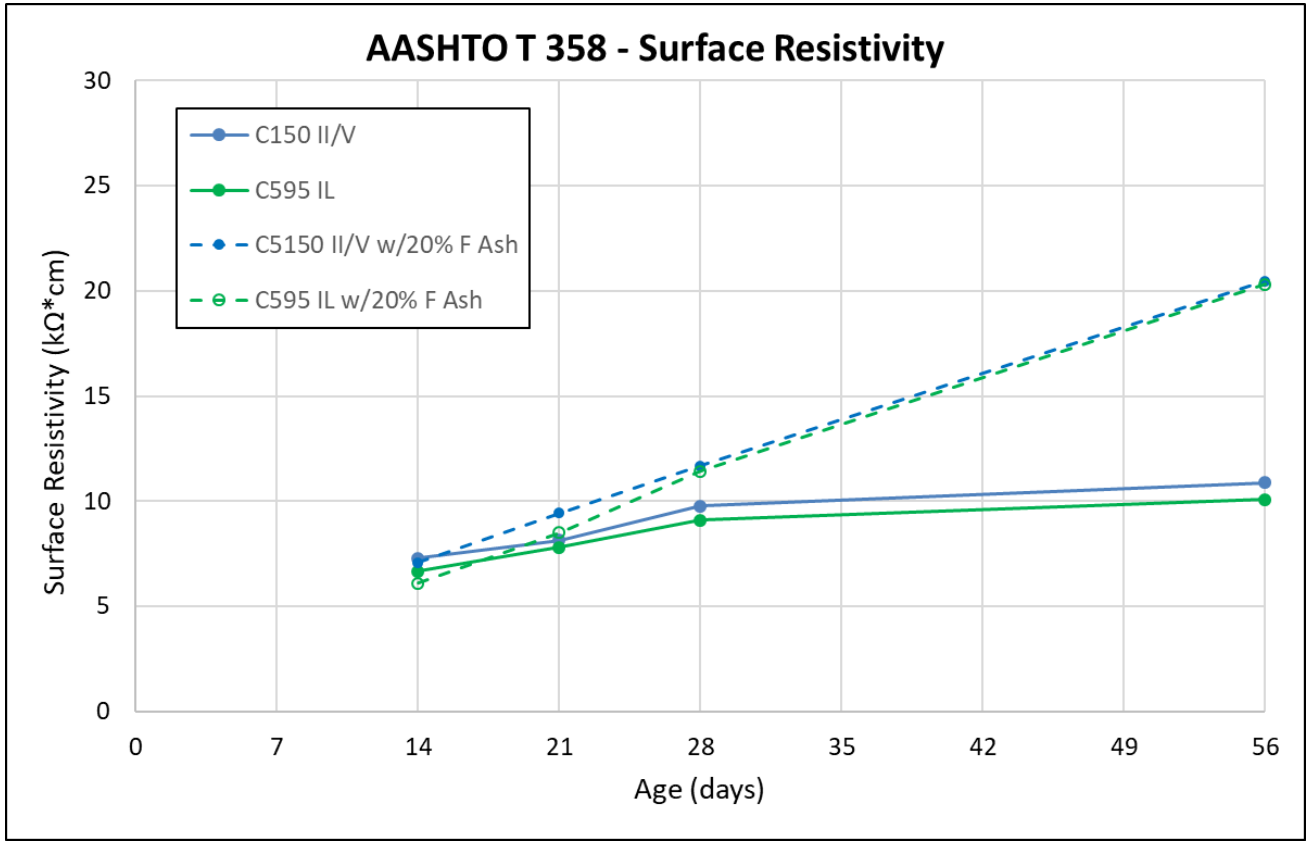


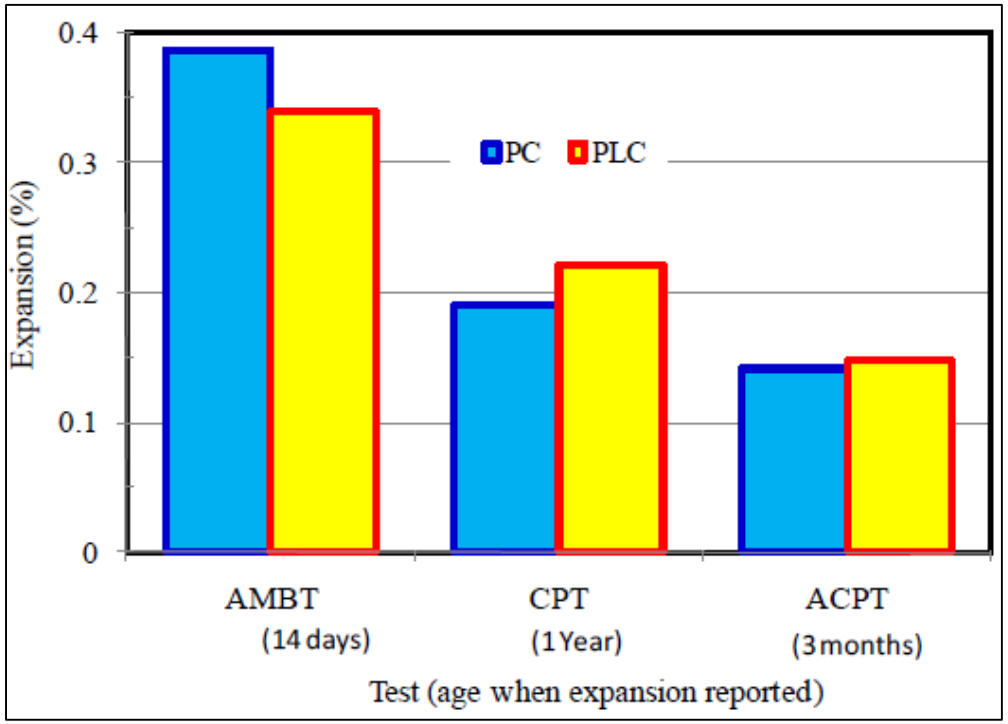
Figure 5. "Rapid Chloride Permeability" – ASTM C1202.

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



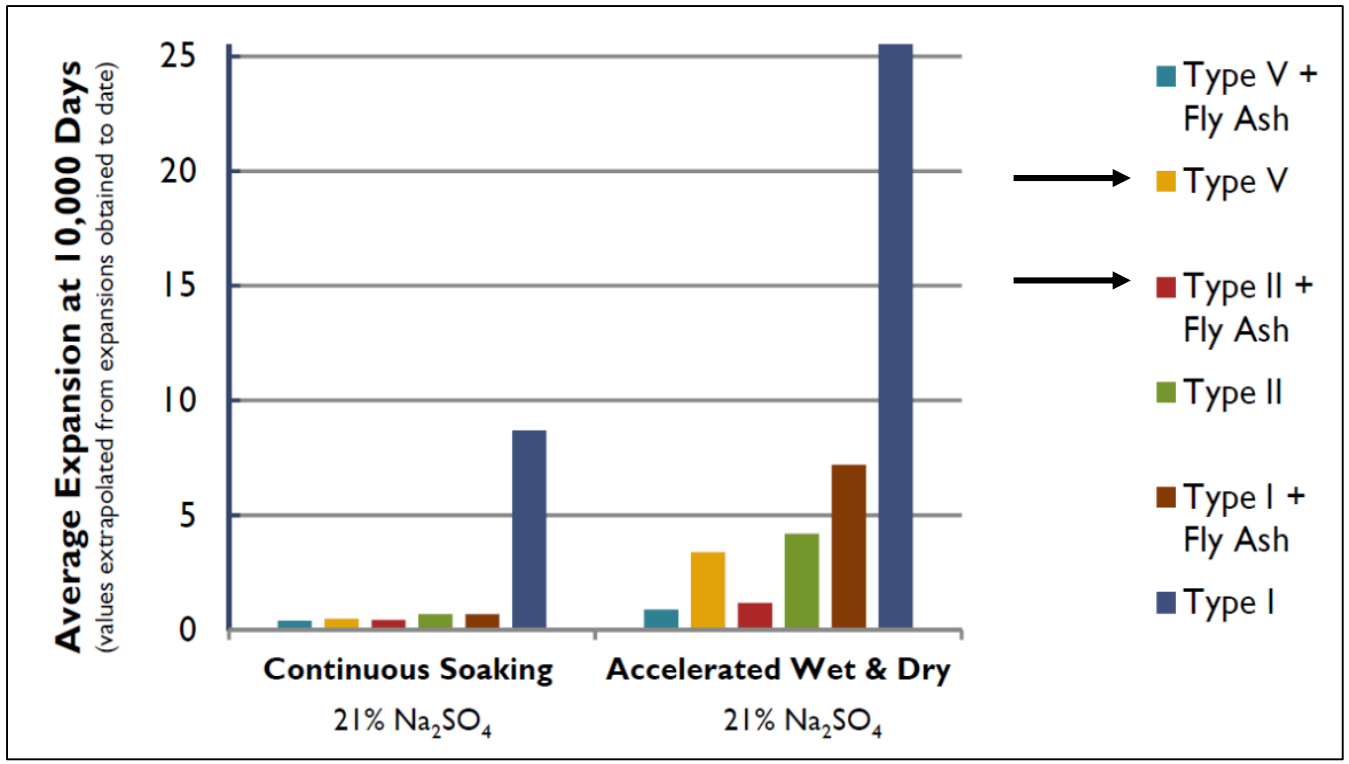
M. Thomas, D. Hooton 2010

Table #1 - ASTM C1260 Percent Expansion Summary, %

Test ID	Cement ID:	Aggregate ID:	0-day	5-day	7-day	12-day	14-day
ASTM C1260	Type I/II	Platte River Sand	0.00	0.12	0.18	0.29	**0.31**
ASTM C1260	Type IL	Platte River Sand	0.00	0.13	0.18	0.27	**0.28**
ASTM C1260	Type I/II	Platte River Sand	0.00	0.14	0.22	0.32	**0.34**
ASTM C1260	Type IL	Platte River Sand	0.00	0.14	0.21	0.30	**0.32**
ASTM C1260	Type I/II	Spratt Coarse	0.00	0.16	0.24	0.32	**0.35**
ASTM C1260	Type IL	Spratt Coarse	0.00	0.15	0.22	0.29	**0.32**
ASTM C1260	Type I/II	Spratt Coarse	0.00	0.15	0.22	0.31	**0.34**
ASTM C1260	Type IL	Spratt Coarse	0.00	0.15	0.22	0.31	**0.34**
ASTM C1260	Type I/II	Asa Sand	0.00	0.07	0.11	0.20	**0.23**
ASTM C1260	Type IL	Asa Sand	0.00	0.07	0.11	0.21	**0.23**

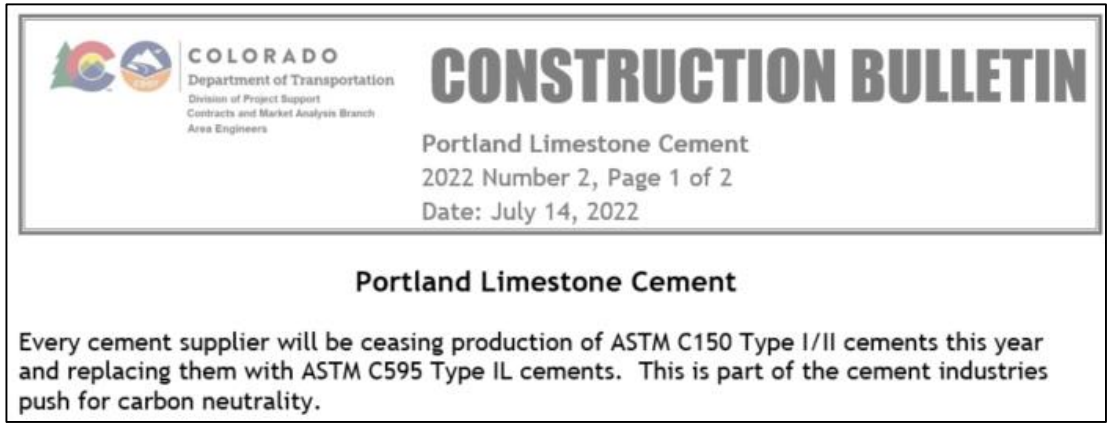
Performance of IL cements (Hardened Properties)

- 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 % C_3A 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 C_3A 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



COLORADO
Department of Transportation
Division of Project Support
Contracts and Market Analysis Branch
Area Engineers

CONSTRUCTION BULLETIN

Portland Limestone Cement
2022 Number 2, Page 1 of 2
Date: July 14, 2022

Portland Limestone Cement

Every cement supplier will be ceasing production of ASTM C150 Type I/II cements this year and replacing them with ASTM C595 Type IL cements. This is part of the cement industries push for carbon neutrality.

- **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

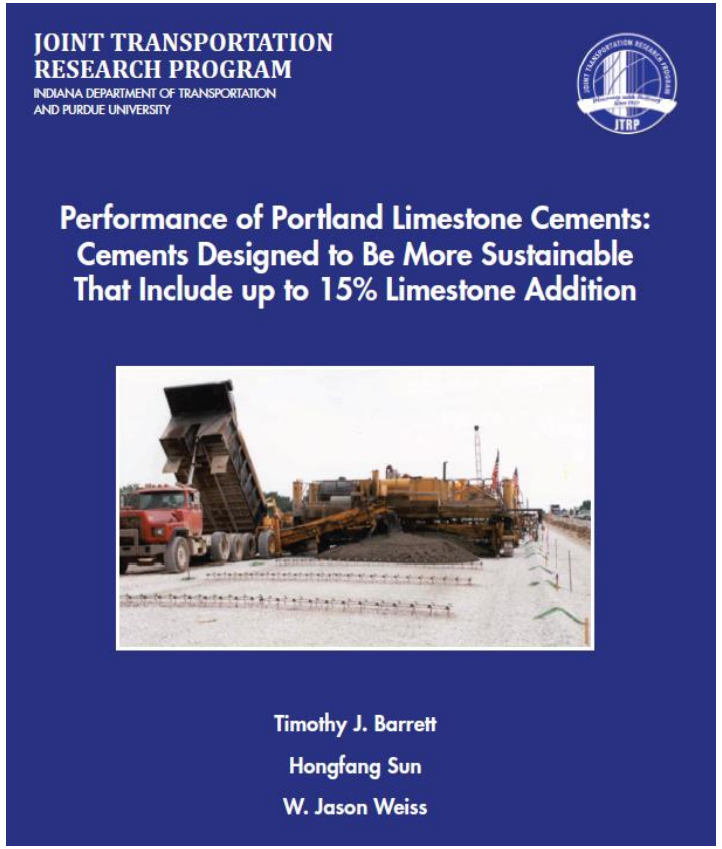
3) Mix designs making a change to Type IL will expire at their natural expiration date after 12/31/22

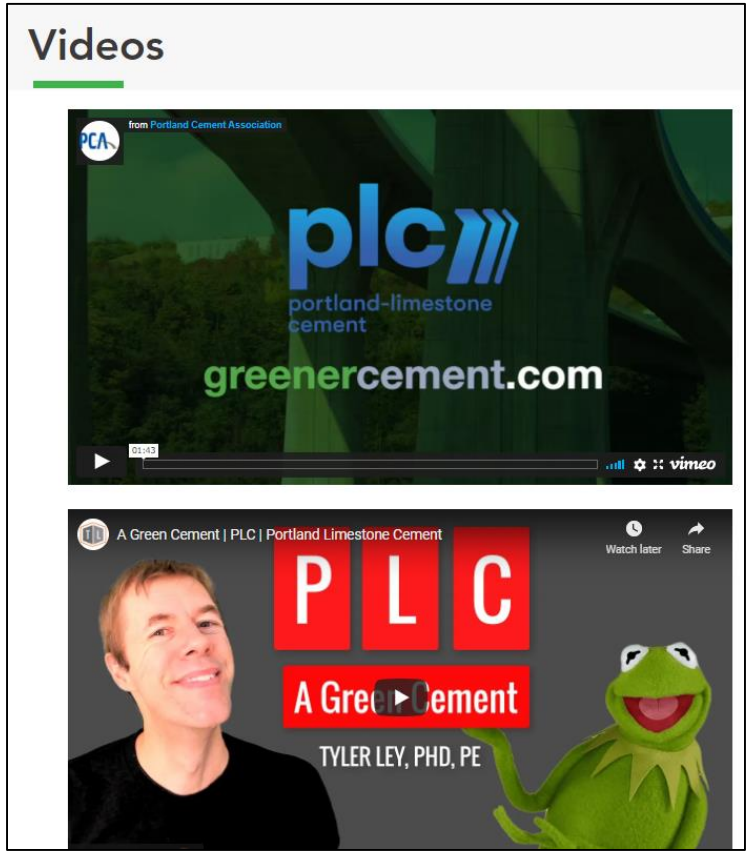
4) Mix designs expiring after 12/31/22 will require a new mix design upon expiring if the producer hasn't already changed over to IL.

crmca

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!

Thank you!!!

Questions…feel free to email:

Dave Figurski
david.figurski@holcim.com