PLC, Performance within the Concrete Construction Industry ?

(New Fangled Cements)

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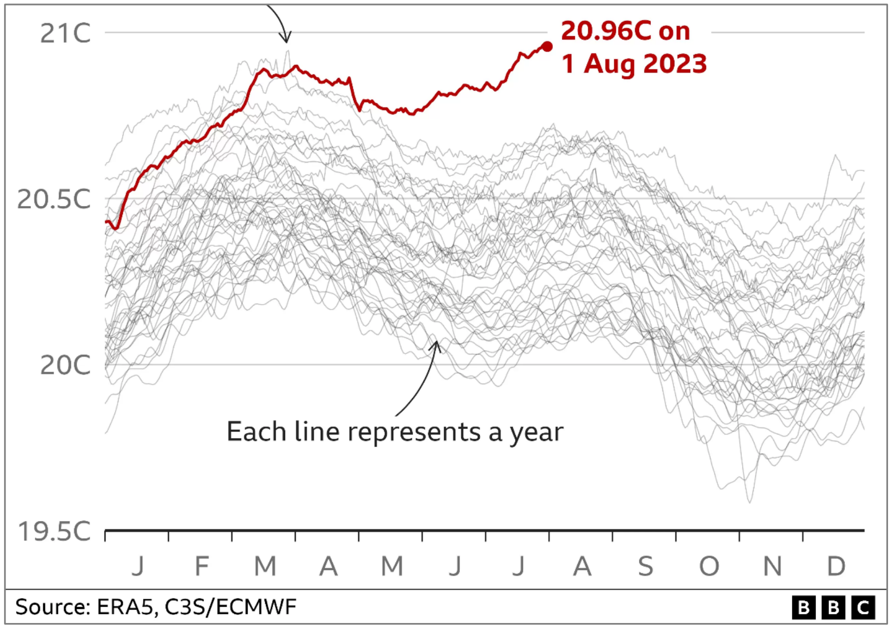
Outline

- Why change
- Reported effects
- Implications
- But wait…
- Where next

Why change?

- It is getting hotter
- Federal Government is pressing to reduce carbon impact
  - At construction
  - Over pavement life



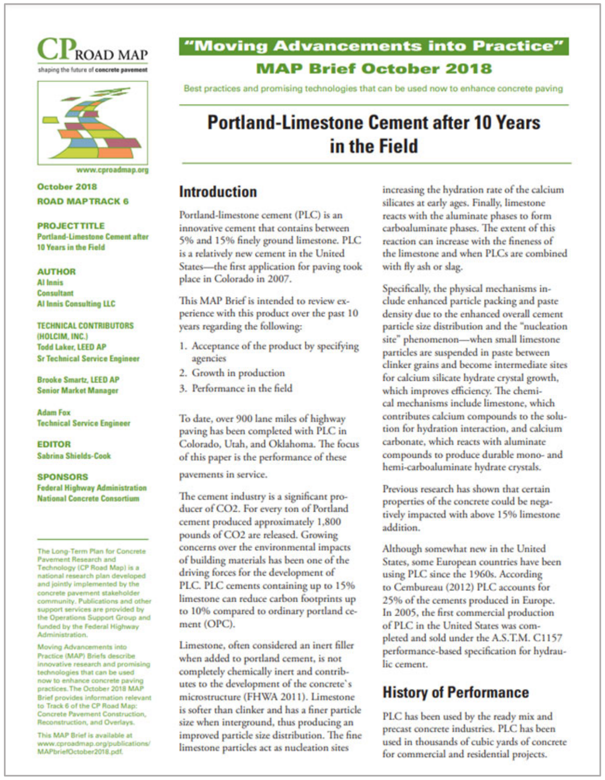
How?

- What can we do to reduce impact?
  - Use less concrete
  - Use less binder in the concrete
  - Use less clinker in the binder
  - Reduce construction impacts
  - Reduce user impacts

Use Less Clinker in the Binder

- Portland Limestone Cements (ASTM C 595)
  - Up to 15% ground limestone
  - <u>Similar</u> performance

  - Becoming the norm



CP ROAD MAP
shaping the future of concrete pavement

www.cproadmap.org

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ROAD MAP TRACK 6

PROJECT TITLE
Portland-Limestone Cement after 10 Years in the Field

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Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The October 2018 MAP Brief provides information relevant to Track 6 of the CP Road Map: Concrete Pavement Construction, Reconstruction, and Overlays.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefOctober2018.pdf.

"Moving Advancements into Practice"
MAP Brief October 2018
Best practices and promising technologies that can be used now to enhance concrete paving

Portland-Limestone Cement after 10 Years in the Field

Introduction

Portland-limestone cement (PLC) is an innovative cement that contains between 5% and 15% finely ground limestone. PLC is a relatively new cement in the United States—the first application for paving took place in Colorado in 2007.

This MAP Brief is intended to review experience with this product over the past 10 years regarding the following:

1. Acceptance of the product by specifying agencies
2. Growth in production
3. Performance in the field

To date, over 900 lane miles of highway paving has been completed with PLC in Colorado, Utah, and Oklahoma. The focus of this paper is the performance of these pavements in service.

The cement industry is a significant producer of CO2. For every ton of Portland cement produced approximately 1,800 pounds of CO2 are released. Growing concerns over the environmental impacts of building materials has been one of the driving forces for the development of PLC. PLC cements containing up to 15% limestone can reduce carbon footprints up to 10% compared to ordinary portland cement (OPC).

Limestone, often considered an inert filler when added to portland cement, is not completely chemically inert and contributes to the development of the concrete`s microstructure (FHWA 2011). Limestone is softer than clinker and has a finer particle size when interground, thus producing an improved particle size distribution. The fine limestone particles act as nucleation sites increasing the hydration rate of the calcium silicates at early ages. Finally, limestone reacts with the aluminate phases to form carboaluminate phases. The extent of this reaction can increase with the fineness of the limestone and when PLCs are combined with fly ash or slag.

Specifically, the physical mechanisms include enhanced particle packing and paste density due to the enhanced overall cement particle size distribution and the "nucleation site" phenomenon—when small limestone particles are suspended in paste between clinker grains and become intermediate sites for calcium silicate hydrate crystal growth, which improves efficiency. The chemical mechanisms include limestone, which contributes calcium compounds to the solution for hydration interaction, and calcium carbonate, which reacts with aluminate compounds to produce durable mono- and hemi-carboaluminate hydrate crystals.

Previous research has shown that certain properties of the concrete could be negatively impacted with above 15% limestone addition.

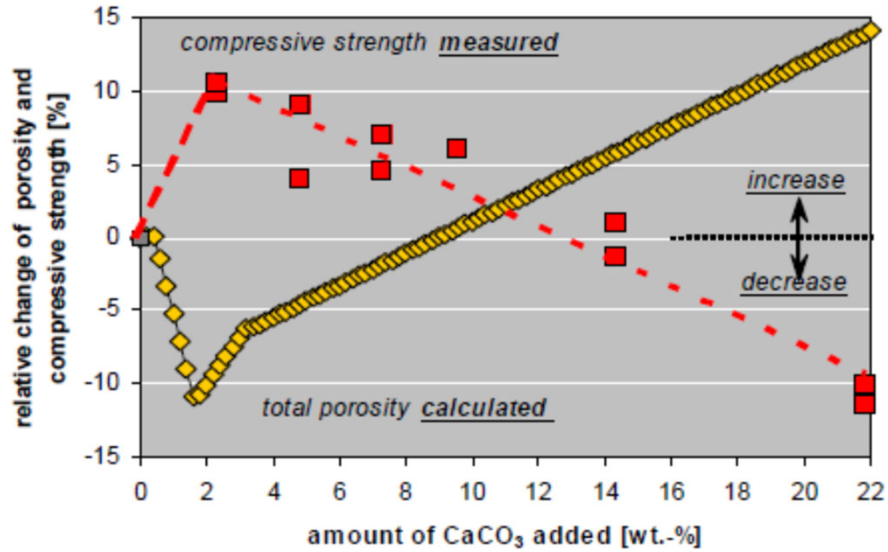
Although somewhat new in the United States, some European countries have been using PLC since the 1960s. According to Cembureau (2012) PLC accounts for 25% of the cements produced in Europe. In 2005, the first commercial production of PLC in the United States was completed and sold under the A.S.T.M. C1157 performance-based specification for hydraulic cement.

History of Performance

PLC has been used by the ready mix and precast concrete industries. PLC has been used in thousands of cubic yards of concrete for commercial and residential projects.

Portland Limestone Cements

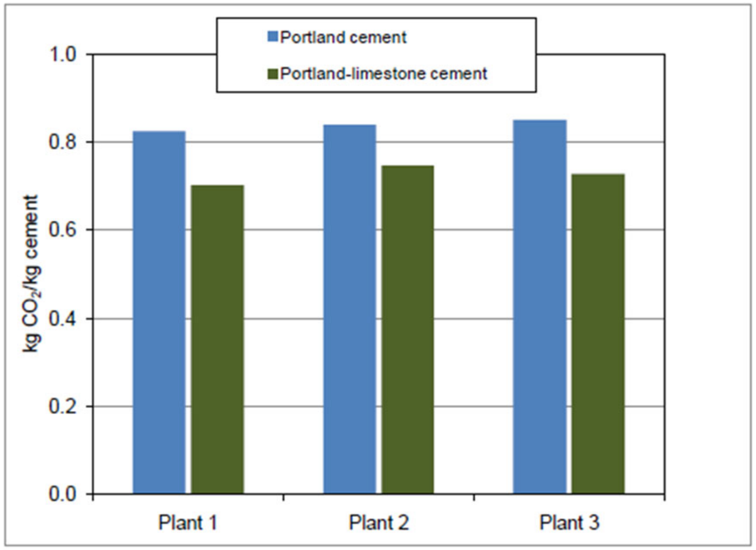
- Why the 15% limit?



Portland Limestone Cements

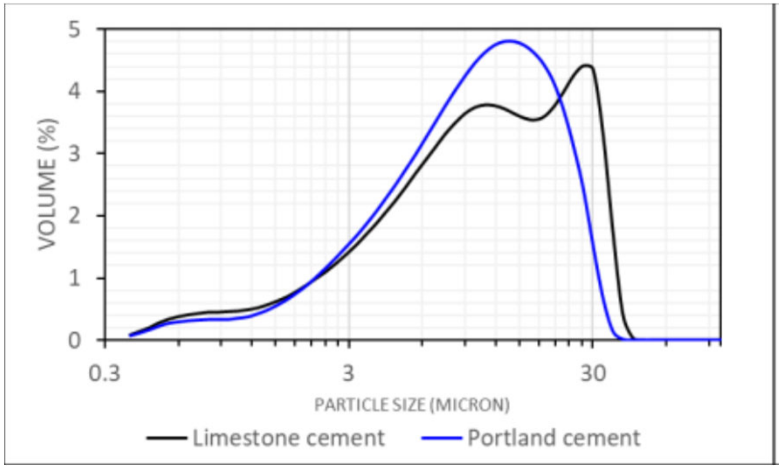
- Potential impacts on carbon
  - ~100 MT cement produced in the USA 2021
  - Means about ~6 MT less CO_2 is possible

- Context
  - USA Carbon emissions ~4,700 MT
  - Cement contribution ~ 41 MT



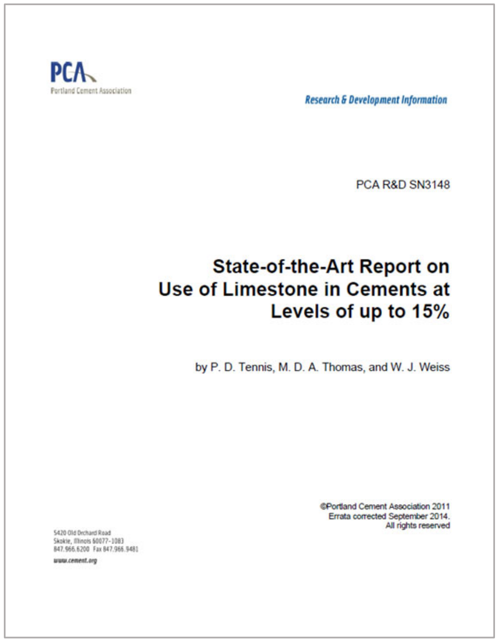
Impacts on Manufacturers

- Finer grinding reduces mill throughput
- New limestone feeders required
- Particle Size Distribution equipment required
- Trials required to identify appropriate fineness target for given % limestone
- New grinding aids & dispensing equipment required
- Trials required to identify correct dosage of grinding aid



Impacts on Users

Workability	Increase or decrease No significant effect on admixtures
Bleeding	Decreases with increasing fineness Generally of no concern
Setting time (initial, final)	May vary
Heat of hydration	Slight increase at early ages (up to 48 hours) But less significant at later ages
Compressive strength	May vary
Scaling and freeze-thaw resistance	Use same techniques as with PC concrete mixes: Proper air-void systems, curing, higher strengths
Sulfate resistance	Use same techniques as with PC concrete mixes: Low w/cm, min. strength, and MS or HS designations


PCA
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
©Portland Cement Association 2011
Errata corrected September 2014.
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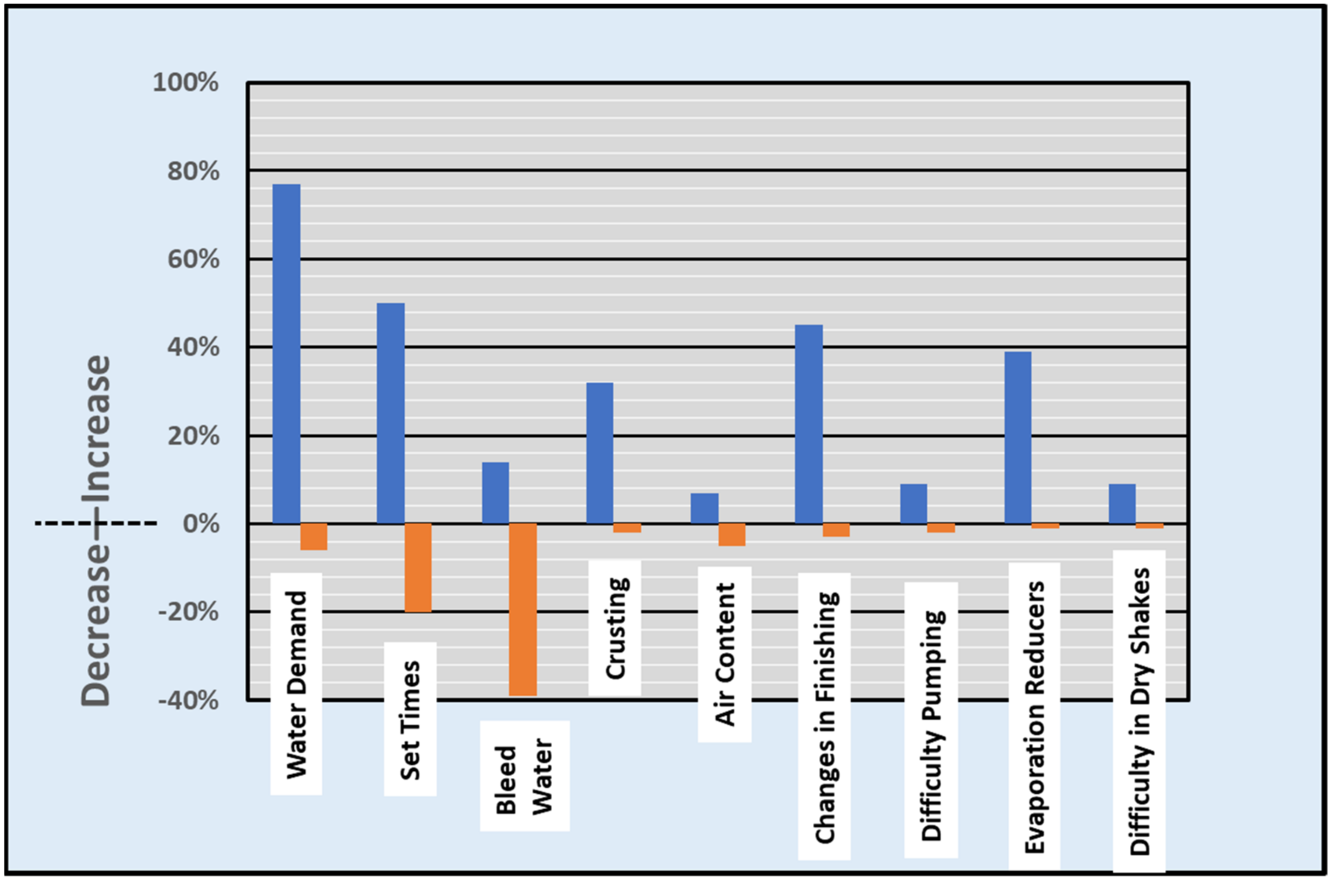
Impacts on Users

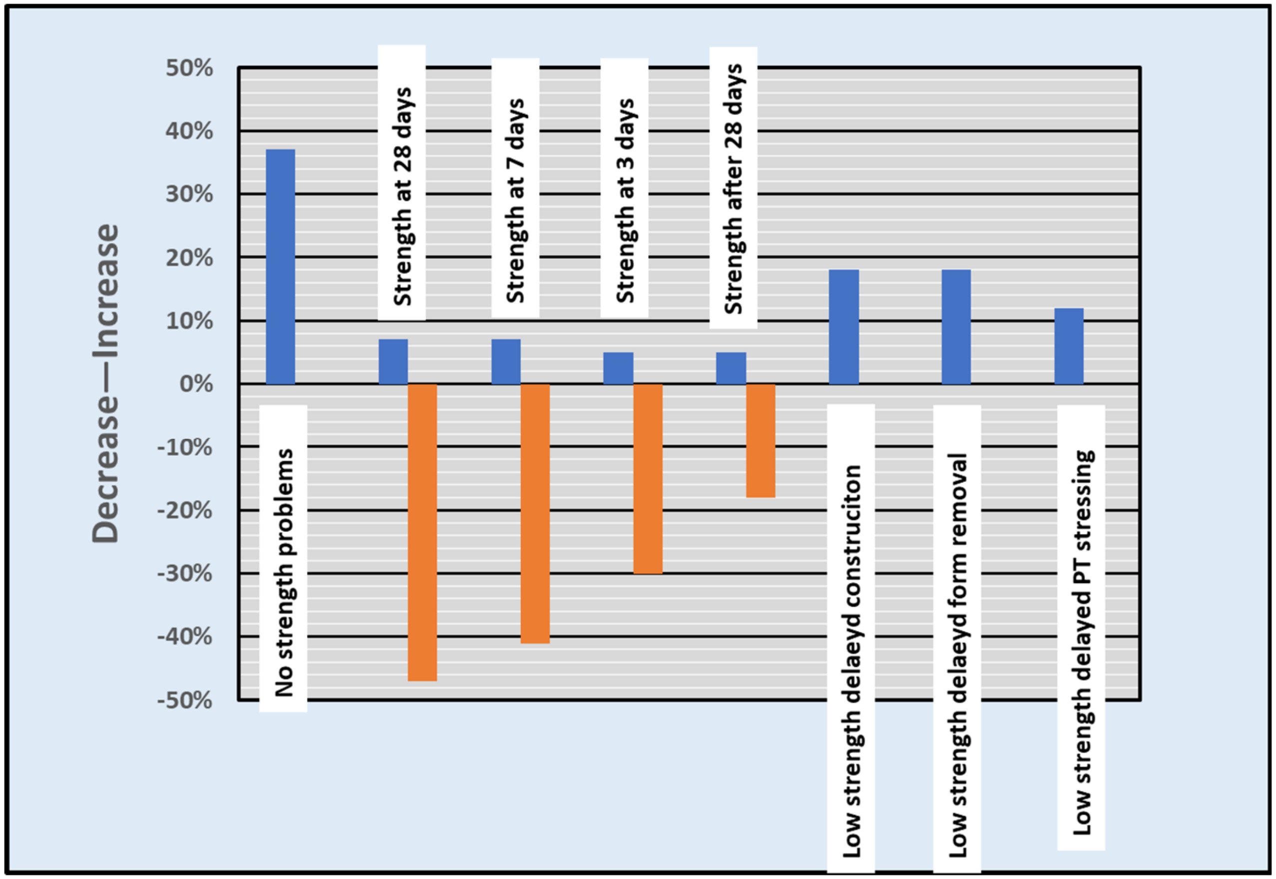
- March 2023 - The sky is falling
  - Strengths
  - Air void systems
  - Bleeding
  - Setting
  - Scaling

  - Variability load to load

ACI 302 ASCC Survey

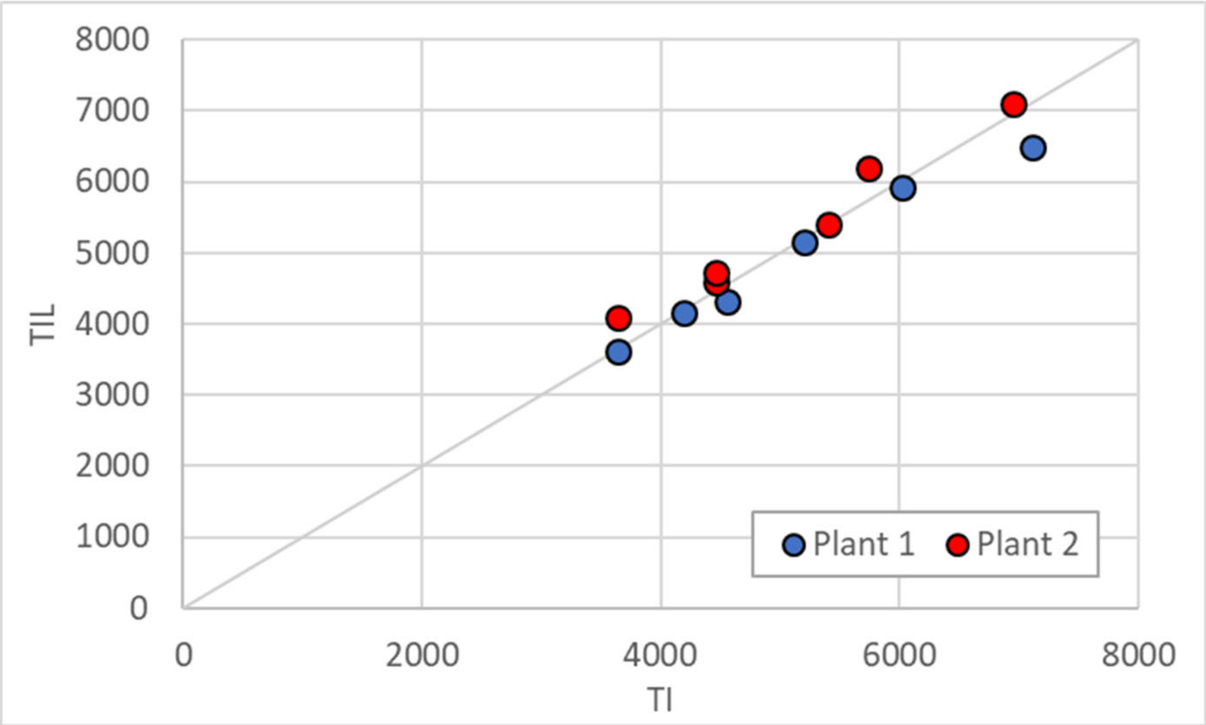


ACI 302 ASCC Survey



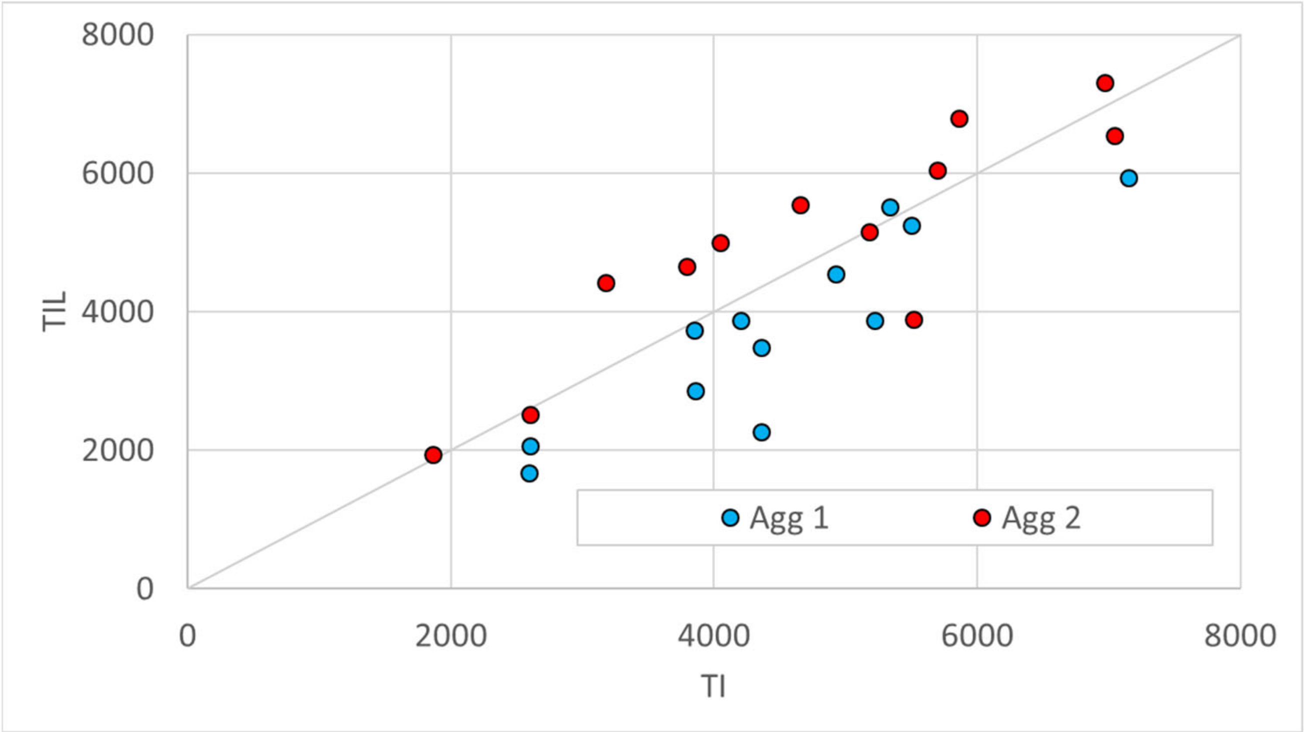
Impacts on Users

- Compressive strength



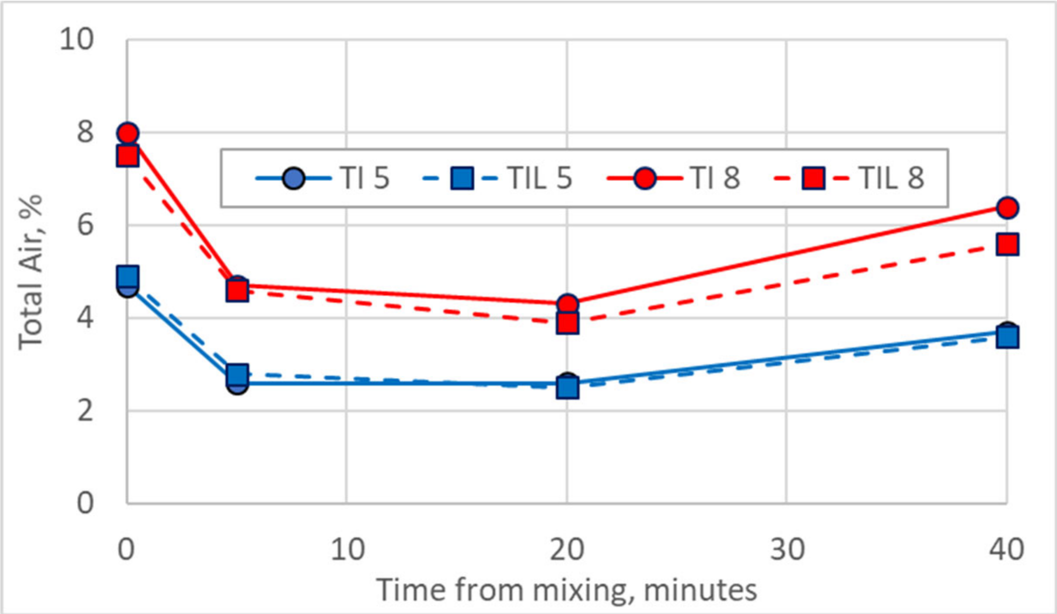
Impacts on Users

- Compressive strength



Impacts on Users

- Air content
  - High airs reported in some petro reports
  - Not repeated in the lab
  - Clustering?

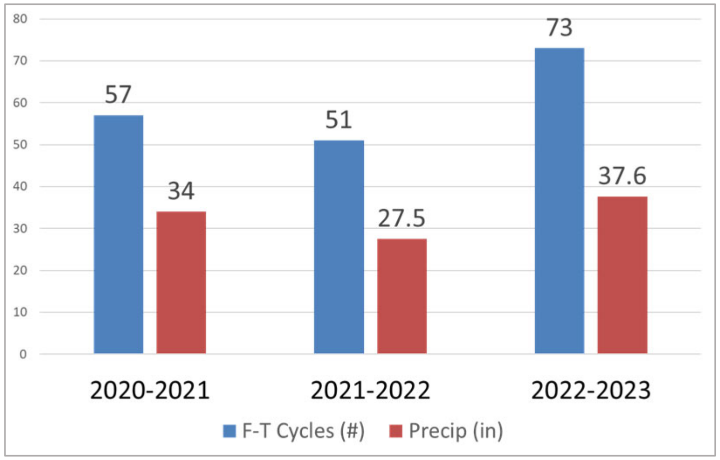


Impacts on Users

- March 2023
  - The sky is falling

- 9 months later:
  - One for one will not work in all cases
  - Trial batches and proportion adjustments are necessary
  - Allow for change in water demand

  - "Works fine when I add 10% more"!



Impacts on Users

- Practices may have to be adjusted
  - Setting time
  - Bleed
  - Strength development

Impacts on Users

- Costs of trials
- Costs of slower construction
- Costs of changing risks
- Are the current specs appropriate?

- What about the variability?

- Why can't we go back to the good old days?
- It's too complicated!

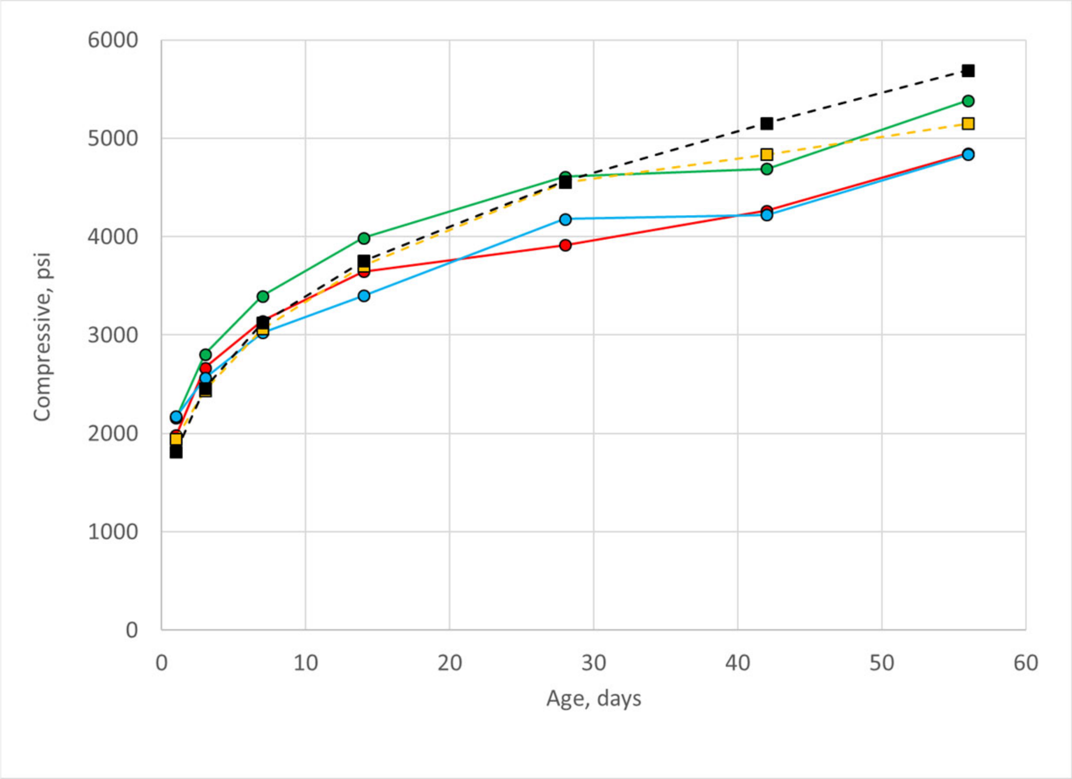
Experience

- Oklahoma 2012
  - PLC with 15% Class C Ash
  - 5,300 psi @28 days

- Reportedly doing well

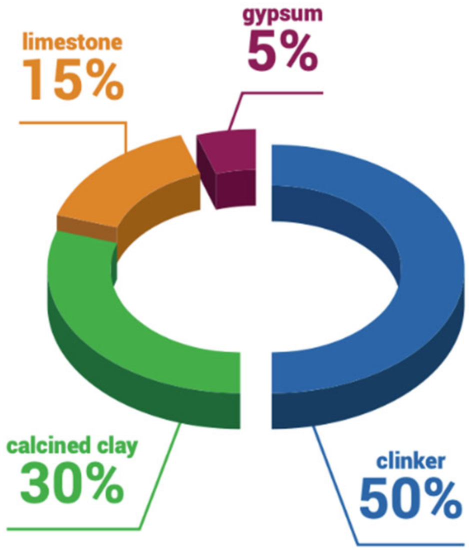
Experience

- MNDOT Test sections 2022 – PLC + 30% fly ash



But Wait – There's More

- Harvested fly ash
- LC3
- 50% clinker
- Geopolymers
- $CaSiO_2$ sourced clinker
- Other powders



Potential Impacts

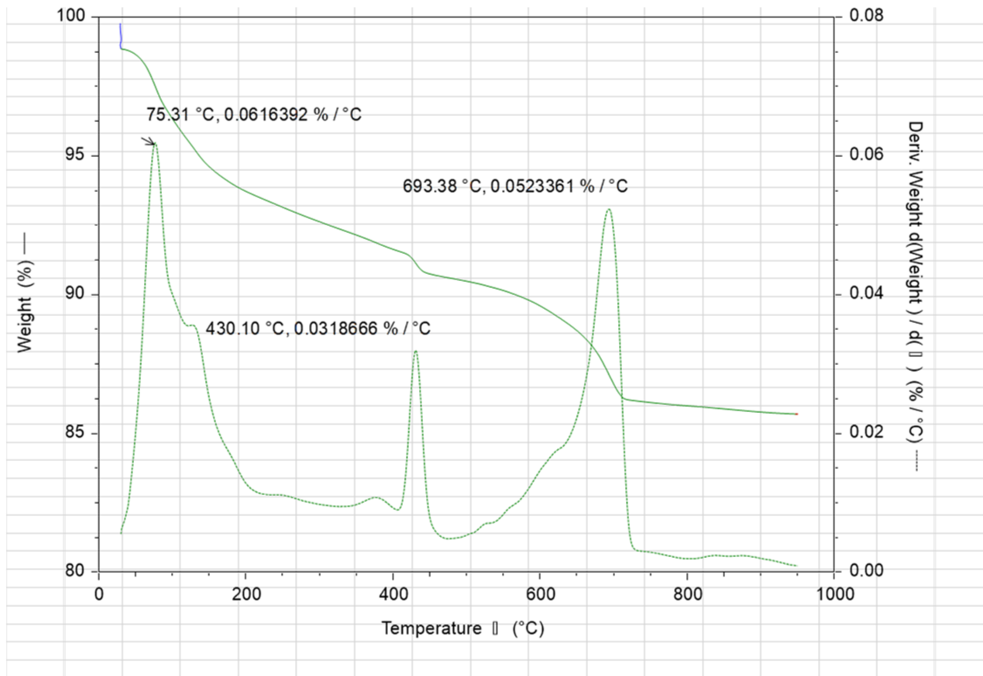
- Shrinkage
  - Joint spacing
  - Warping
  - Steel requirements
- Strain capacity
  - 300 με may no longer be valid
- Stiffness
  - $E = 57{,}000\sqrt{f_c}$ may no longer be valid
- Poisson's ratio
  - P = 0.2 may no longer be valid

Potential Impacts

- Batch sequencing
- Finishing timing
- Curing needs
- Sawing timing
- Form stripping

Potential Impacts

- I have to know what's in it
  - How good is your chemistry?



Impacts on Owners

- I have to know what it does - but what?
  - Are we specifying the right things for cements?
    - Set time
    - Strength gain
    - HOH
    - Sulfate expansion
    - Autoclave
    - Air
  - Is anything missing?
    - Permeability
    - Shrinkage
  - Or do we worry about the concrete?

TABLE 1 Standard Physical Requirements

Cement Type	Applicable Test Method	GU	HE	MS	HS	MH	LH
Fineness	C204, and C430 or C1891	A	A	A	A	A	A
Autoclave length change, max, %	C151/C151M	0.80	0.80	0.80	0.80	0.80	0.80
Time of setting, Vicat test[B]	C191						
Initial, not less than, minutes		45	45	45	45	45	45
Initial, not more than, minutes		420	420	420	420	420	420
Air content of mortar volume, max, %[C]	C185	12	12	12	12	12	12
Compressive strength minimum, MPa [psi][D]	C109/C109M						
1 day		...	12.0 [1740]	...	...	...	...
3 days		13.0 [1890]	24.0 [3480]	11.0 [1600]	11.0 [1600]	5.0 [725]	...
7 days		20.0 [2900]	...	18.0 [2610]	18.0 [2610]	11.0 [1600]	11.0 [1600]
28 days		28.0 [4060]	...	...	25.0 [3620]	...	21.0 [3050]
Heat of hydration, max, kJ/kg [cal/g]	C1702						
3 days		...	...	...	...	335 [80]	200 [50]
7 days		...	...	...	...	...	225 [55]
Mortar bar expansion	C1038/C1038M						
14 days, % max		0.020	0.020	0.020	0.020	0.020	0.020
Sulfate expansion (sulfate resistance)[E]	C1012/C1012M						
6 months, max, %		...	...	0.10	0.05	...	...
1 year, max, %		...	...	...	0.10	...	...
Optional Physical Requirements							
Option A—Air entraining[C,F]	C185						
Air content of mortar, vol %							
max		22	22	22	22	22	22
min		16	16	16	16	16	16
Option R—Low reactivity with alkali-silica-reactive aggregates[G]	C227						
Expansion at							
14 days, max, %		0.020	0.020	0.020	0.020	0.020	0.020
56 days, max, %		0.060	0.060	0.060	0.060	0.060	0.060
Early stiffening, final penetration, min,%	C451	50	50	50	50	50	50
Compressive strength,[D] 28 days, min, MPa	C109/C109M	...	...	28.0	...	22.0	...

Where next

- Learning and thinking required
- Talk to your supplier
- Specify the properties you need
- Do those trial batches
  - Call if you need help
  - Stay away from the cliff edge

- Let’s talk about the future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