

Portland-Limestone Blended Cements

Today's Objectives

- What is a portland-limestone blended cement
- History
- Performance
 - Concrete
 - Environmental
- Changes to the Specifications



Portland-Limestone Cement

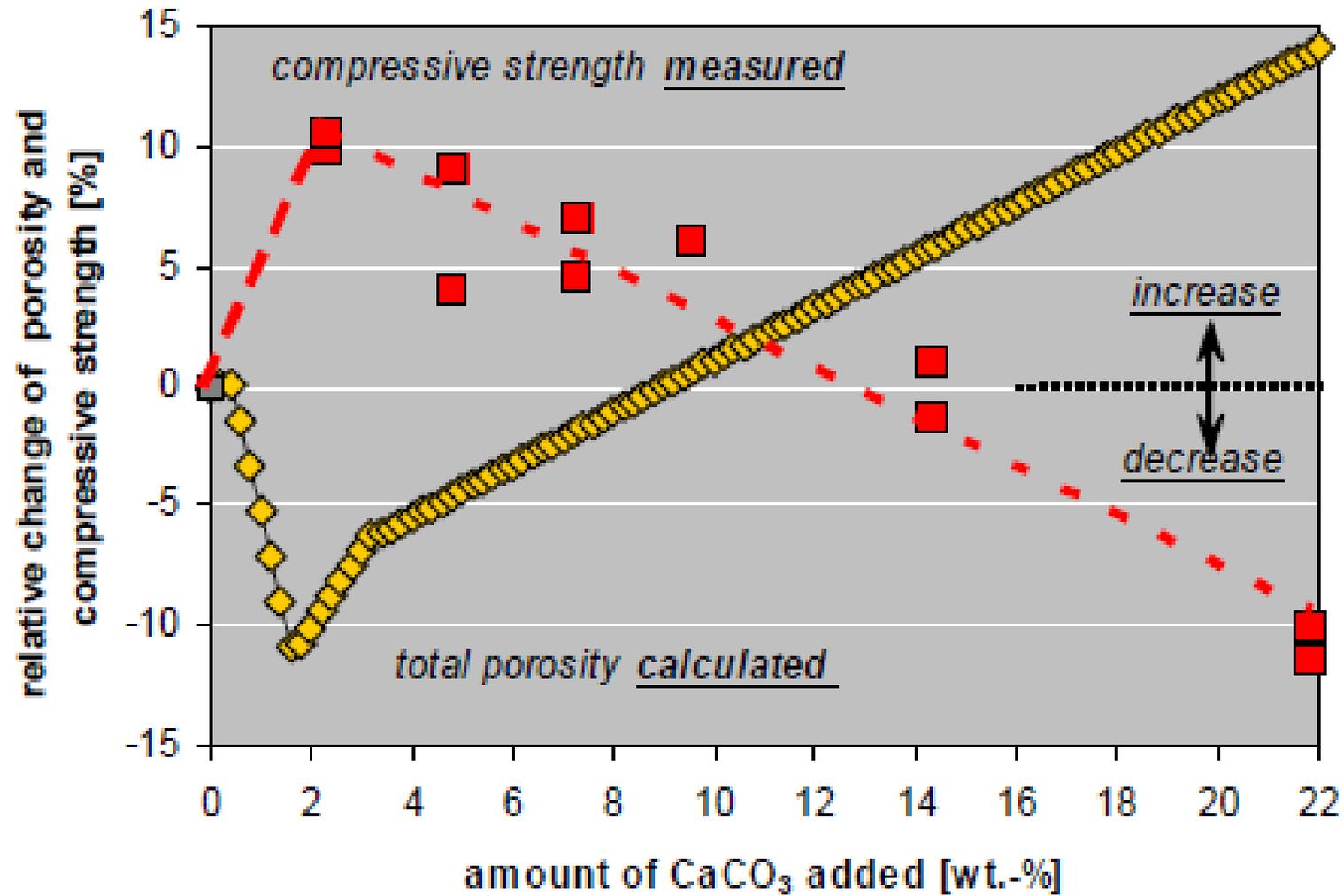
- What is a PLC?
 - Type IL cement
 - 5% to 15% limestone in ASTM C595/AASHTO M240
 - Ternary cements

History of Use of Limestone in Cements

- 1965 Cement with 20% limestone cement in Germany for specialty applications
- 1979 French cement standards allows limestone additions.
- 1983 CSA A5 allows up to 5% in portland cement
- 1990 15±5% limestone blended cements routinely used in Germany
- 1992 UK specs allows up to 20% in limestone cement
- 2000 EN 197-1 allows 5% MAC (typ. limestone) in all 27 common cements, as was commonly practiced in various European cement standards prior to that.
- 2004 ASTM C 150 allows 5% in Types I-V
- 2006 CSA A3001 allows 5% in other Types than GU
- 2008 CSA A3001 includes PLC containing 5%-15% limestone
- 2012 ASTM C-595 includes PLC containing 5%-15% limestone
- 2017 ASTM C-595 allows the use of PLC in sulfate environments.

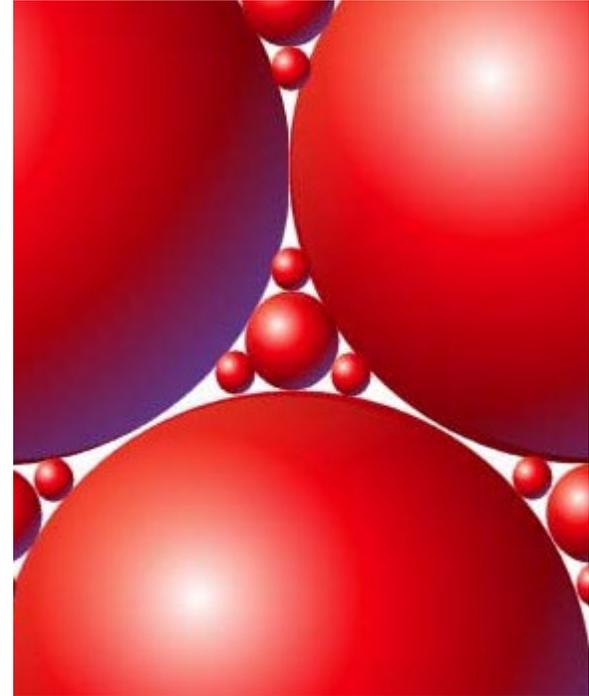
How Limestone Works

Why 15%?



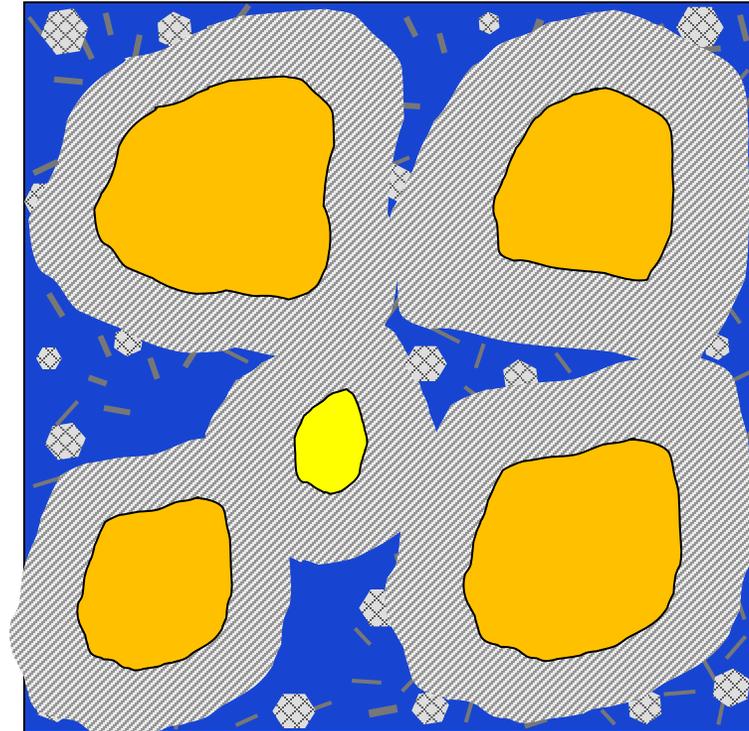
How Limestone Works

- Particle packing
 - Improved particle size distribution
- Nucleation
 - Surfaces for precipitation
- Chemical reactions
 - Only a small amount, but...



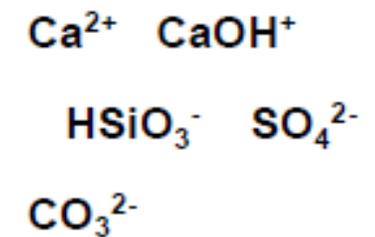
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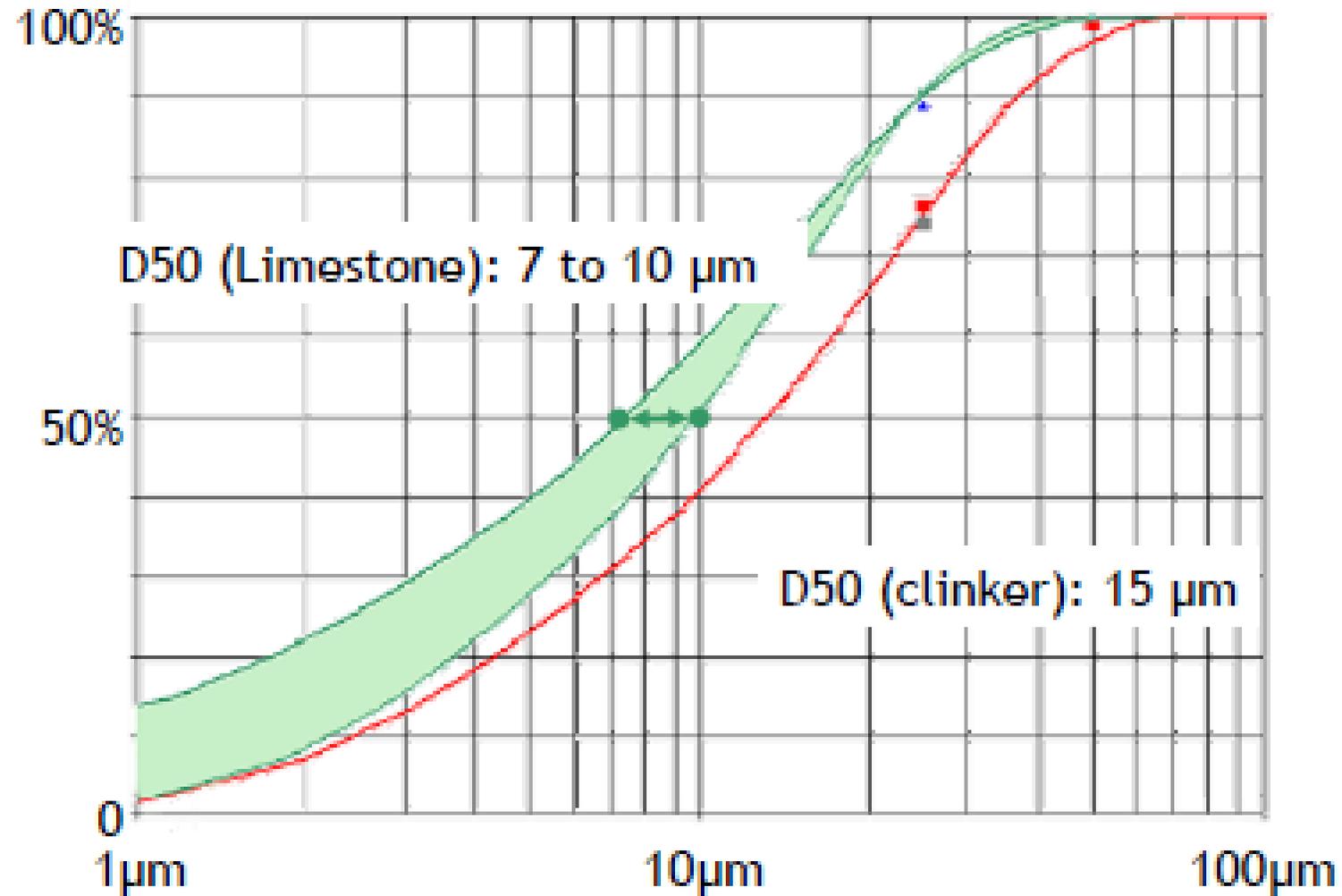
- Particle packing
 - Improved particle size distribution
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 - Surfaces for precipitation
- Chemical reactions
 - Only a small amount, but...
 - Vaterite, others....



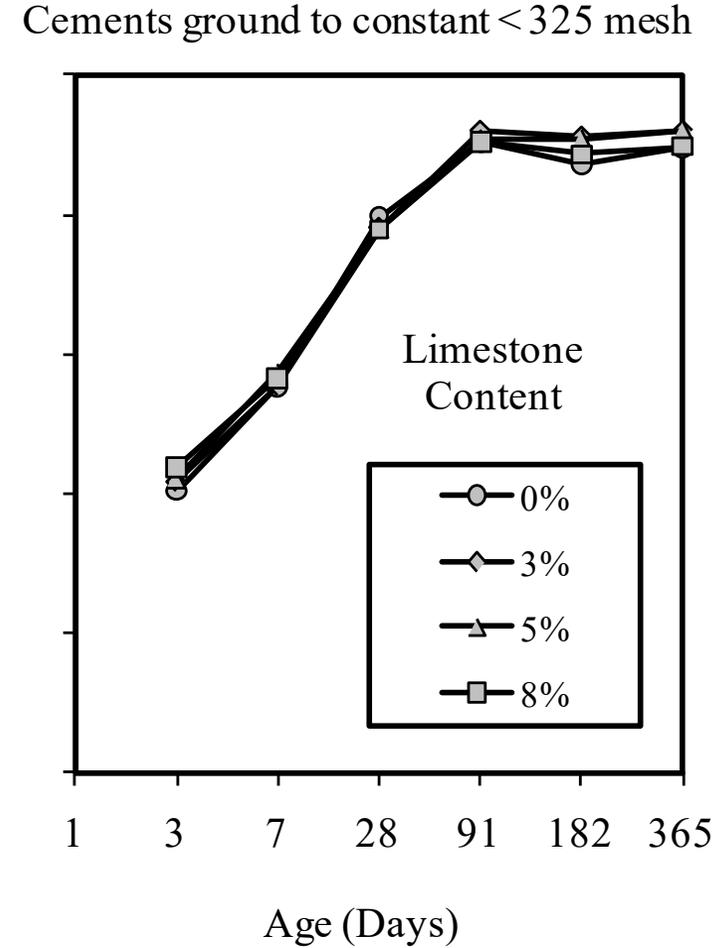
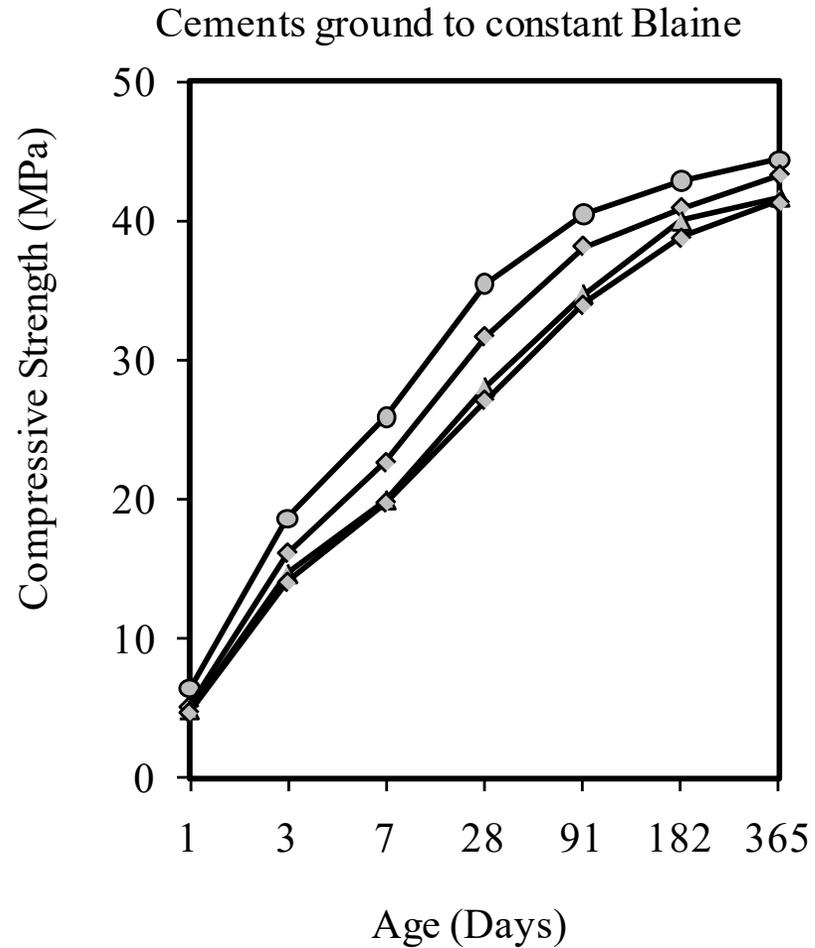


Performance: Cement

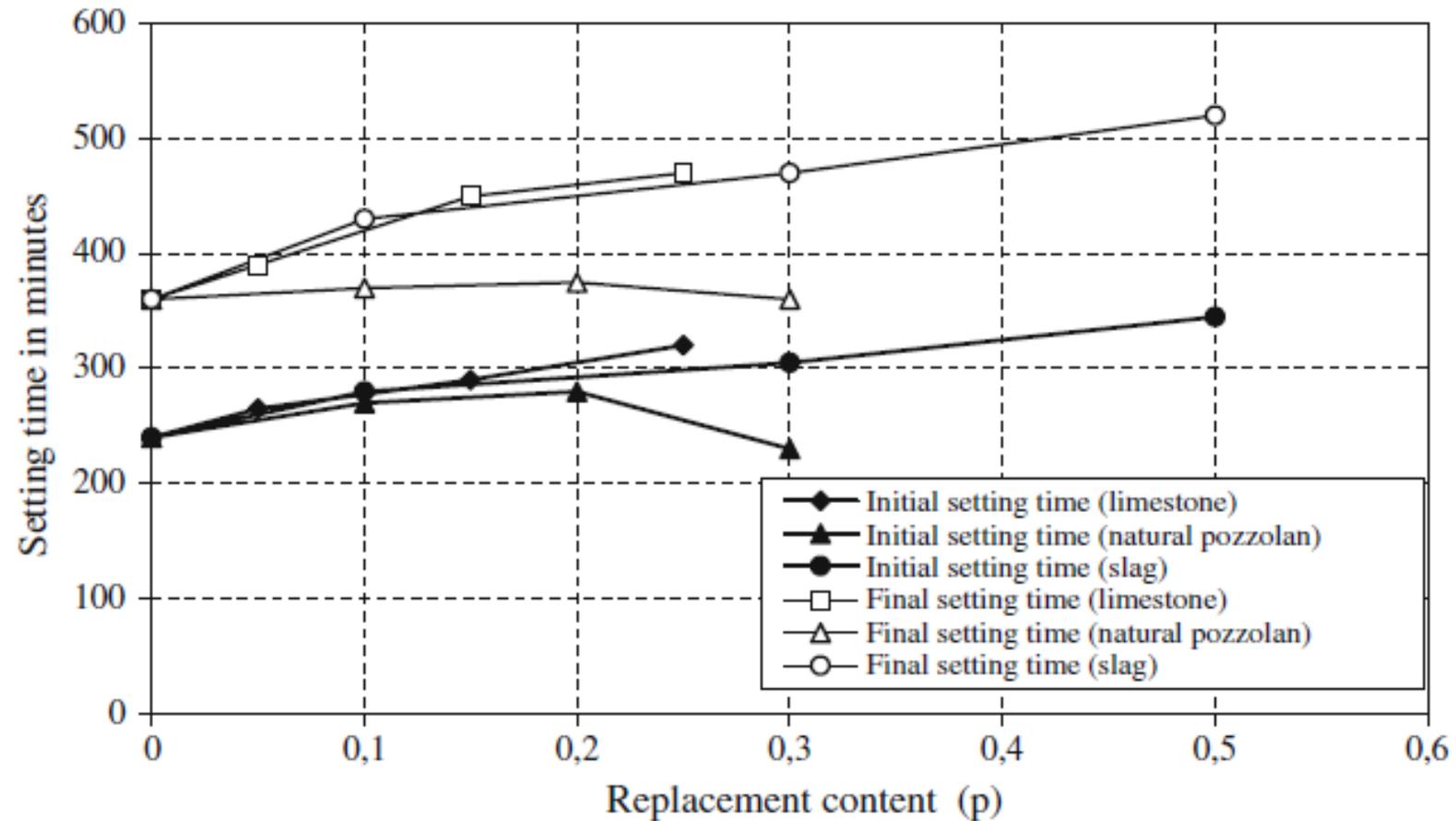
Particle size



Particle size and strength

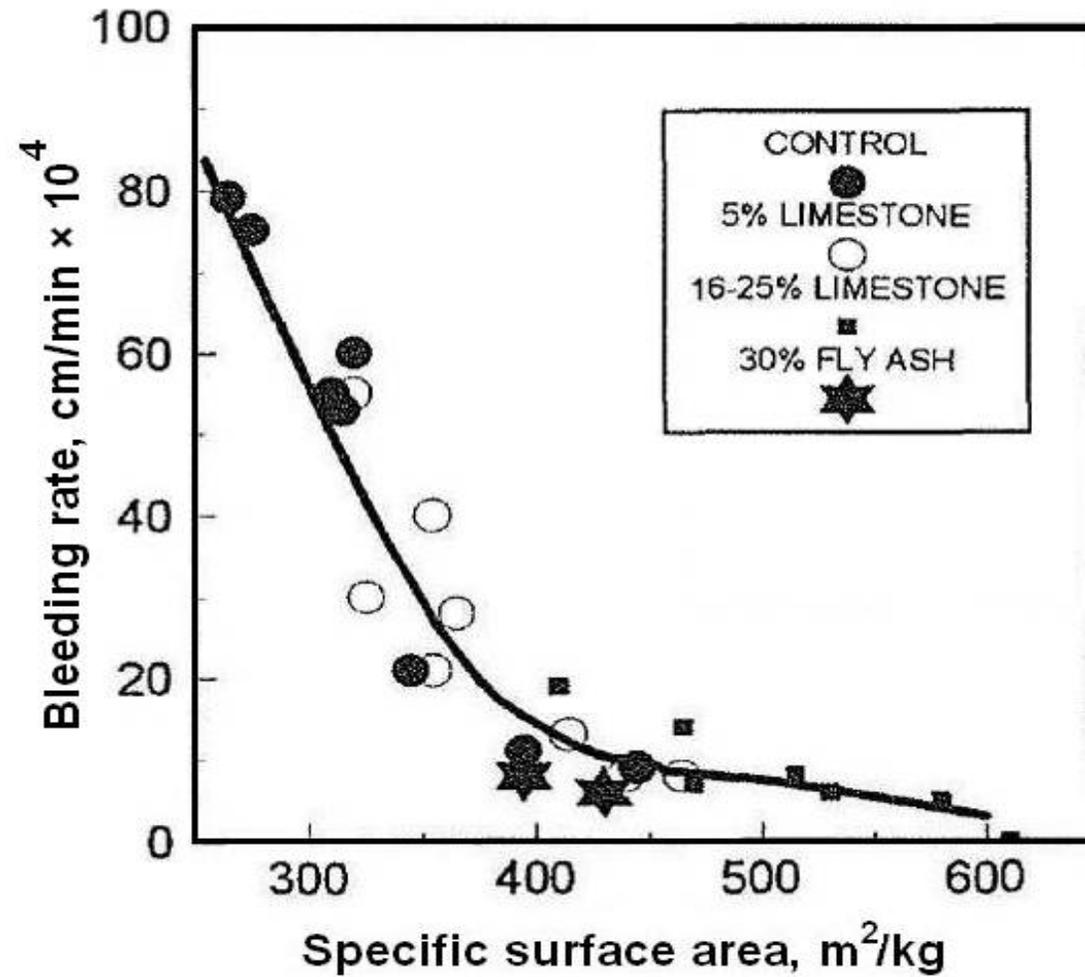


Setting time



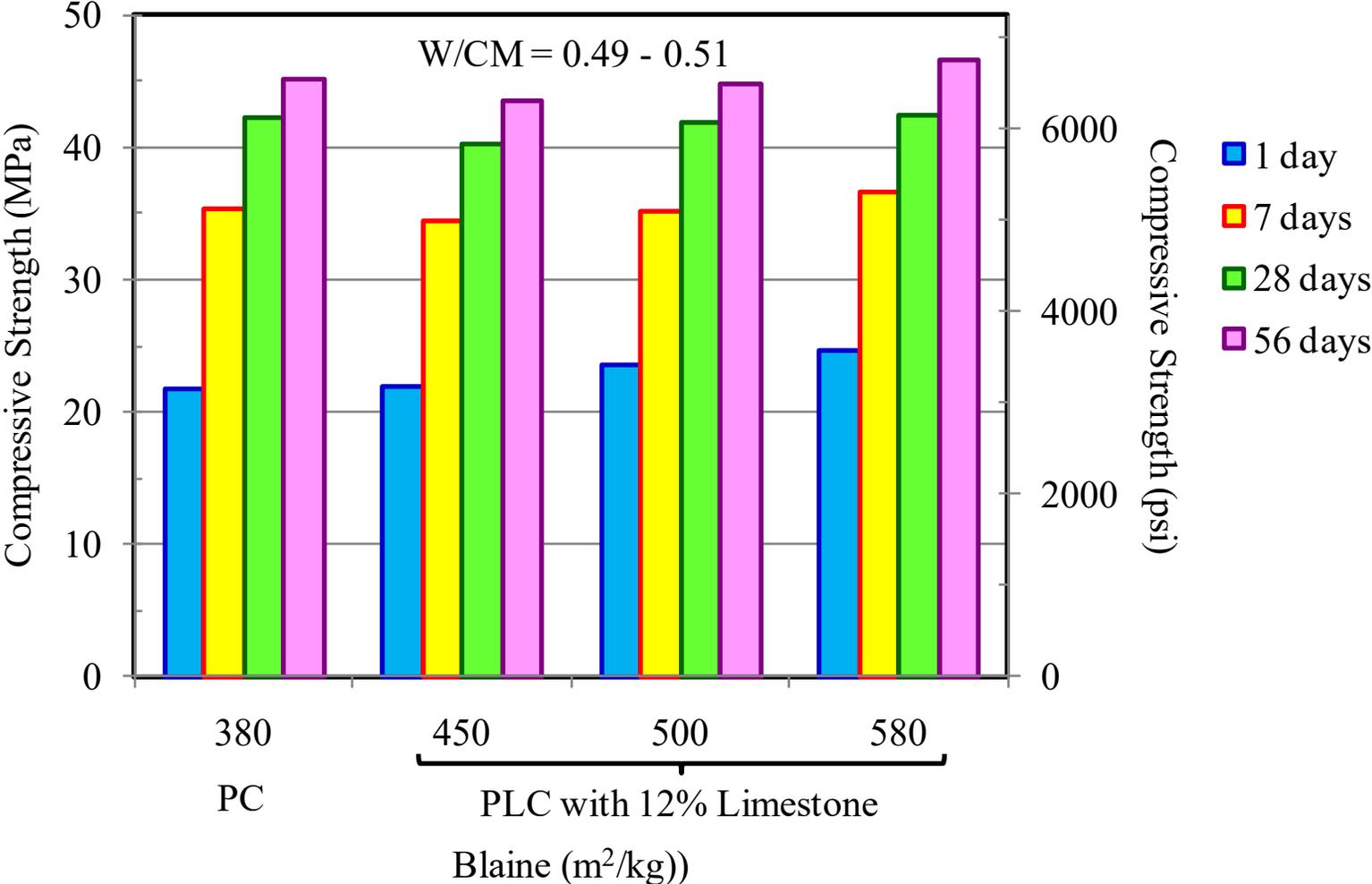
Performance: Fresh Concrete

Bleeding

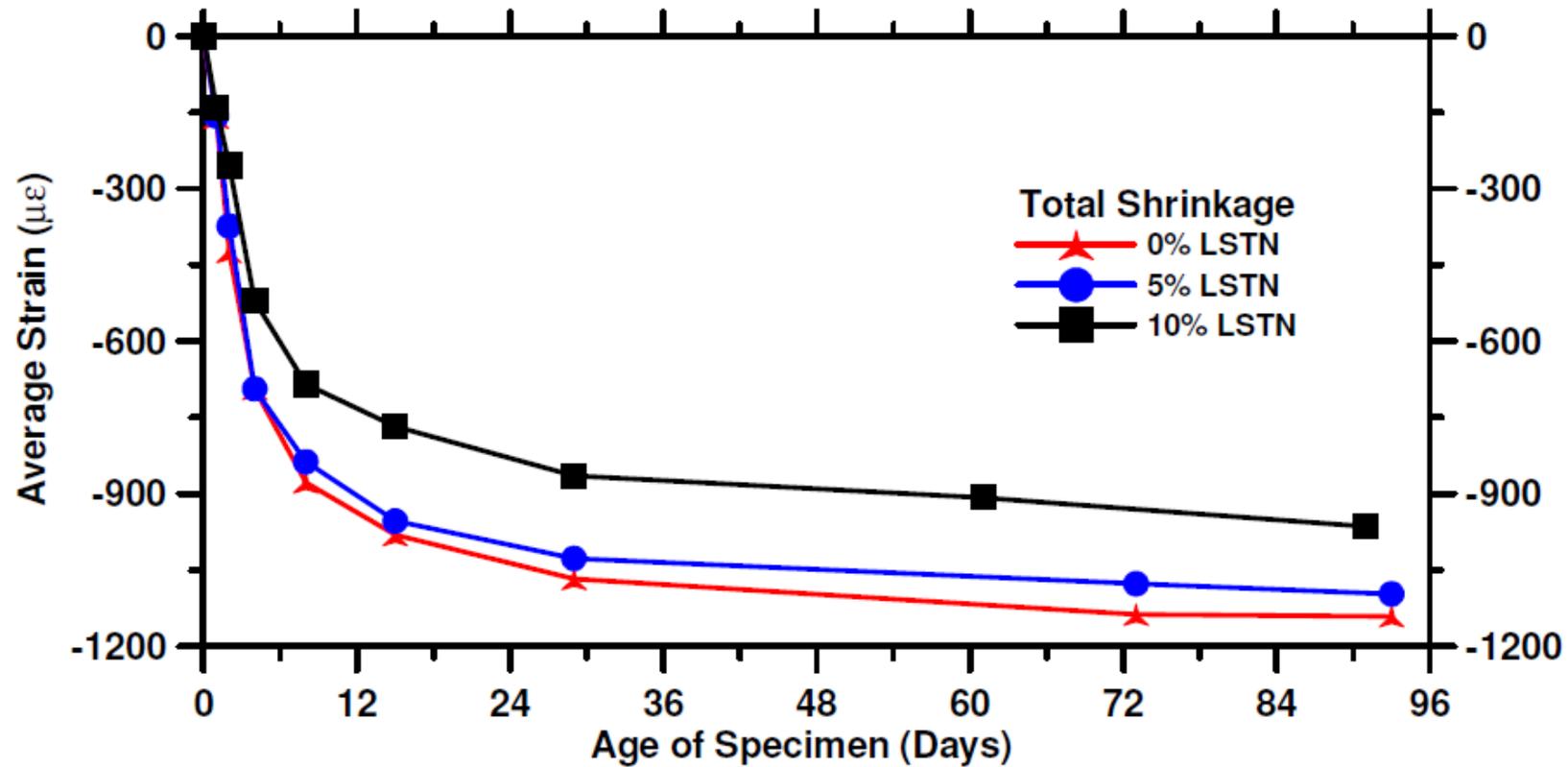


Performance: Hardened Concrete

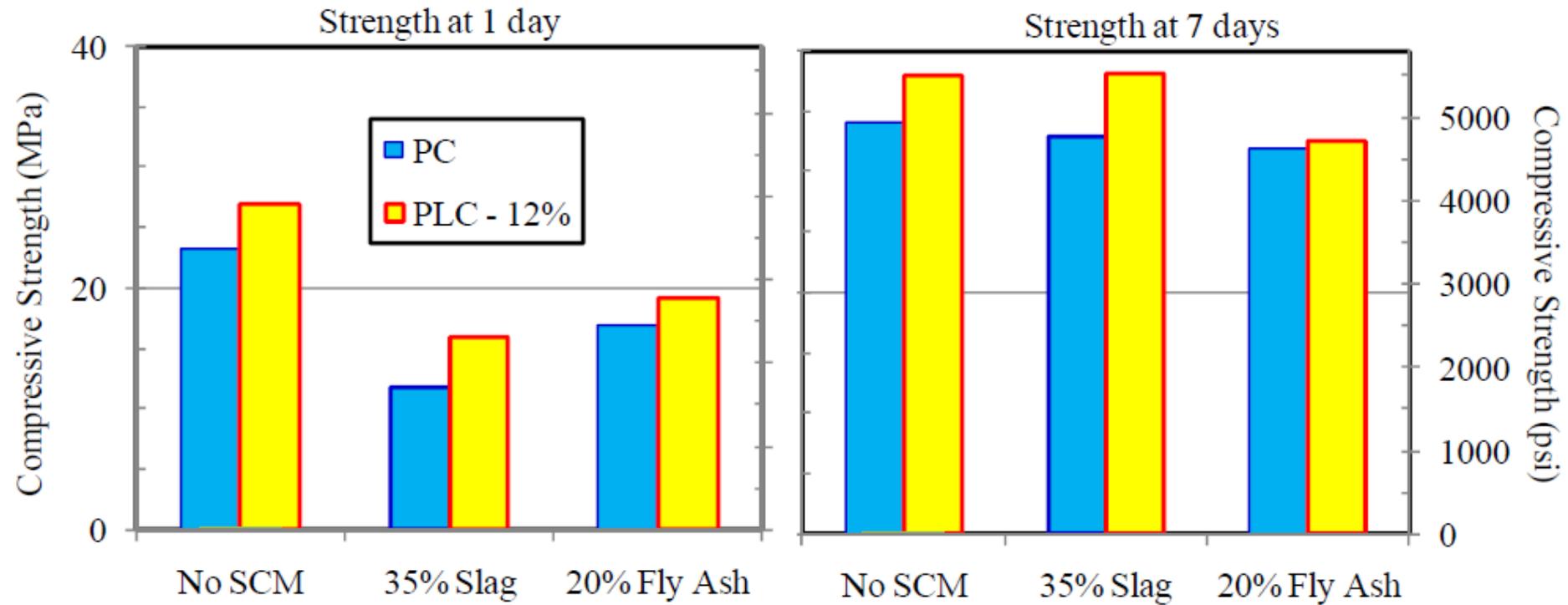
Blaine Fineness



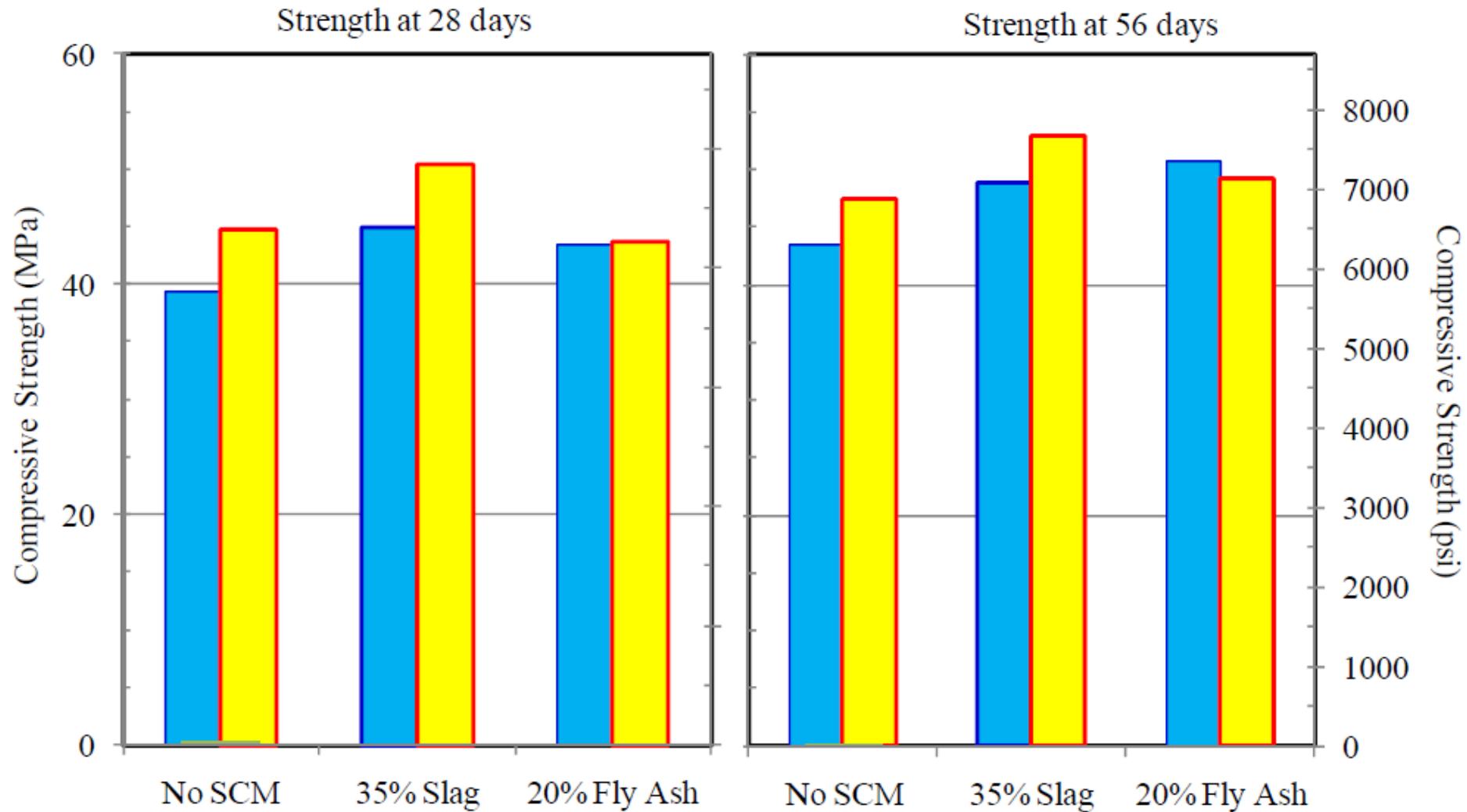
Shrinkage data



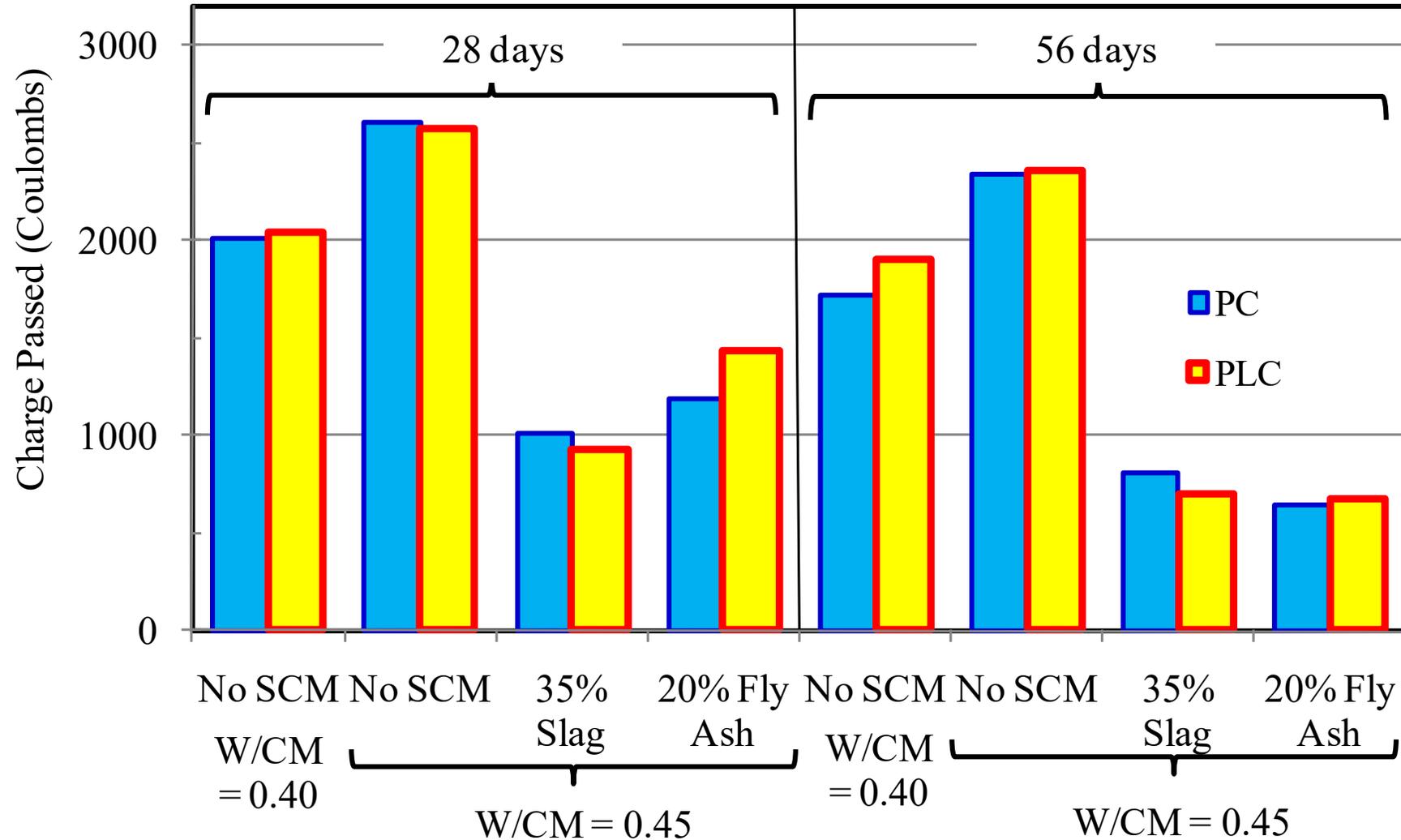
Performance: Strength



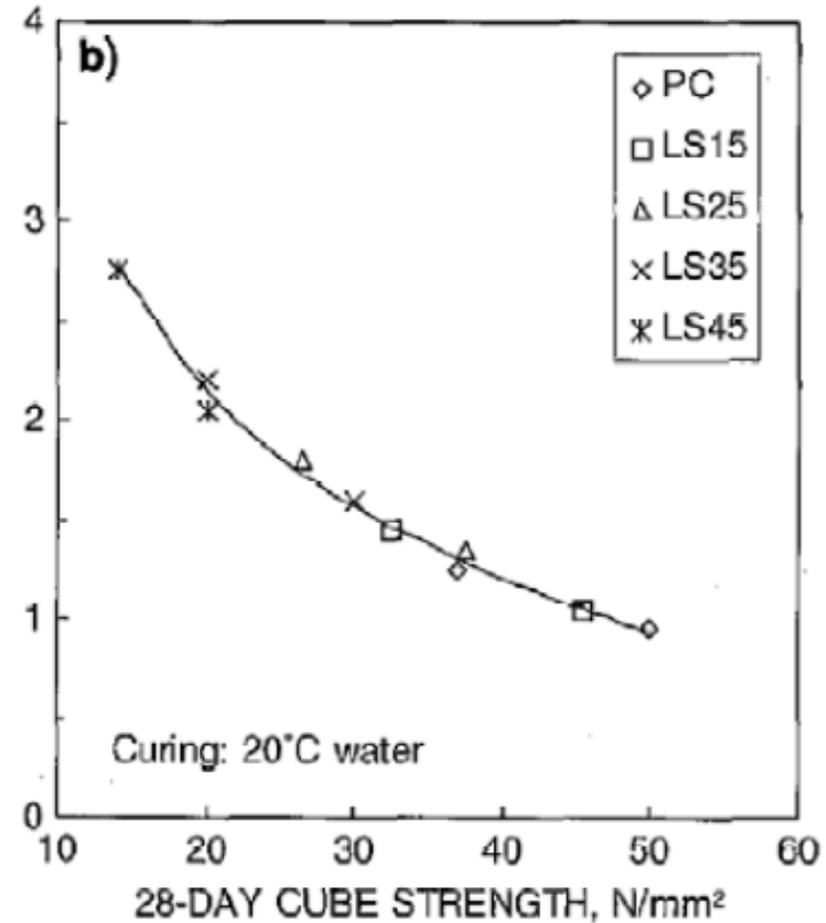
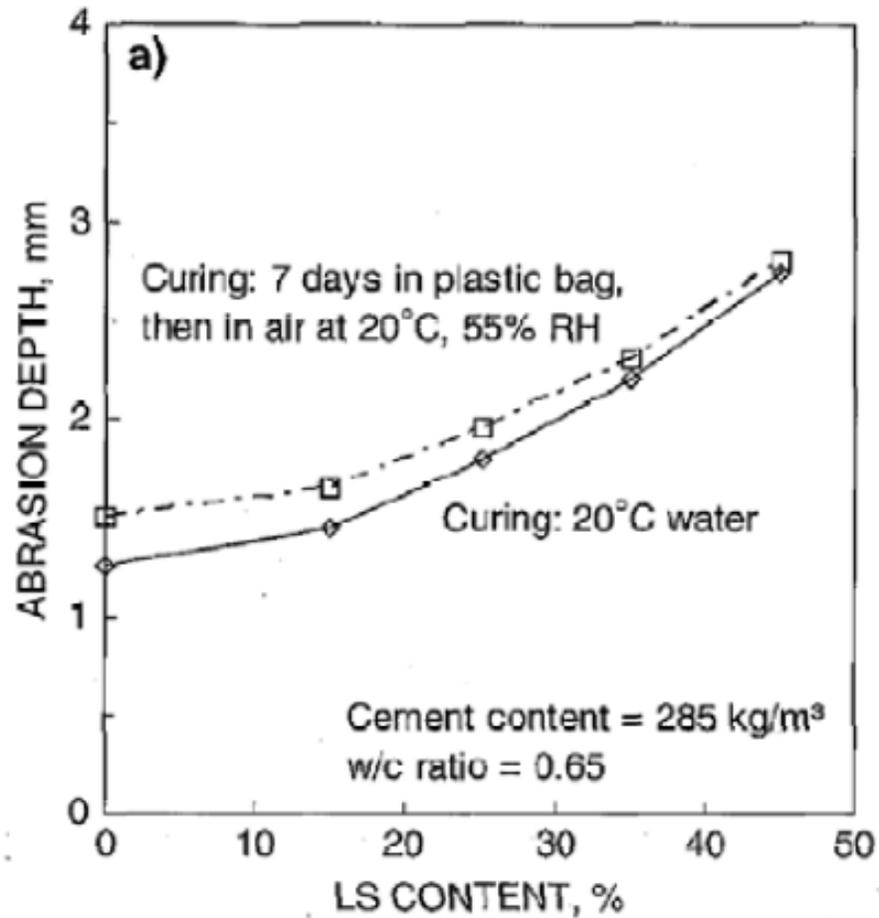
Performance: Strength



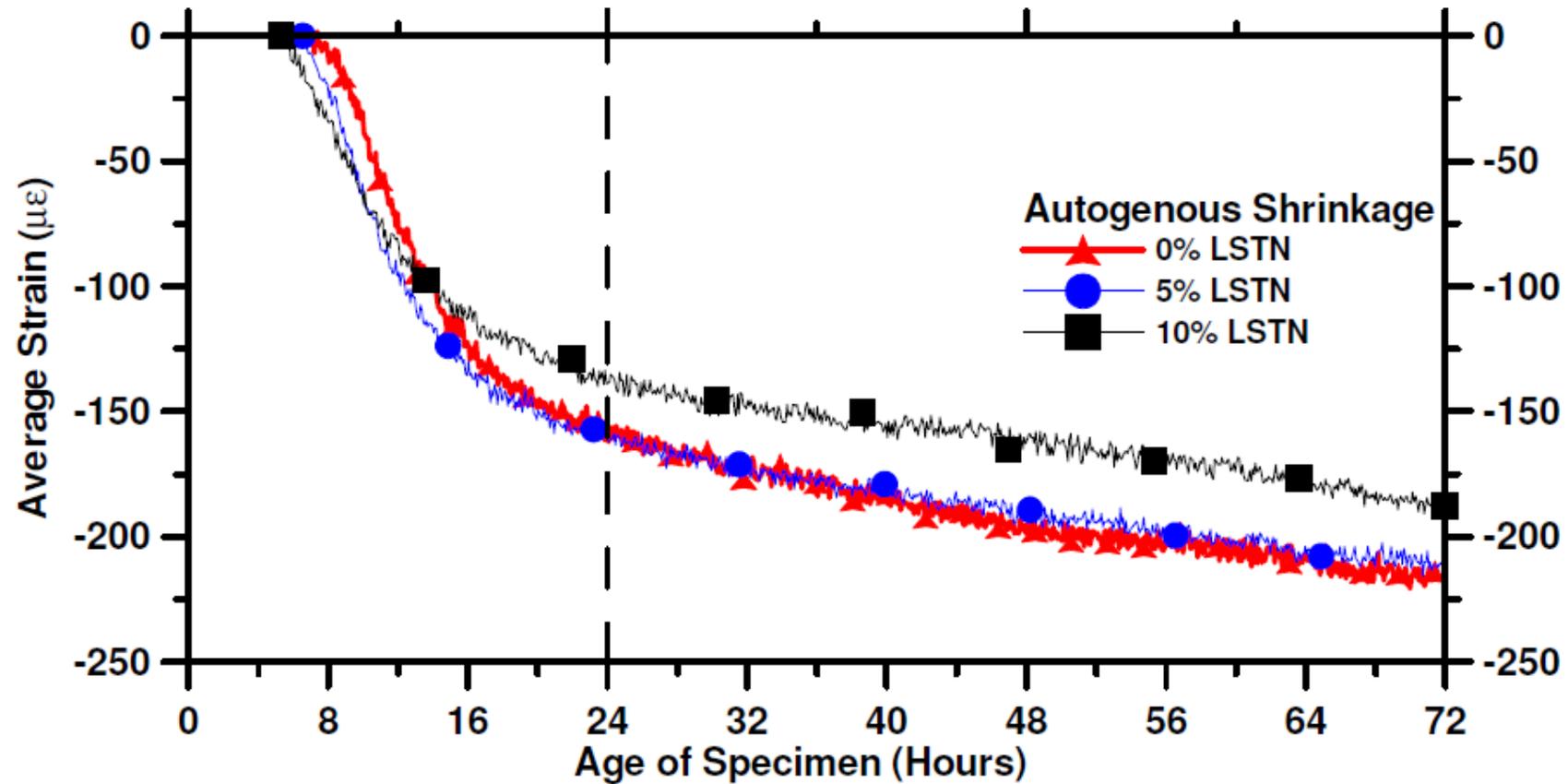
Performance: "Permeability" T277/C1202



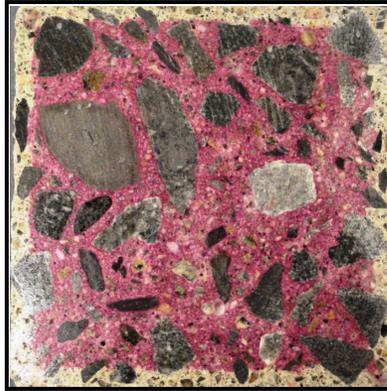
Abrasion Resistance



Autogenous Shrinkage



GU



GUL

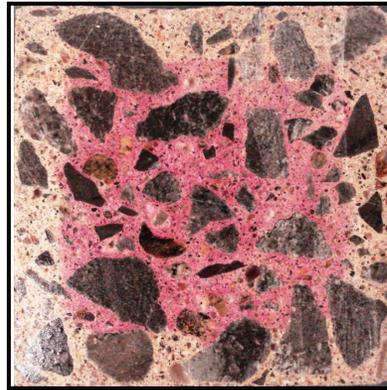


- 0.55 w/cm
- 3d curing

GU +
40% FA



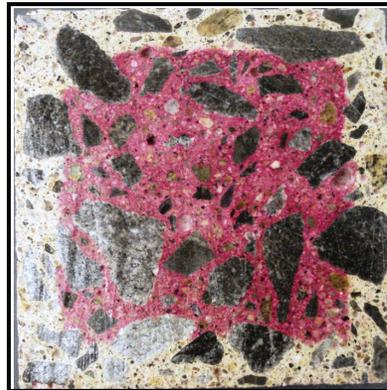
GUL +
40% FA



GU +
60% Slag



GUL +
60% Slag

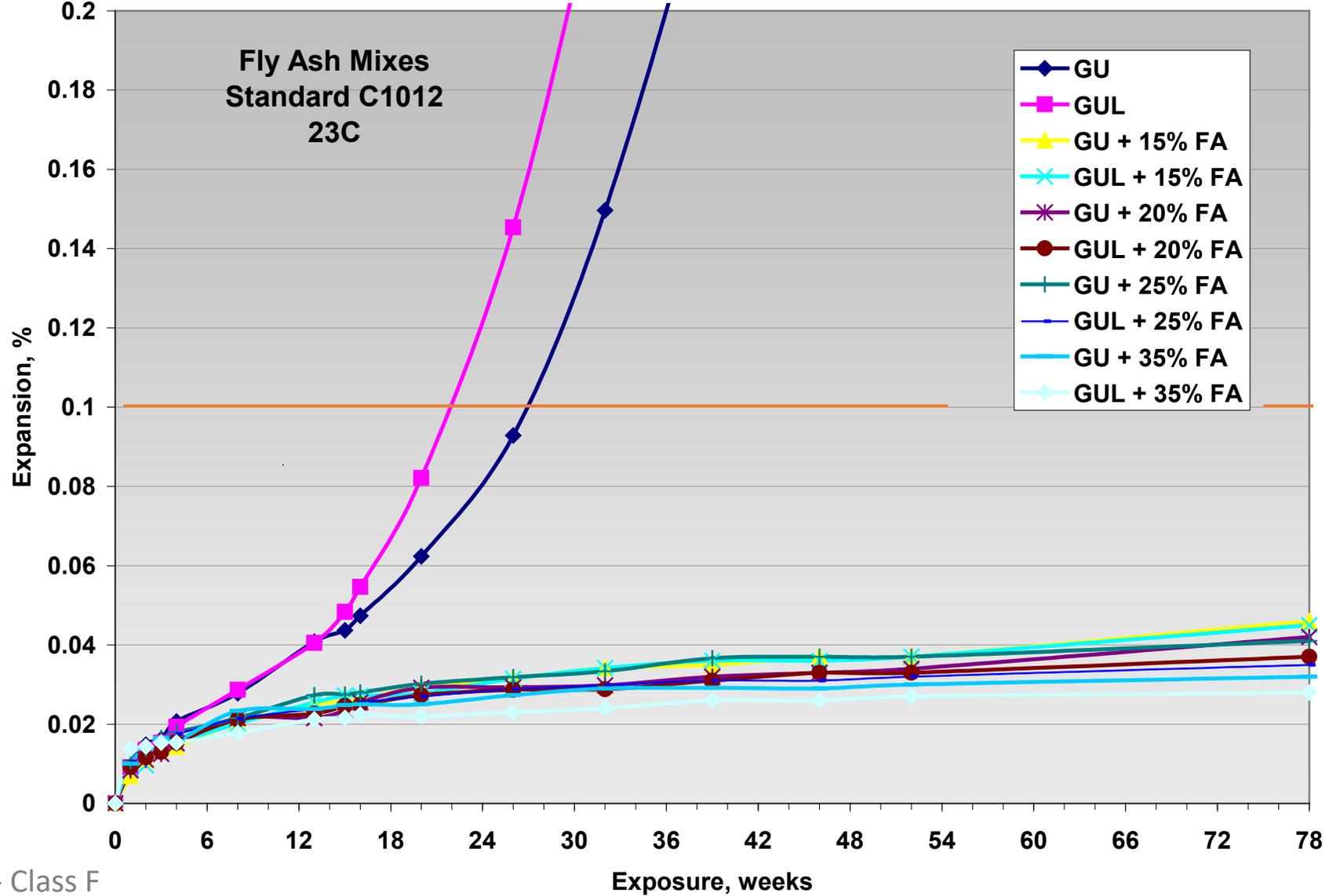


No significant difference between GU and GUL

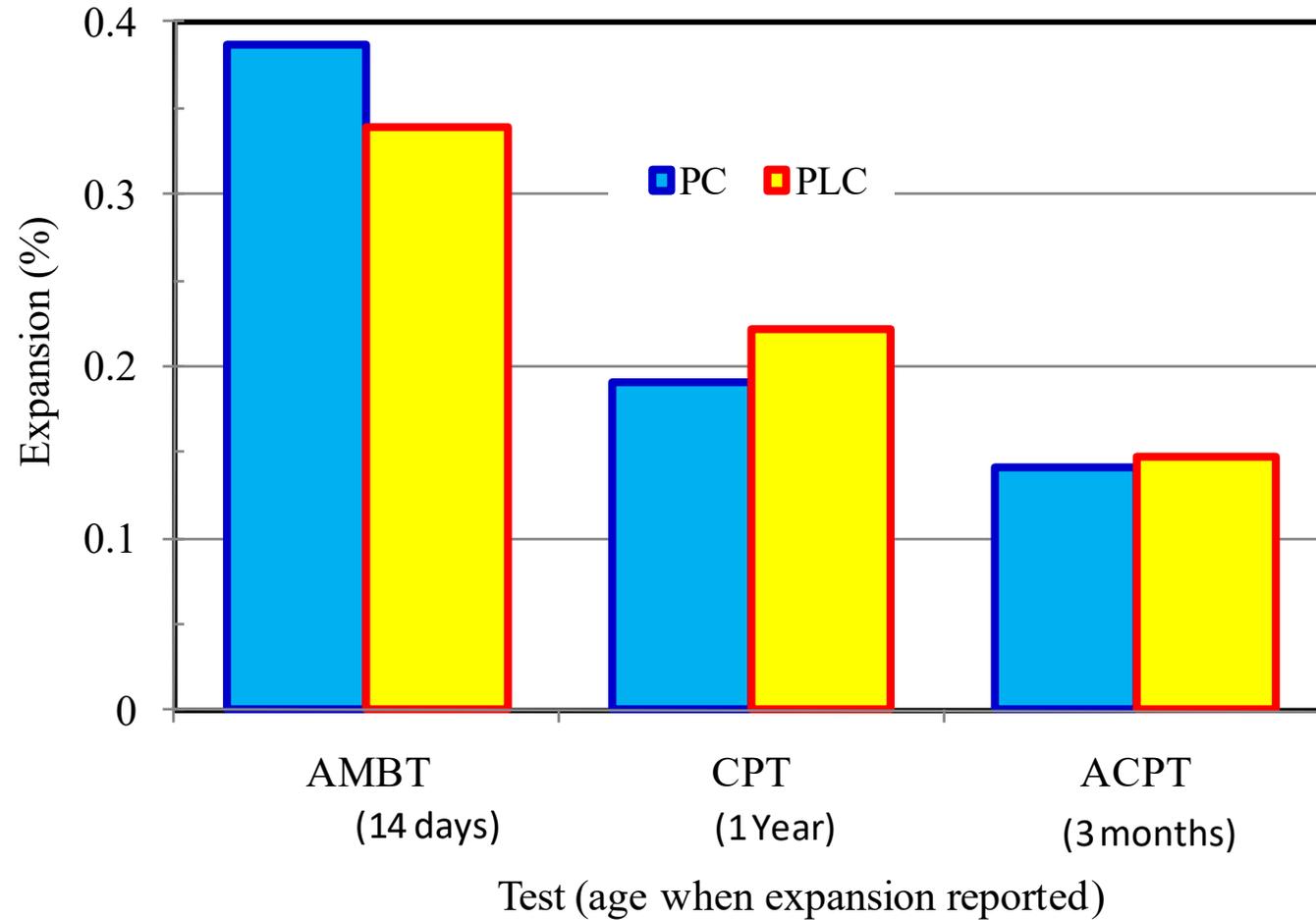
Performance: Sulfate

- Concrete sulfate resistance
 - Low water:cement ratios
 - Low C_3A content
 - Adequate cement and SCM contents
- Thaumasite sulfate attack

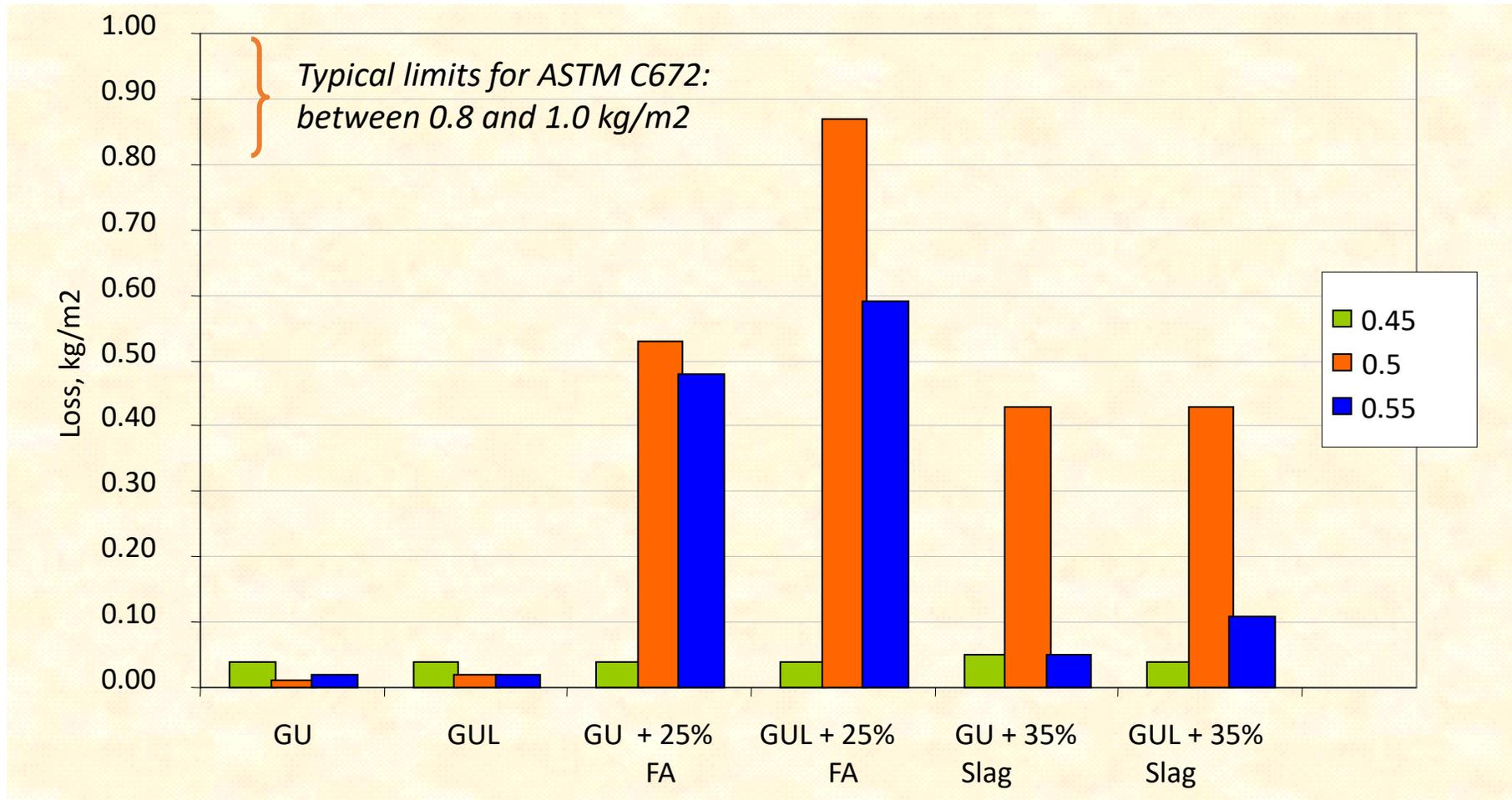
Sulfate Resistance C1012



ASR Resistance

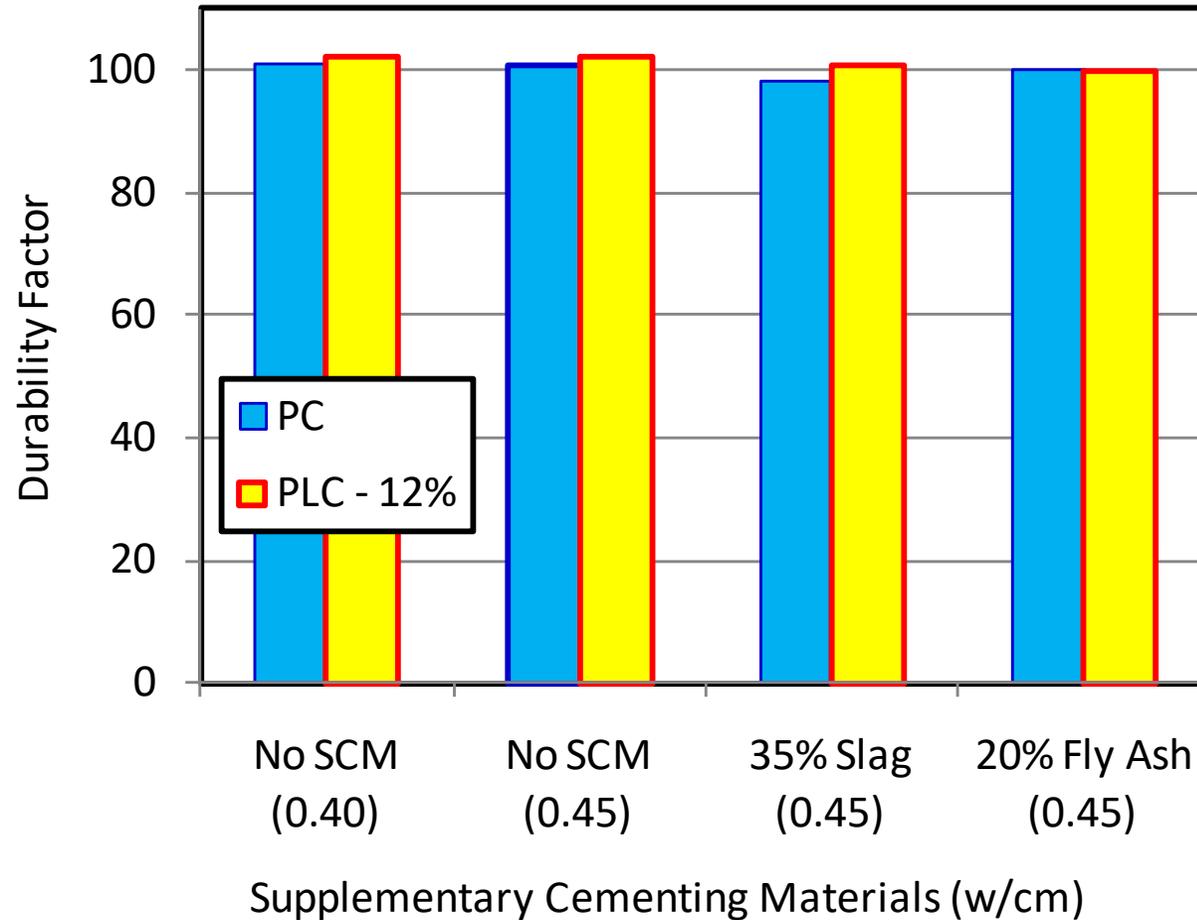


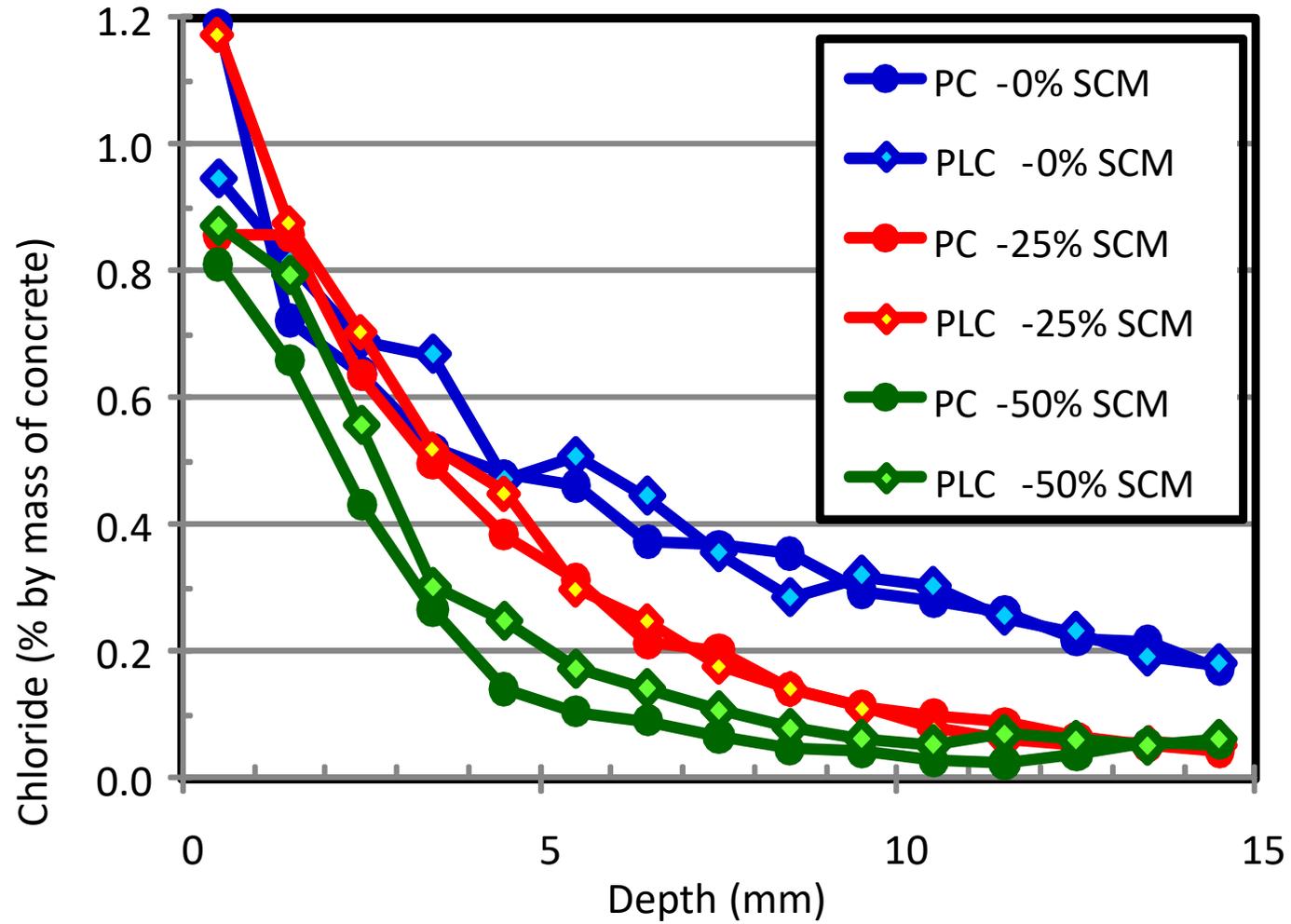
Scaling – ASTM C672



- *Lab scaling results tend to indicate impact of w/c*
- No measurable difference between GU and GUL

Freeze-Thaw Resistance (ASTM C666)

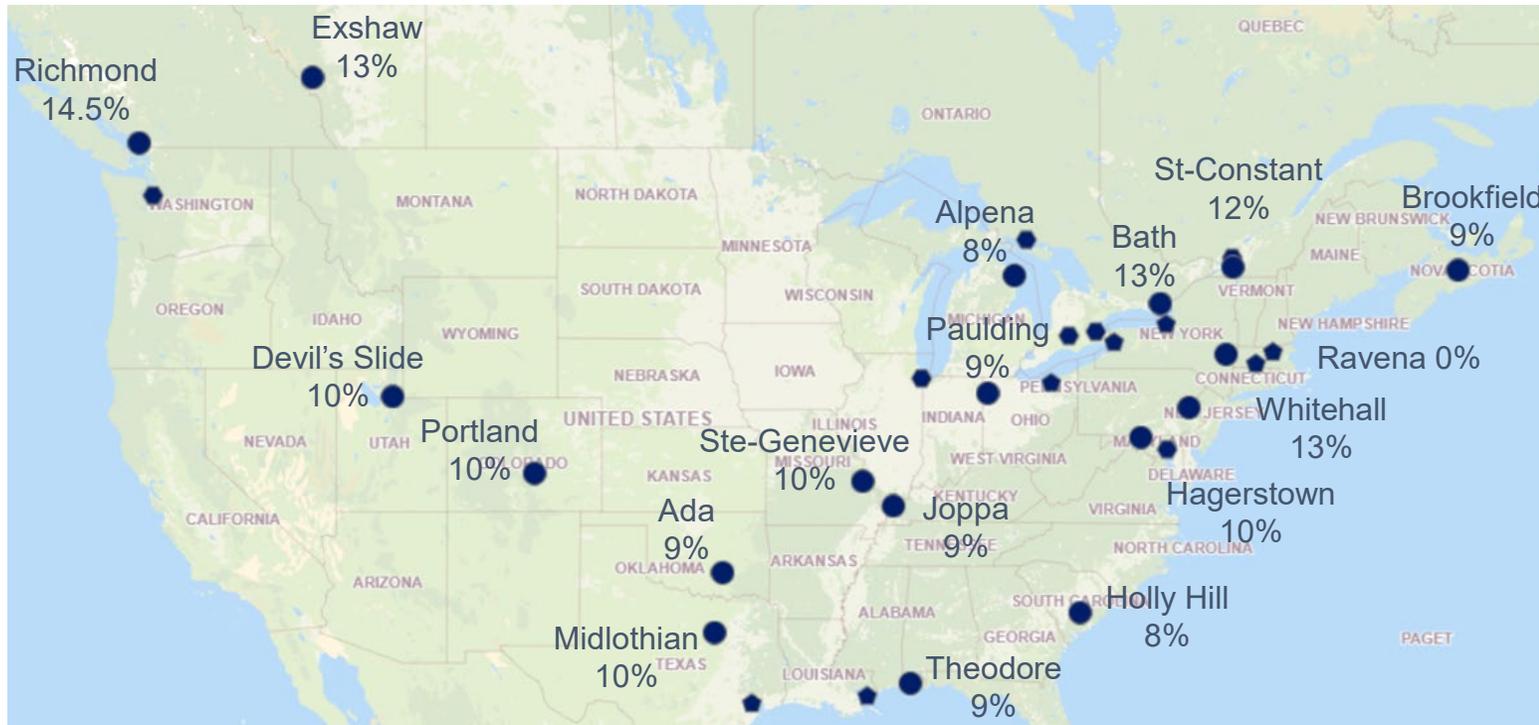




No measurable difference between PC and PLC

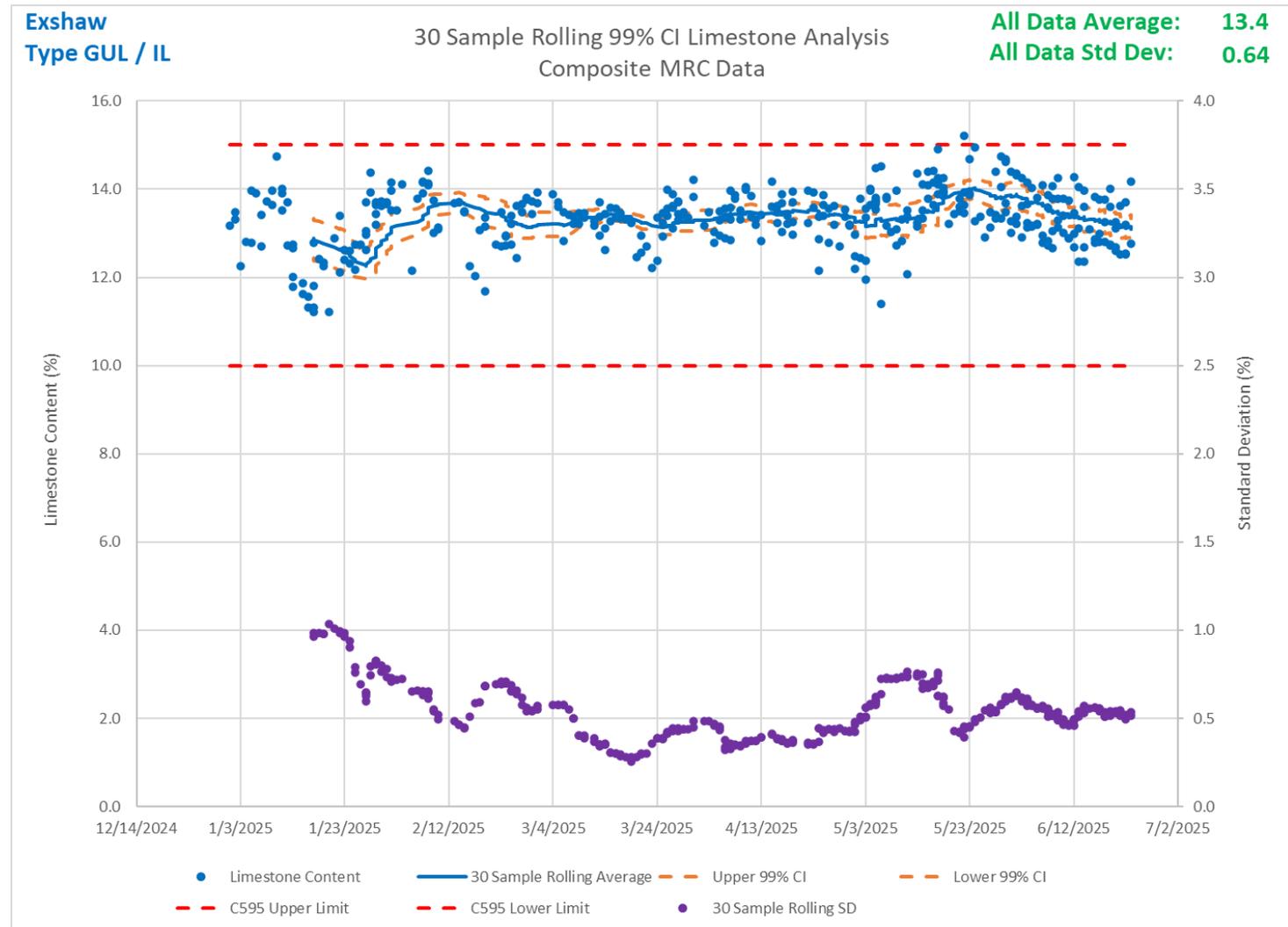
TYPE IL UPDATE

- Canadian Market Acceptance generally positive
- US pressure to transition back to Type I



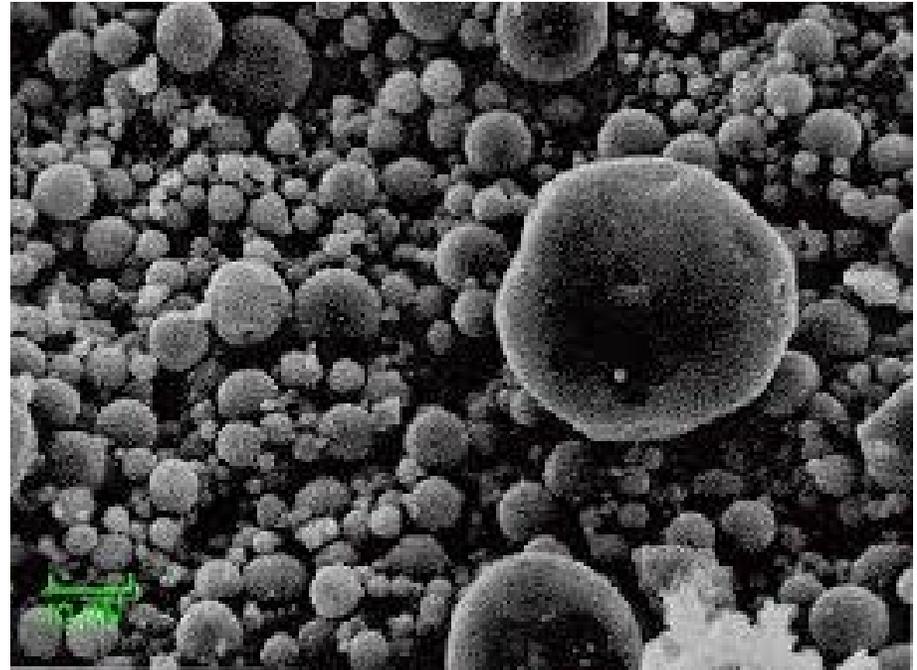
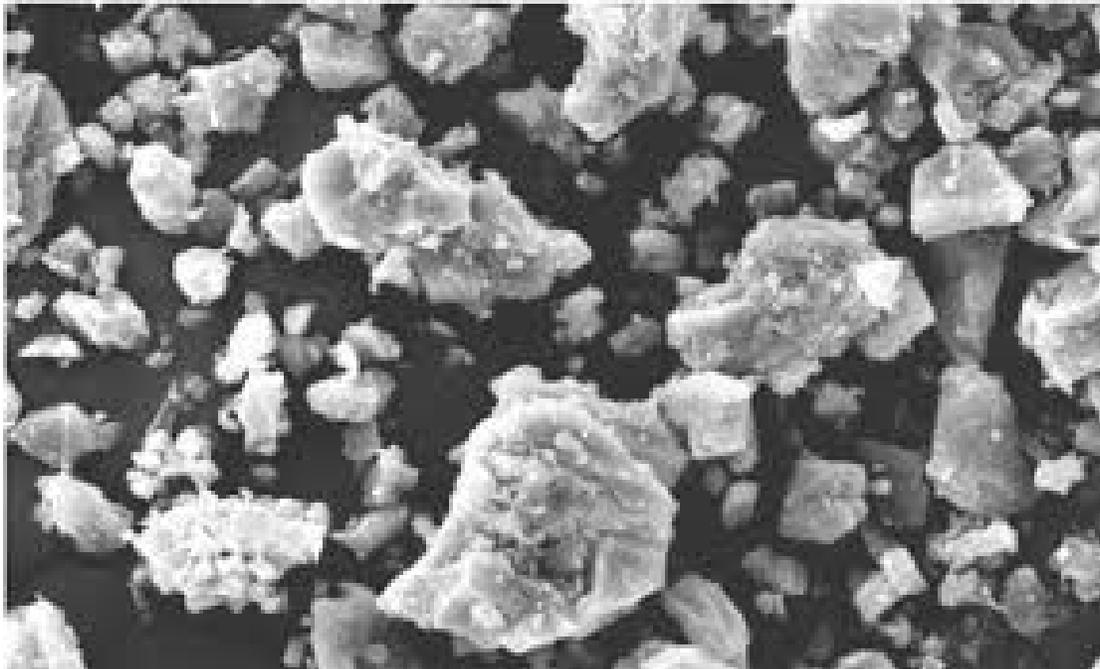
Other Reoccurring Questions

- How Consistent is the limestone Percentage?
 - ASTM +/- 2.5% and....



Other Reoccurring Questions

- Does the limestone Float to the top of the mix
 - Not more than any other cement or SCM



TYPE IL Research UPDATE

Active Participation in Industry Initiatives

NC2 (National Concrete Consortium)

- 1 year data collection survey of limestone percentage variations - How does it really impact product performance ?
- Conclusion from internal review - percentage consistency could be improved at some sites

FHWA - Oregon State Study

- 6 month: 2 Samples per month Industry Study
- Real impact of limestone variation on strength, bleed, HOH, rheology, bleed

Scaling - Oklahoma State Study

- Correlation of limestone to scaling
 - So far no correlation
 - May have other mechanisms that influence scaling

Supplementary Cementing Materials

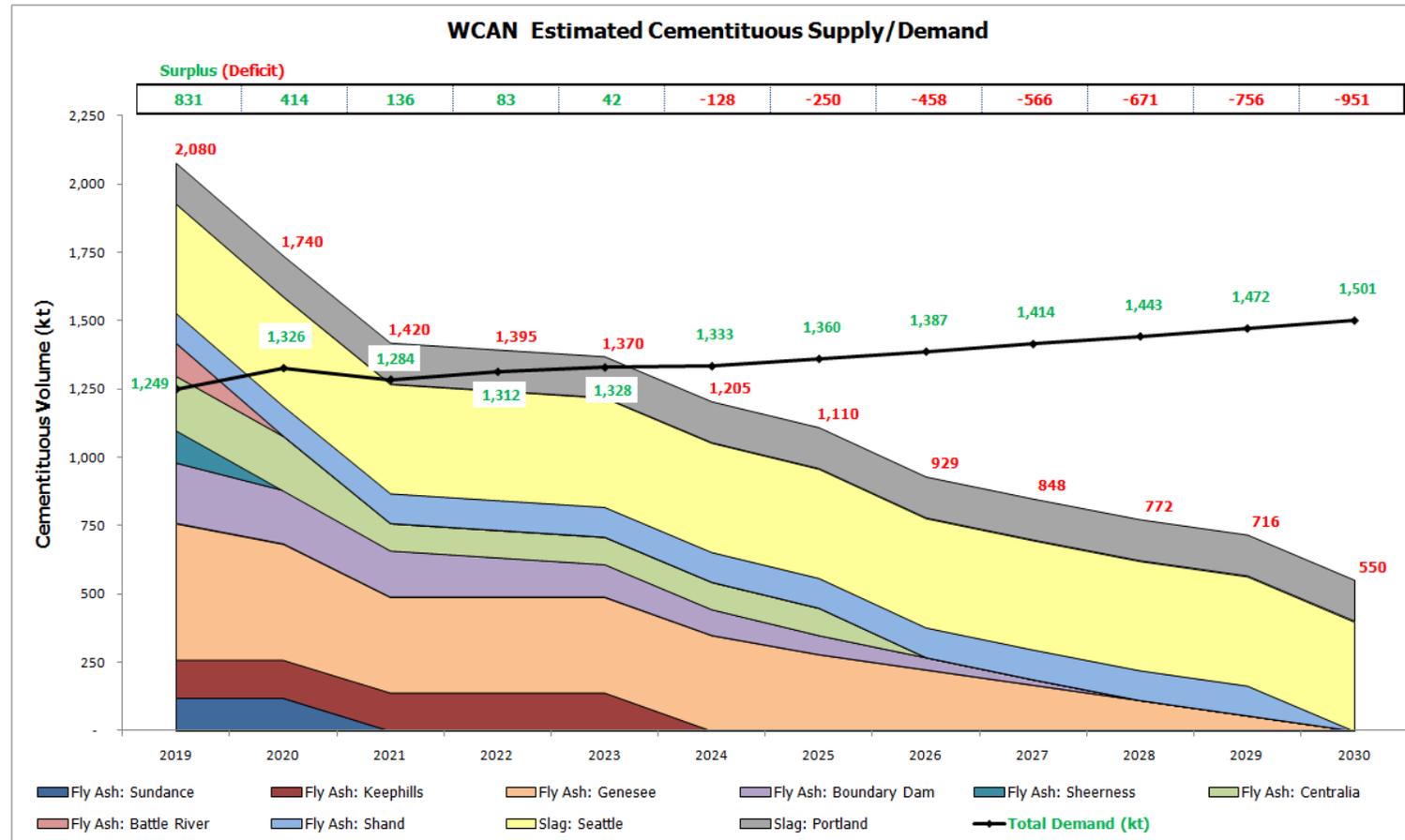
What can you expect in the Inland NW?

- Slag Cement and Flyash or a blended Slag/flyash are common.
 - For decades – Flyash was the only SCM available. Slag has been recent.
- Concrete producers may be limited by silo capacity
 - May only have cement
- The SCM they choose may be that they need to mitigate for ASR or sulfate attack
- Cost to get the material on site
- What specifications are allowing or demanding
 - I prefer specifiers use more performance-based specifications than prescriptive. Some specs use both prescriptive and performance can lead to unintended consequences.

Evaluating New Materials

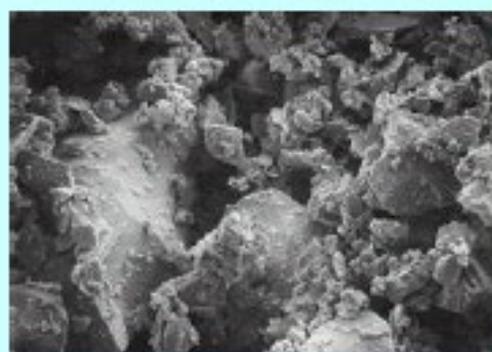
- Material producers measure performance typically
 - Water Demand, slump, air, strength at various ages
 - Set time and bleed rate are sometimes measured
- Does it improve finishability? Does it make it worse?
 - Subjective

Projected Cementitious Supply/Demand



Supplementary Cementing Materials – SCM's

- **Natural Pozzolans**
- **Fly Ash**
- **Silica Fume**
- **Slag (GGBFS)**



HOW IS SLAG CLASSIFIED?



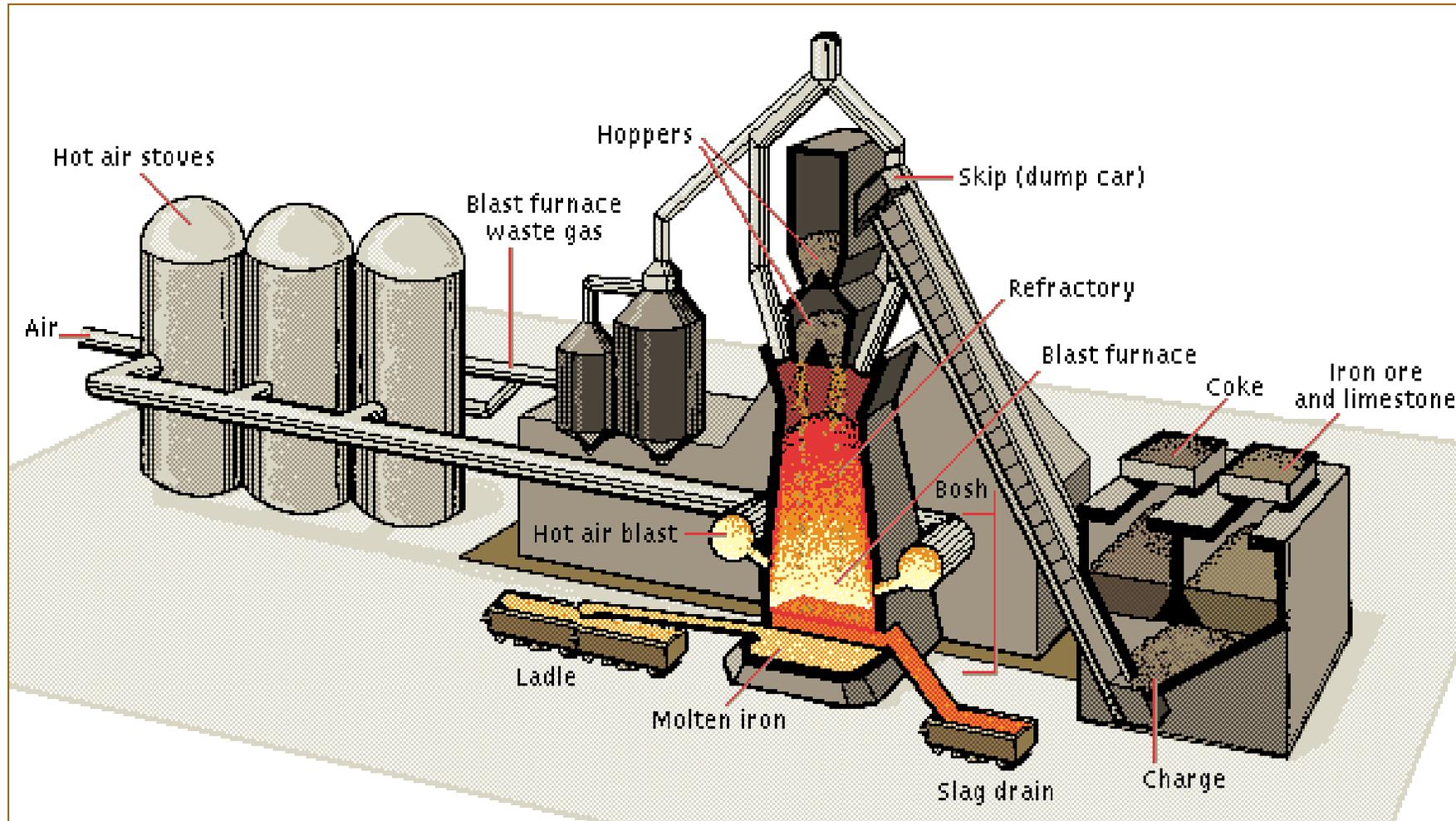
Definitions

GROUND GRANULATED BLAST FURNACE SLAG (GGBFS)....

The new name **SLAG CEMENT** has been adopted by the SLAG CEMENT ASSOCIATION (SCA). **SLAG CEMENT** is a hydraulic cement that will hydrate and gain strengths independent of other materials.

Iron/Slag Manufacturing

The Blast Furnace







Granulated Slag

- **Molten blast furnace slag is rapidly chilled by immersion in water or quenching.**
 - Glassy, granular material.
 - High glass content (above 90%)
 - Raw material that is ground in a roller or ball grinding mill to produce **Slag Cement**.

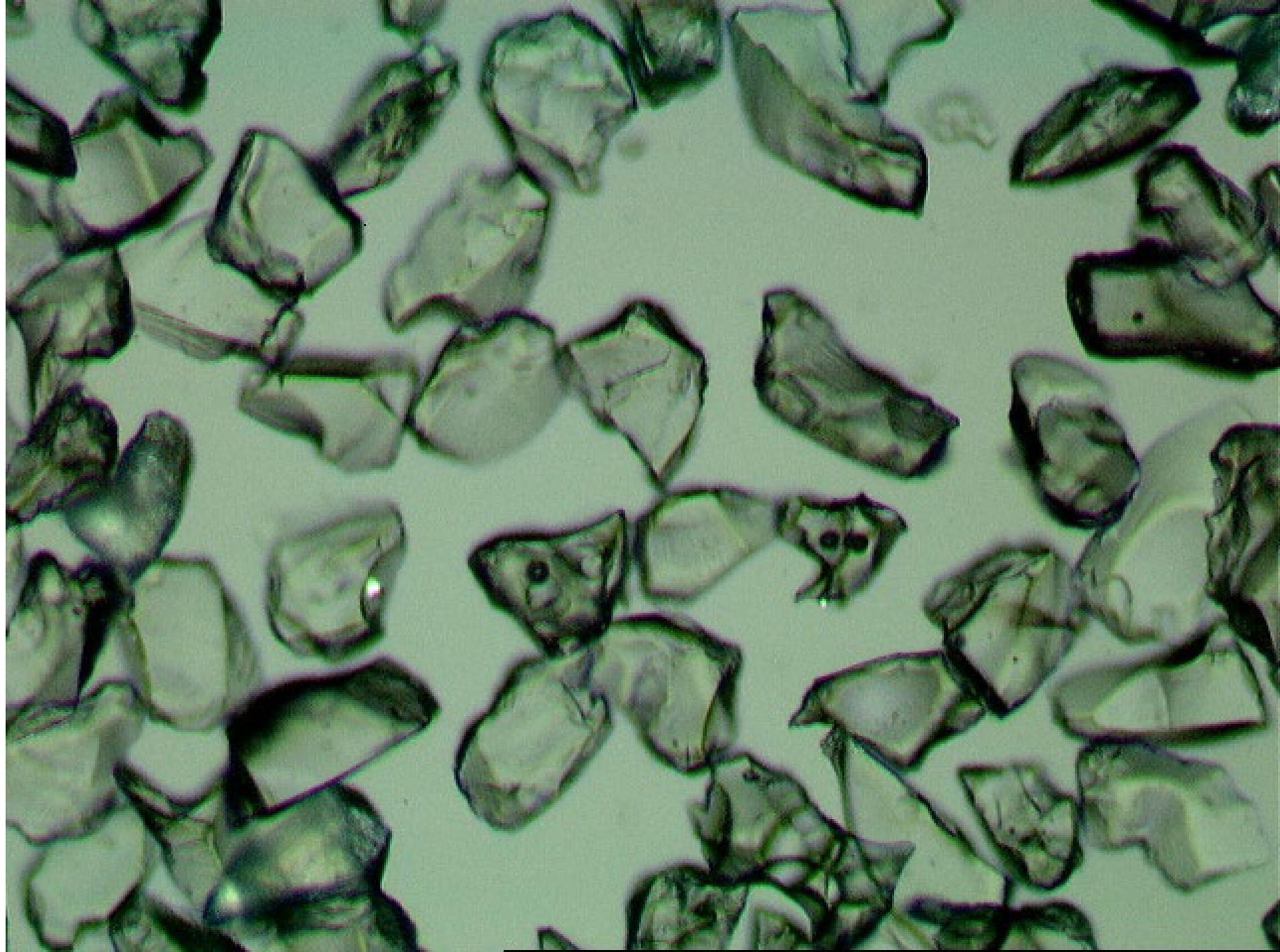




Slag Dryer







Slag-activity Index

ASTM C989 - AASTH M302

| | Min. 7-day <u>% of Reference</u> | Min. 28-day <u>% of Reference</u> |
|-----------|-------------------------------------|--------------------------------------|
| Grade 80 | ---- | 75 |
| Grade 100 | 75 | 95 |
| Grade 120 | 95 | 115 |

Seattle NewCem 92

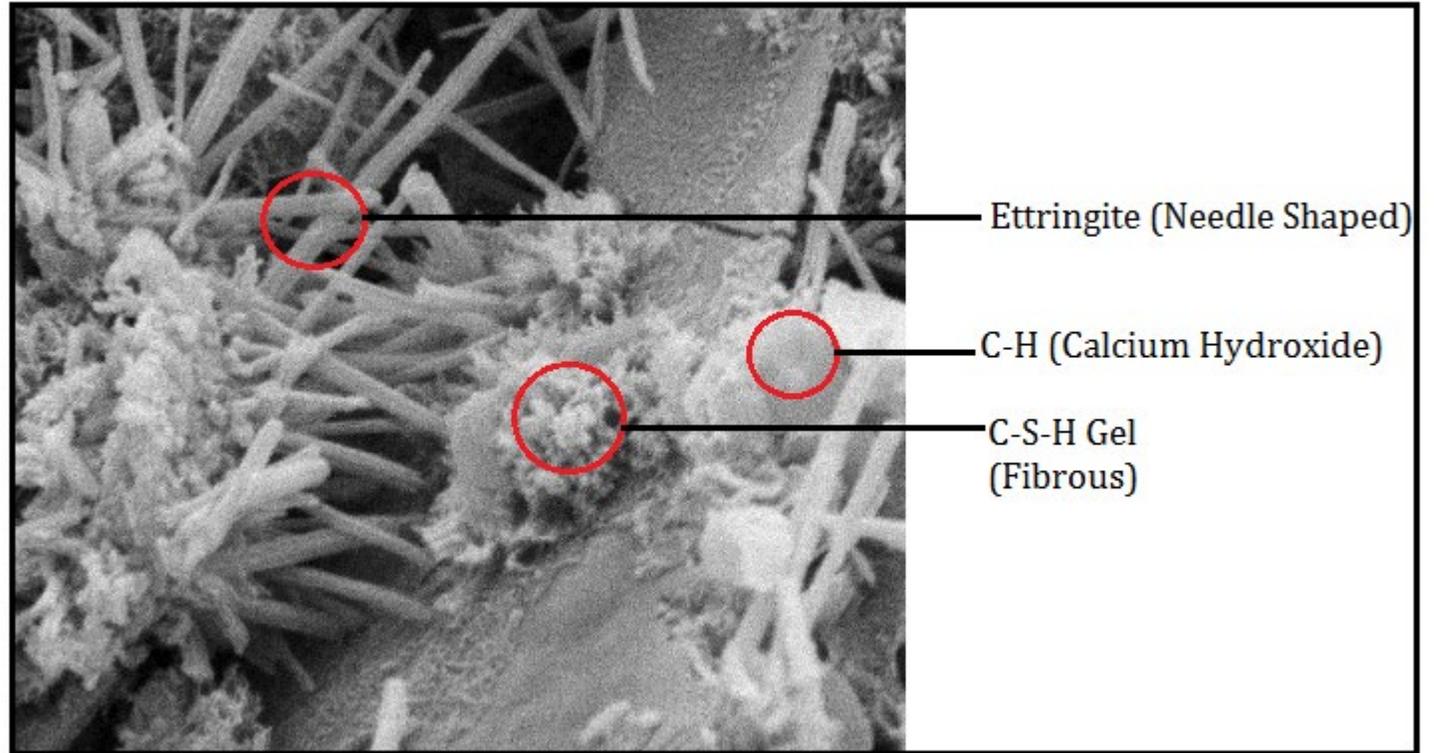
118

Grade 100

ASTM C-595 Blended Cements

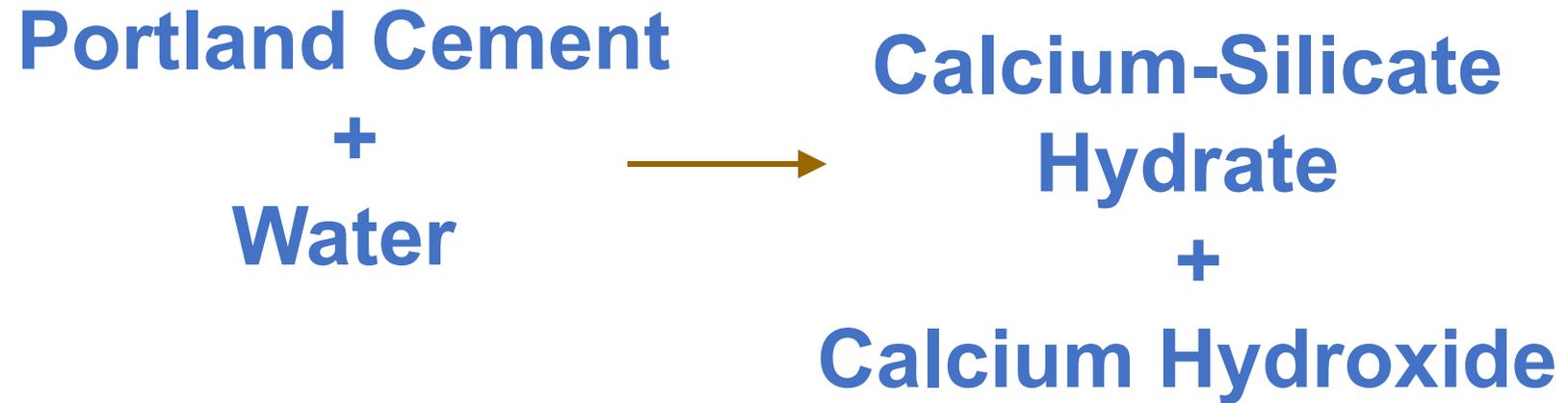
- Blended Similar to Type IP(X)
 - Inter-ground or Pneumatically Blended
- Slag Blend – Type IS(X)
 - Currently Sold Locally as Type IS(30)
 - Low Alkali – Below 0.60%

Why does Slag Cement
produce better Concrete?

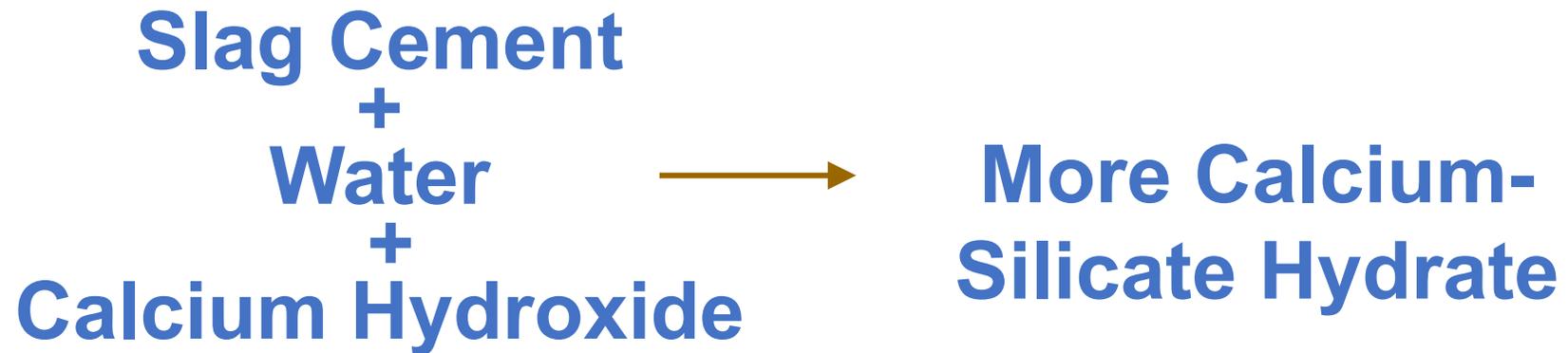
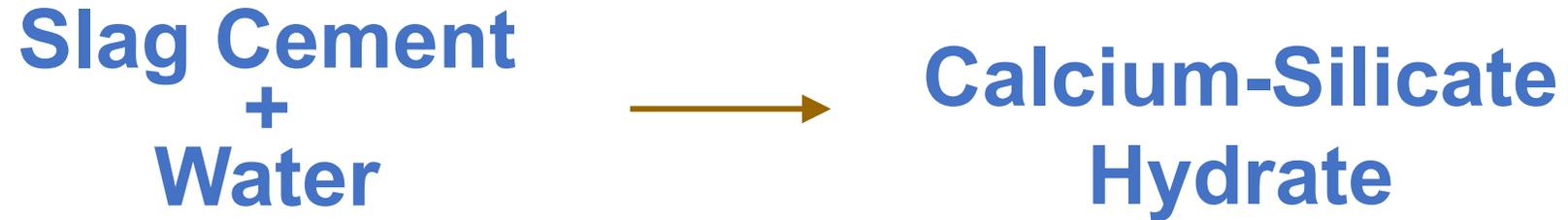


First: The “hardening” of Portland Cement is the Chemical Process of hydration.

Portland Cement Reaction



Slag Cement Reaction



From Portland Cement



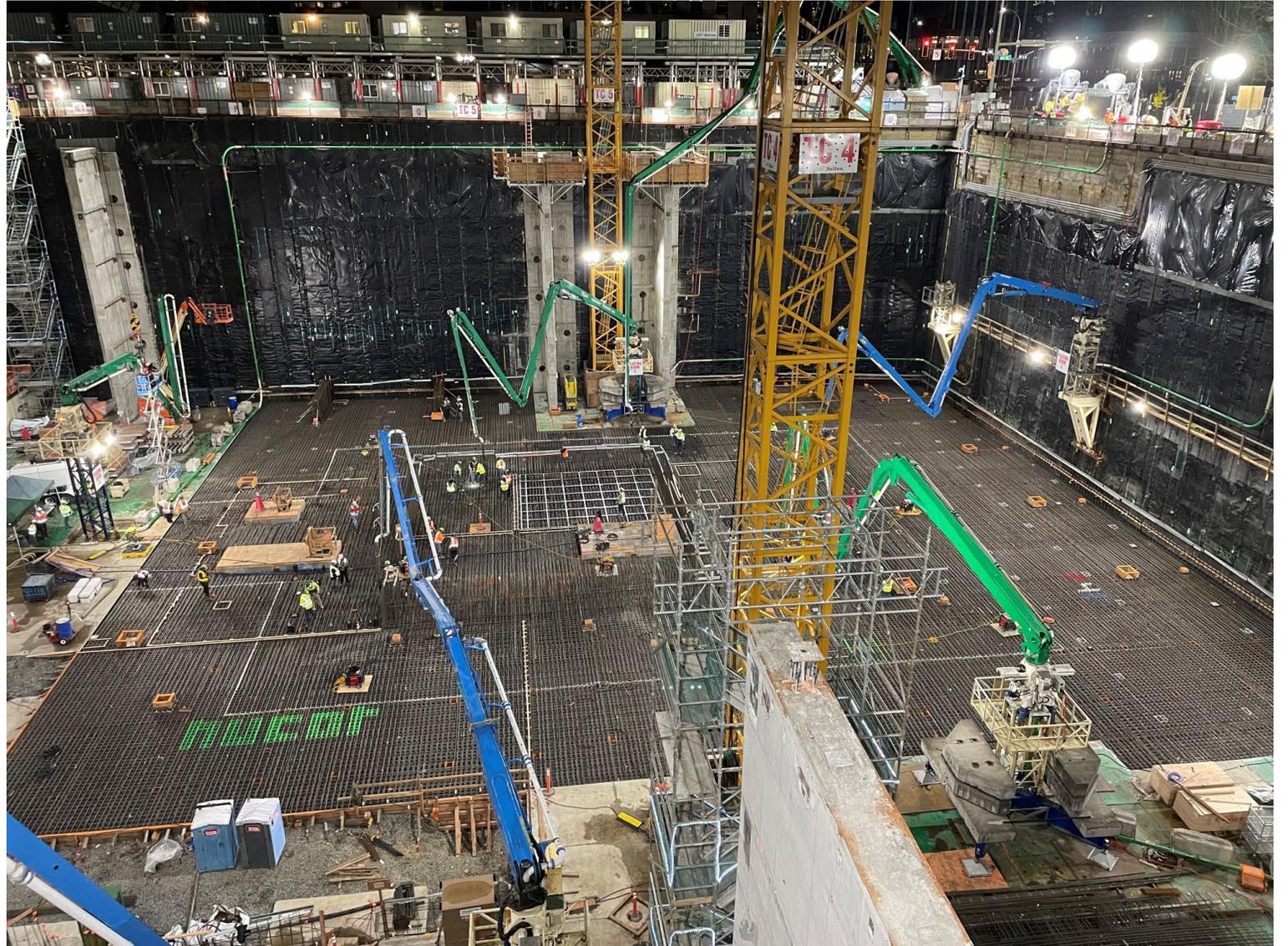
Plastic Properties

- Better slump retention
- Enhanced workability
- Easier consolidation
- Improved pumpability
- Superior finishability
- Consistent air content

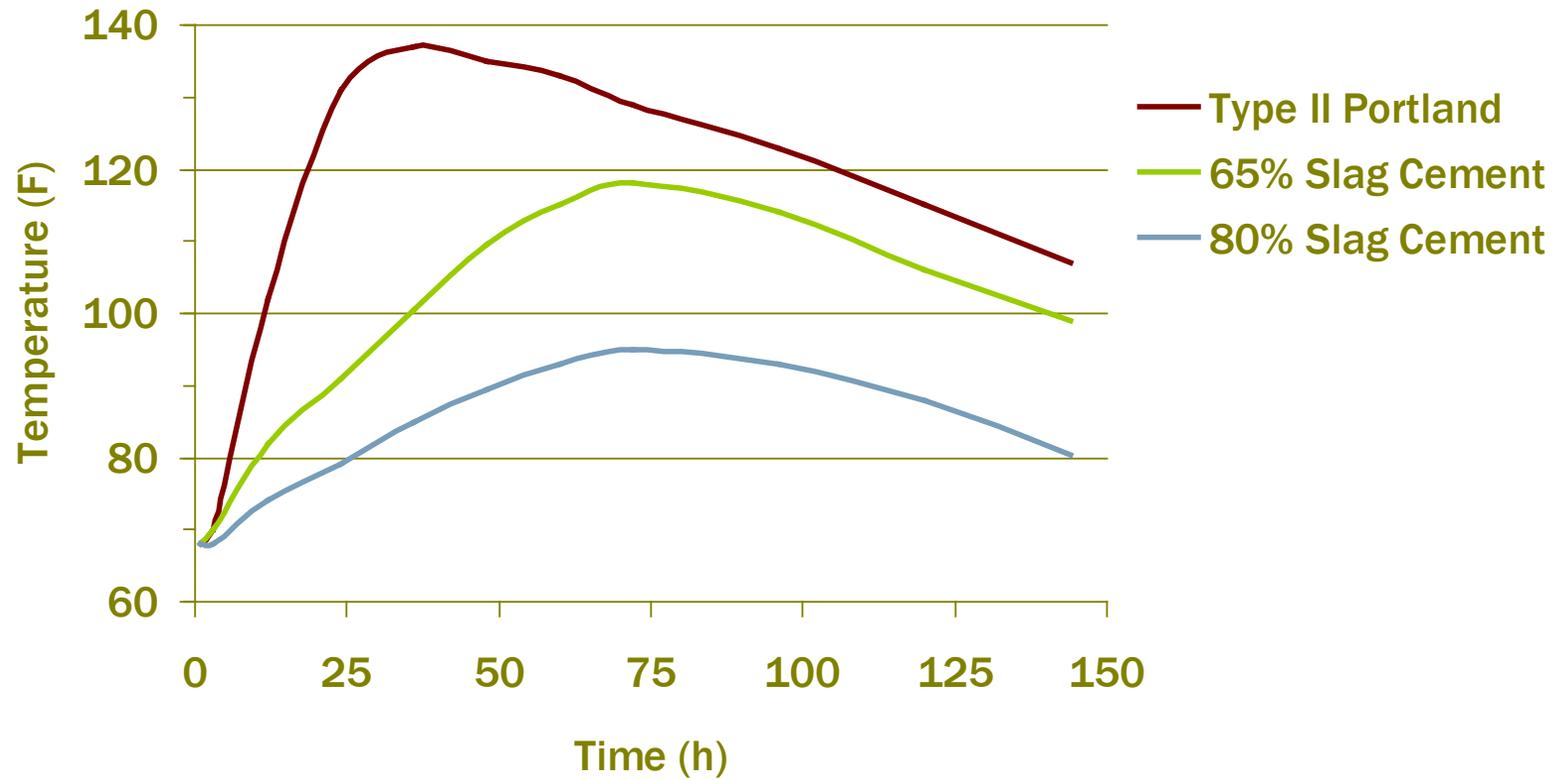
Hardened Properties

- Improved Compressive and Flexural Strengths
- Reduced Permeability
- Improved Corrosion Resistance
- Increased Resistance to Sulfate Attack and Alkali-Silica Reaction
- Reduced Heat Generation

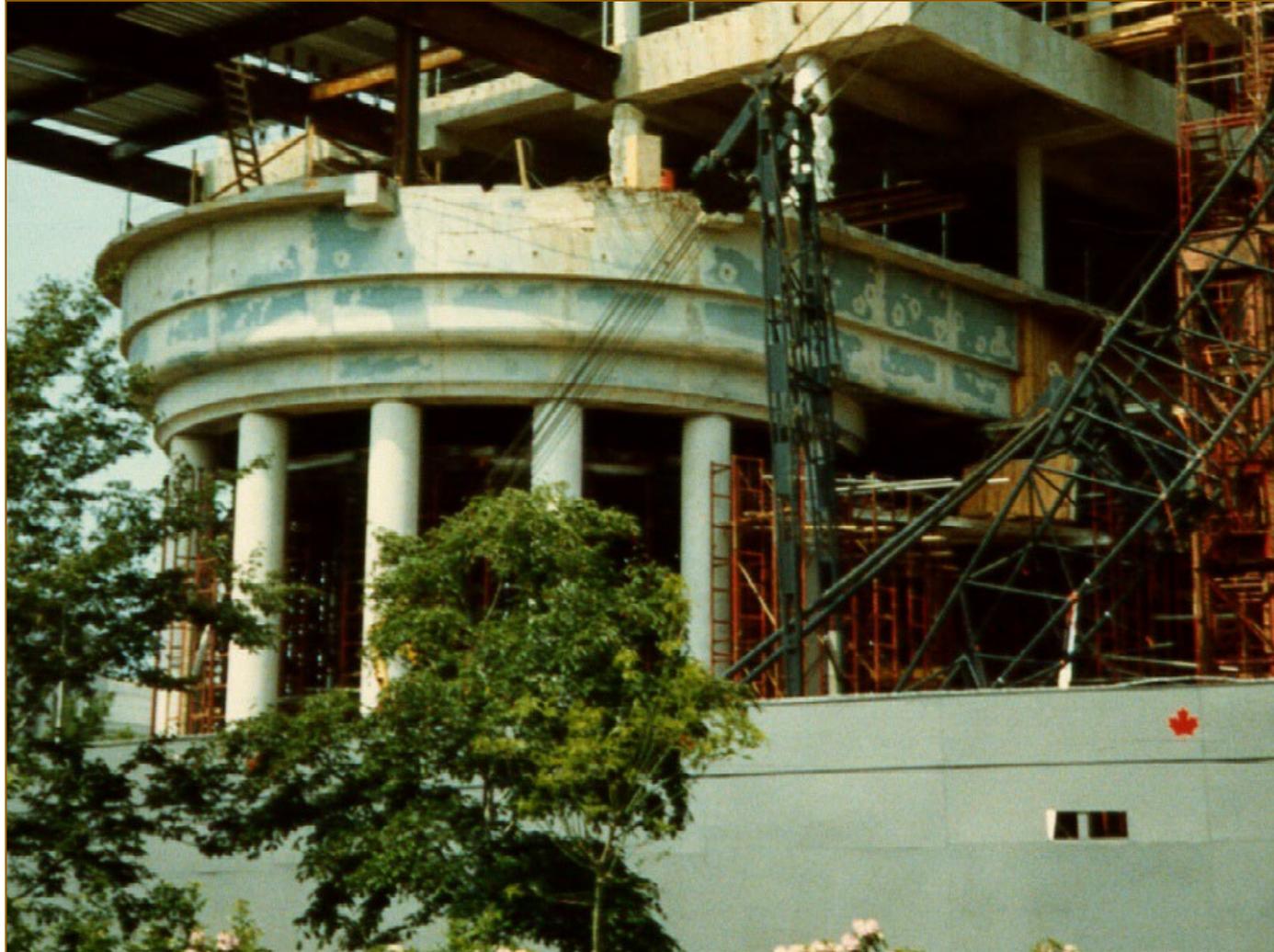
Mass Concrete



Effect of Slag Cement on Heat Rise in Concrete



“Greening”



“Greening”



Slag Cement And The Environment

Environmental Benefits

- Slag cement makes concrete “greener”
 - Reduced energy demand
 - Reduced greenhouse gasses
 - Reduced use of virgin materials
 - Reduced disposal/storage
 - Reduced urban heat island effects
 - Reduced lighting requirements
 - Reduces emissions at steel plant
 - Helps meet environmental initiatives and mandates

Coal Ash / Reclaimed Ash



Benefits of Fly Ash

- Improves the quality of concrete
- Improved workability/reduces bleeding
- Spherical shape helps fill voids in the mix
- Extends set times - good summer “mix”
- Natural fit with NewCem & cement
- Complements the range of binders

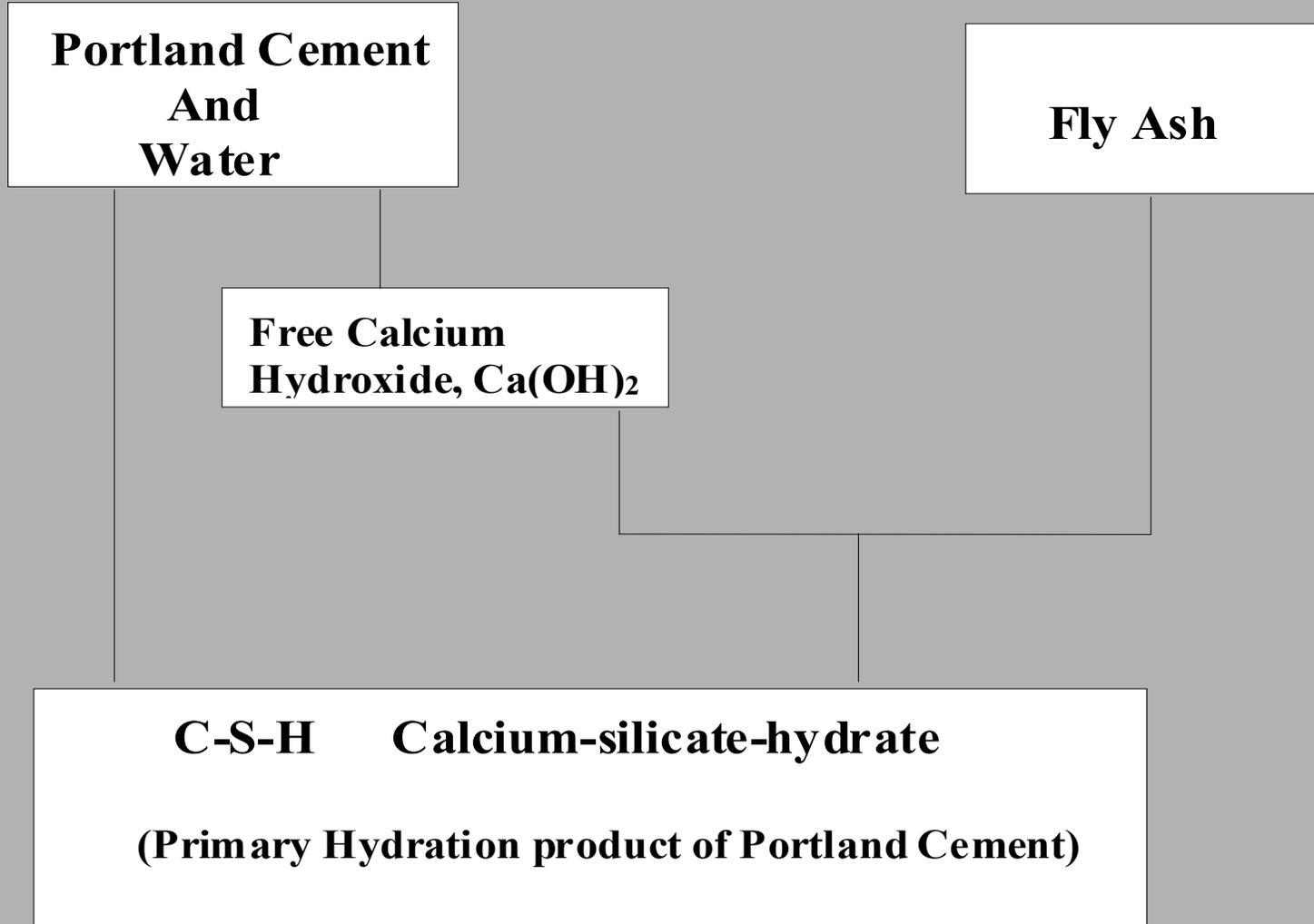
Fly Ash is

- A by-product of coal-fired electric generating power plants
- Finely divided residue resulting from the burning of coal at coal fired power plants
- A by-product of pulverized coal which is ignited in a burning chamber, in which the remaining solids are fly ash and bottom ash

Pozzolan

- Finely divided siliceous or siliceous and alumina material which by itself possesses little or no cementitious value
- However, in the presence of moisture, it will chemically react with calcium hydroxide at ordinary temperatures to form cementitious compounds

Pozzolanic Reaction



Class F Fly Ash

- Normally produced from burning anthracite or bituminous (eastern) coal
- Lower calcium oxide content, higher silicate content
- Has pozzolanic, but no cementitious properties
- Light gray to dark gray in color
- Lower density (specific gravity) 2.2 to 2.5
- 15% CaO and Lower



Natural Pozzolan Sites



Natural Pozzolans

- Still being developed in the Northwest
- Materials at each location are being developed and tested
- Some sources have shown higher water demand than Flyash or Slag

Thank You