National Concrete Consortium
Research and Technology Presentation

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Performance of Concrete Made With Slag Cement and Portland-Limestone Blended Cement

Philadelphia, Pennsylvania

April 2, 2013

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Today's Discussion

- The materials
  - Slag cement
  - Portland-limestone cement
- Use in concrete
  - Individually
  - Together
- Conclusions

What is slag cement?

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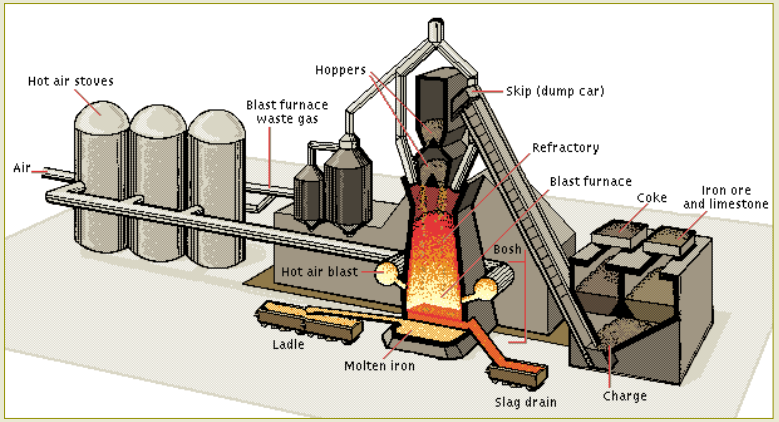
- Non-metallic product of an iron blast furnace
- Granulated



What is slag cement?

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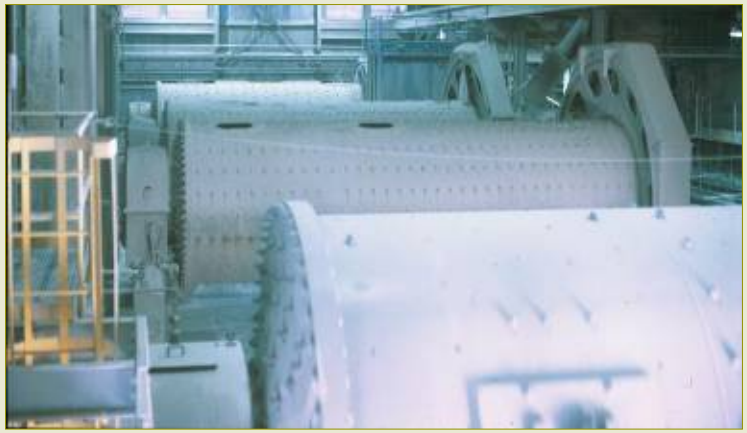
- Non-metallic product of an iron blast furnace
- Granulated
- Ground
- Cementitious material



Use of Slag Cement in Concrete Standard Specifications

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- Slag cement as an SCM in concrete
  - AASHTO M302 or ASTM C989 *Standard Specification for Slag Cement for Use in Concrete and Mortars*
    - *Specs define Grades 80, 100, 120*
- Slag cement as a constituent of blended cement
  - ASTM C595 or AASHTO M 240 "*Standard Specification for Blended Hydraulic Cements*"
    - *Type IS(35) = 65% PC + 35% Slag*
    - *Type IT(S25)(P10) = 65% PC + 25% Slag + 10% Pozzolan*

Effect of Slag Cement on Concrete

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- Enhanced performance
  - Strength
  - Durability
  - Reduced Heat
- Reduced environmental footprint
  - Raw materials
  - Energy
  - Greenhouse gas

Environmental Savings
Material, Energy and Greenhouse Gas

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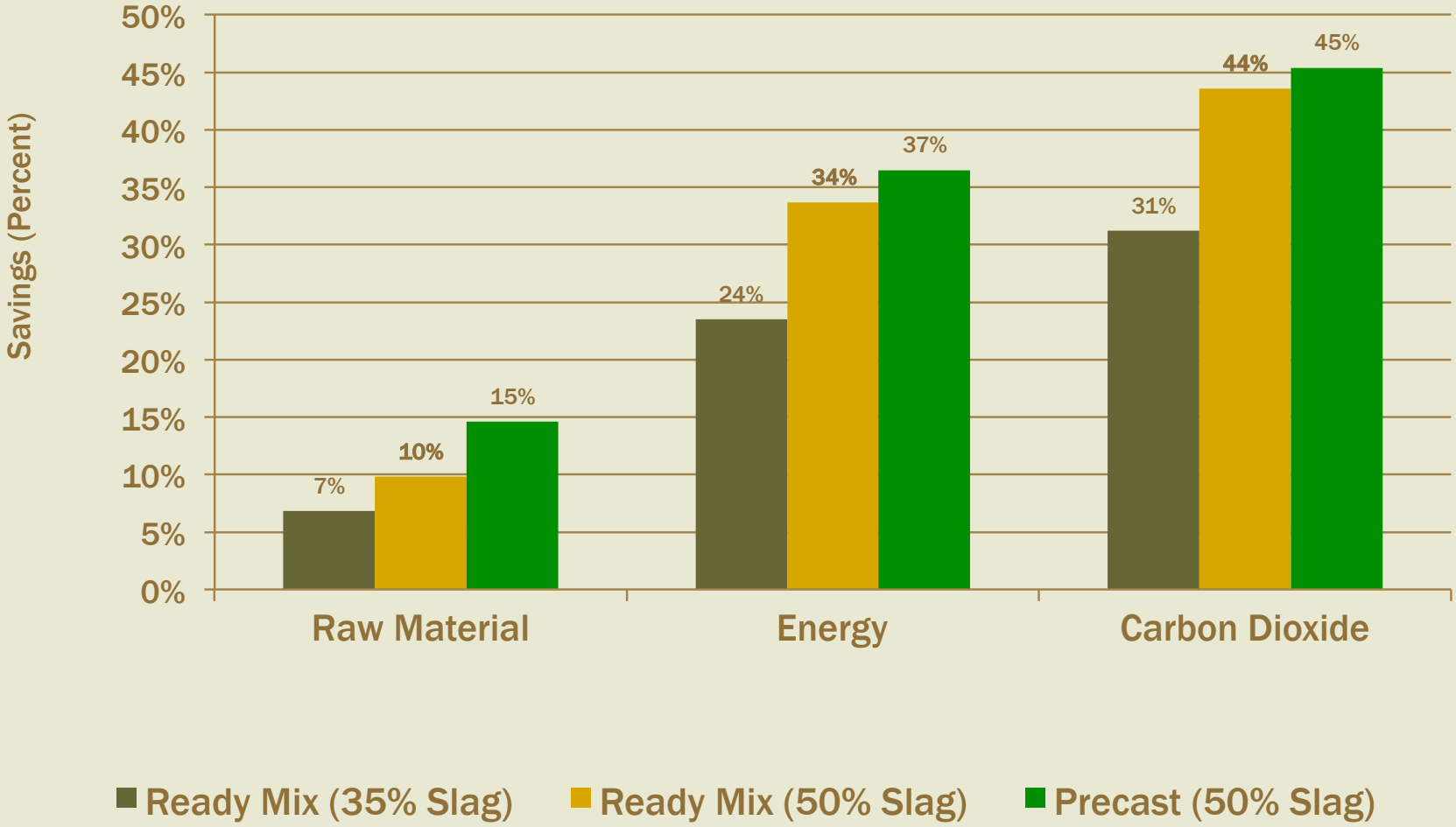
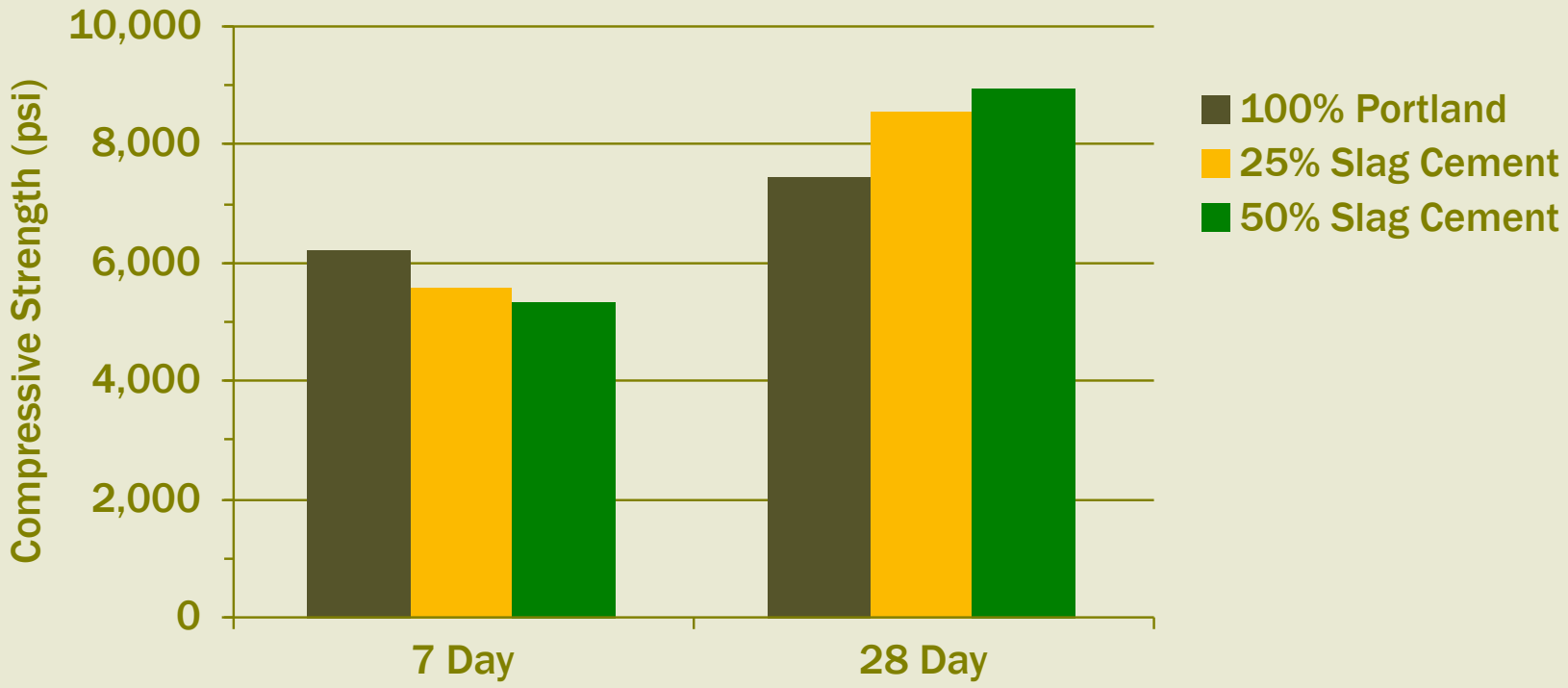
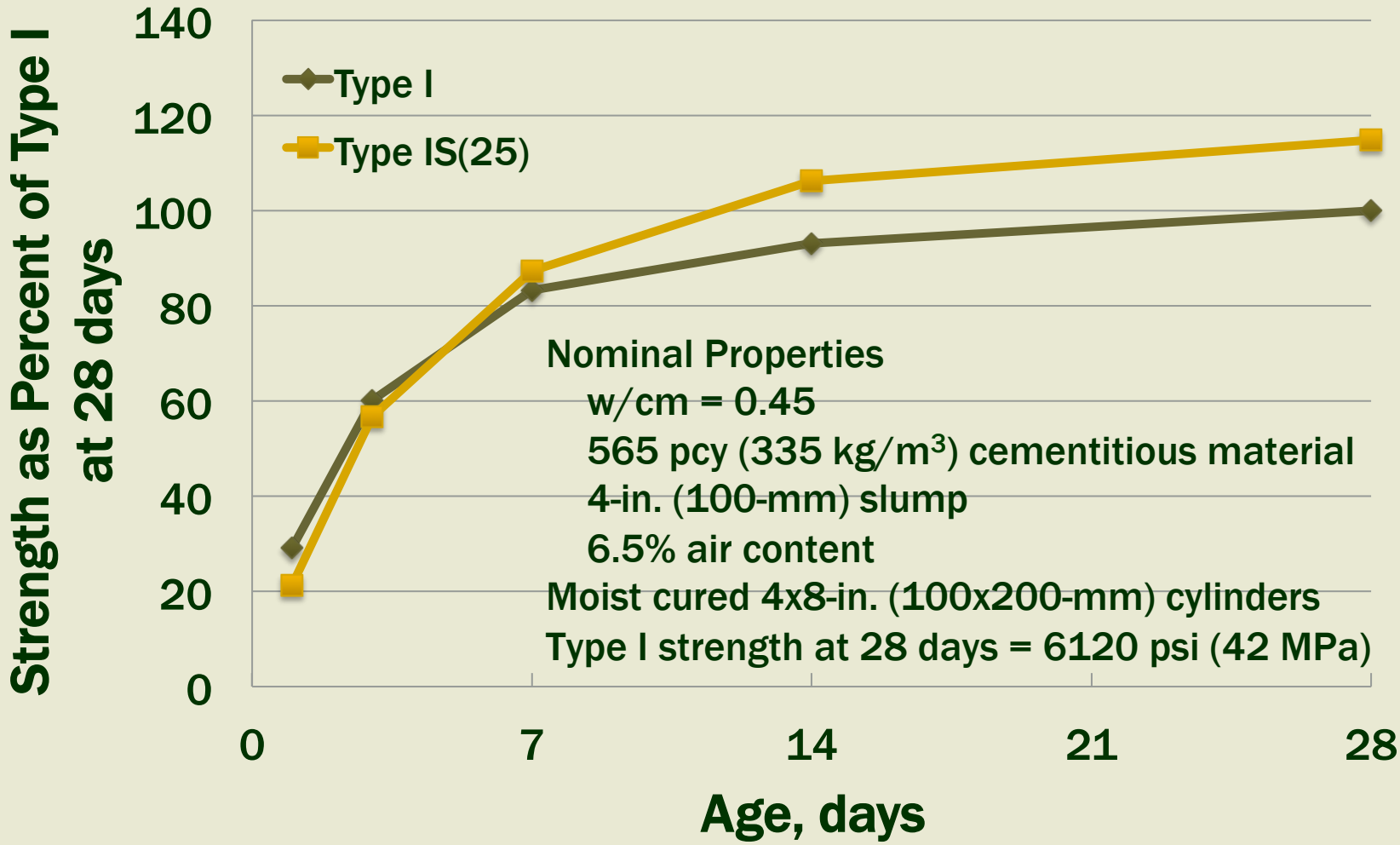


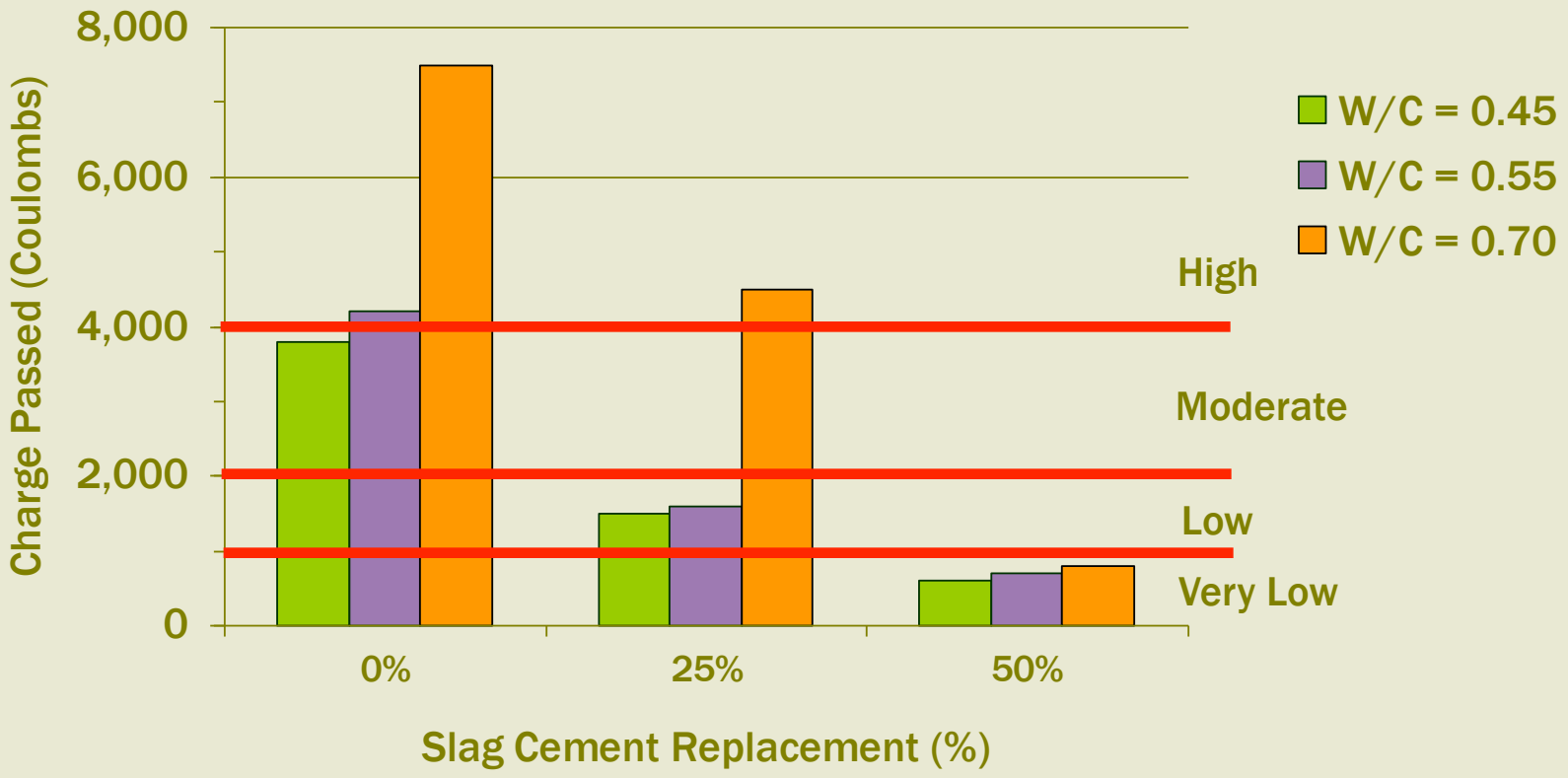
Compressive Strength – Slag Cement



Compressive Strength Blended Cement – Type IS(25)



Durability - Chloride Permeability
ASTM C1202



Effect of Slag Cement on Sulfate Resistance

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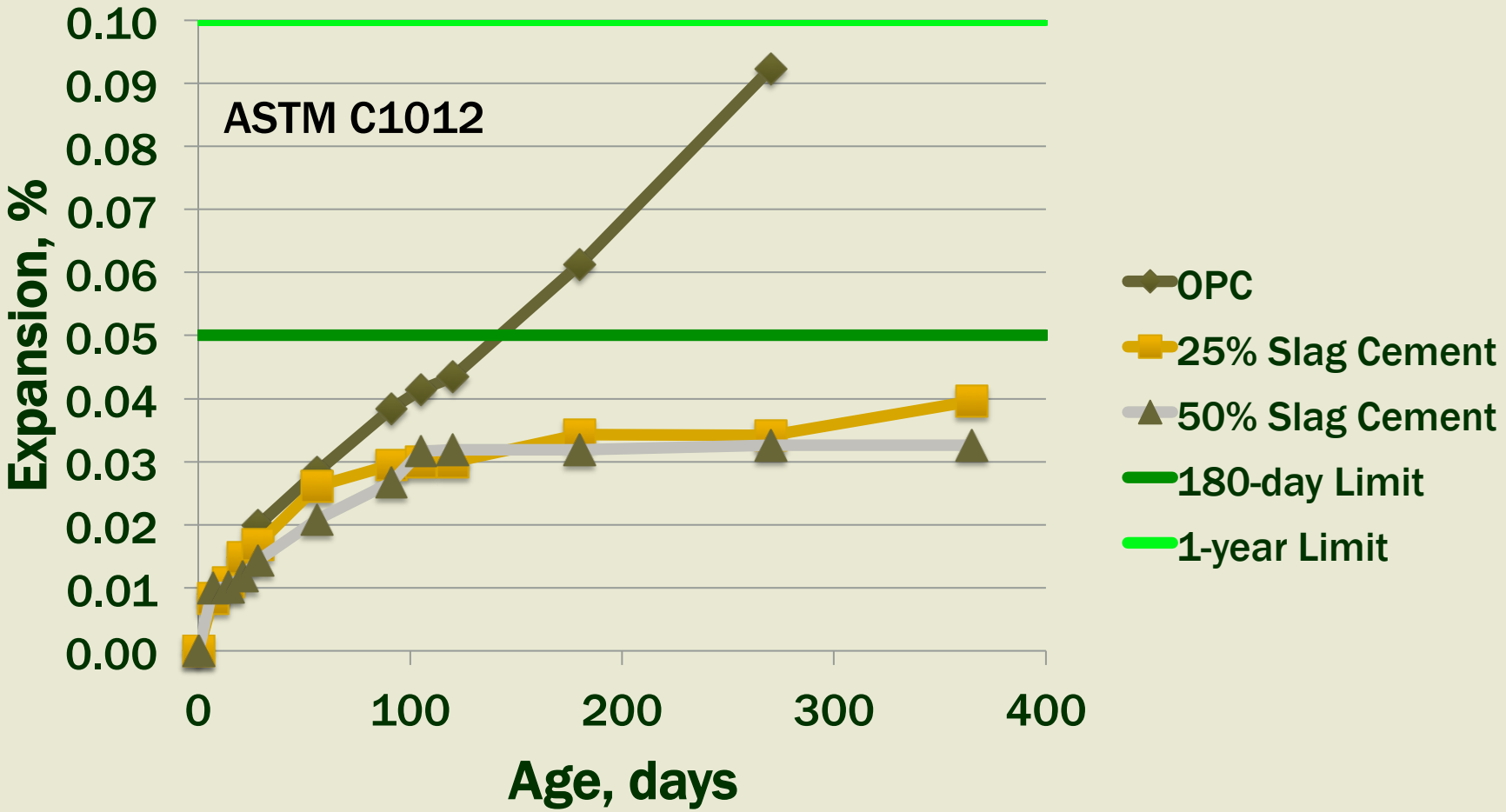
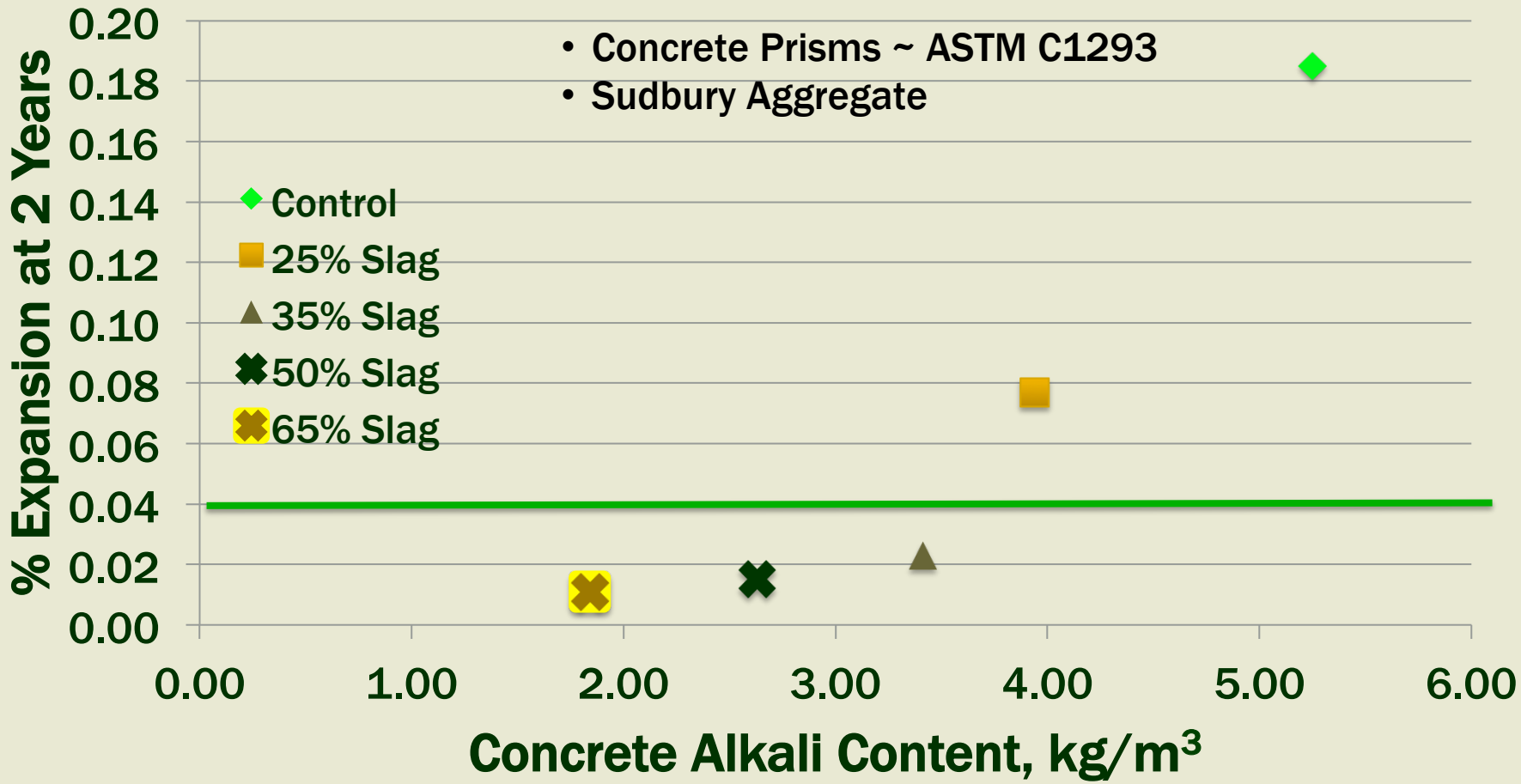
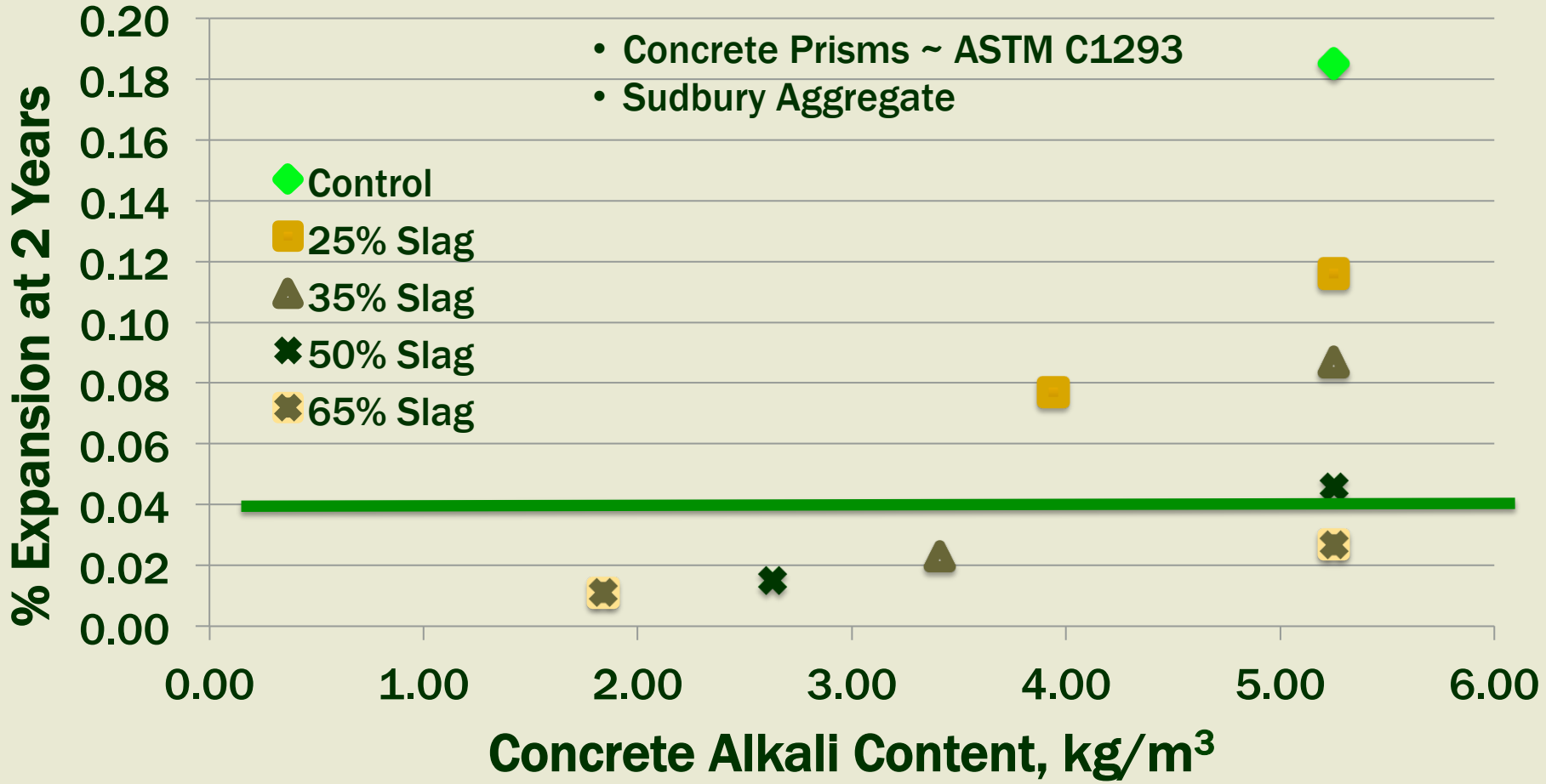


Slag Cement and Total Concrete Alkali Loading



From Thomas and Innis, 1998

Slag Cement and Total Concrete Alkali Loading



From Thomas and Innis, 1998

Effect of Slag Cement on Heat of Hydration

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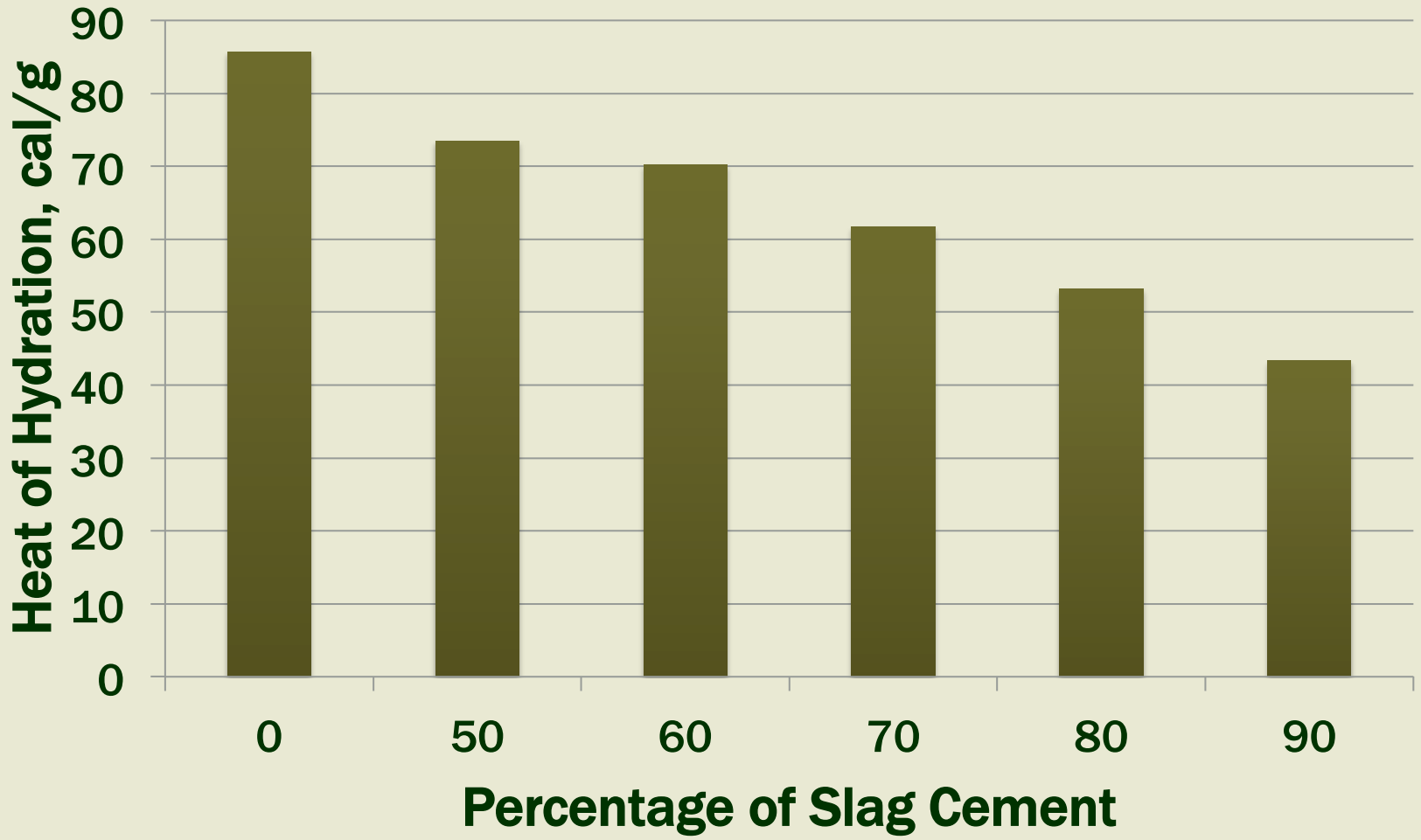

Temperature Rise – 20-ft. (6-m) Mass Placement

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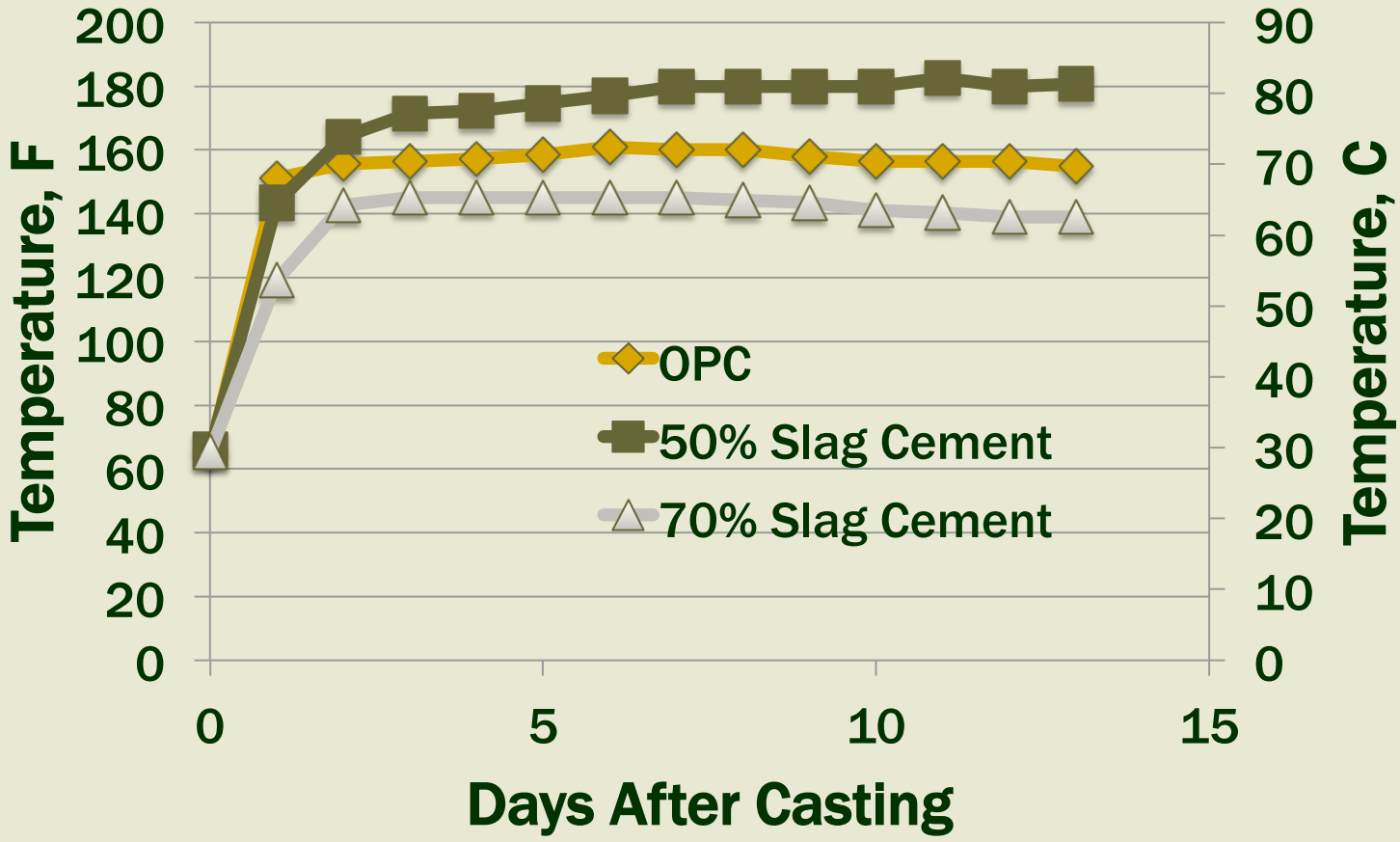

What is Portland-Limestone Cement?

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- ASTM C595/M240 2012 Editions
  - 5% to 15% limestone
  - Type IL(10) = 90% PC + 10% LS
  - Type IT(S35)(L10) = 55% PC + 35% Slag + 10% LS
  - Same physical requirements as for existing C595/M240 cements
  - More than 5% limestone not permitted in moderate sulfate (MS) or high sulfate (HS) resistant blended cements

Performance of Type IL Cement in Concrete

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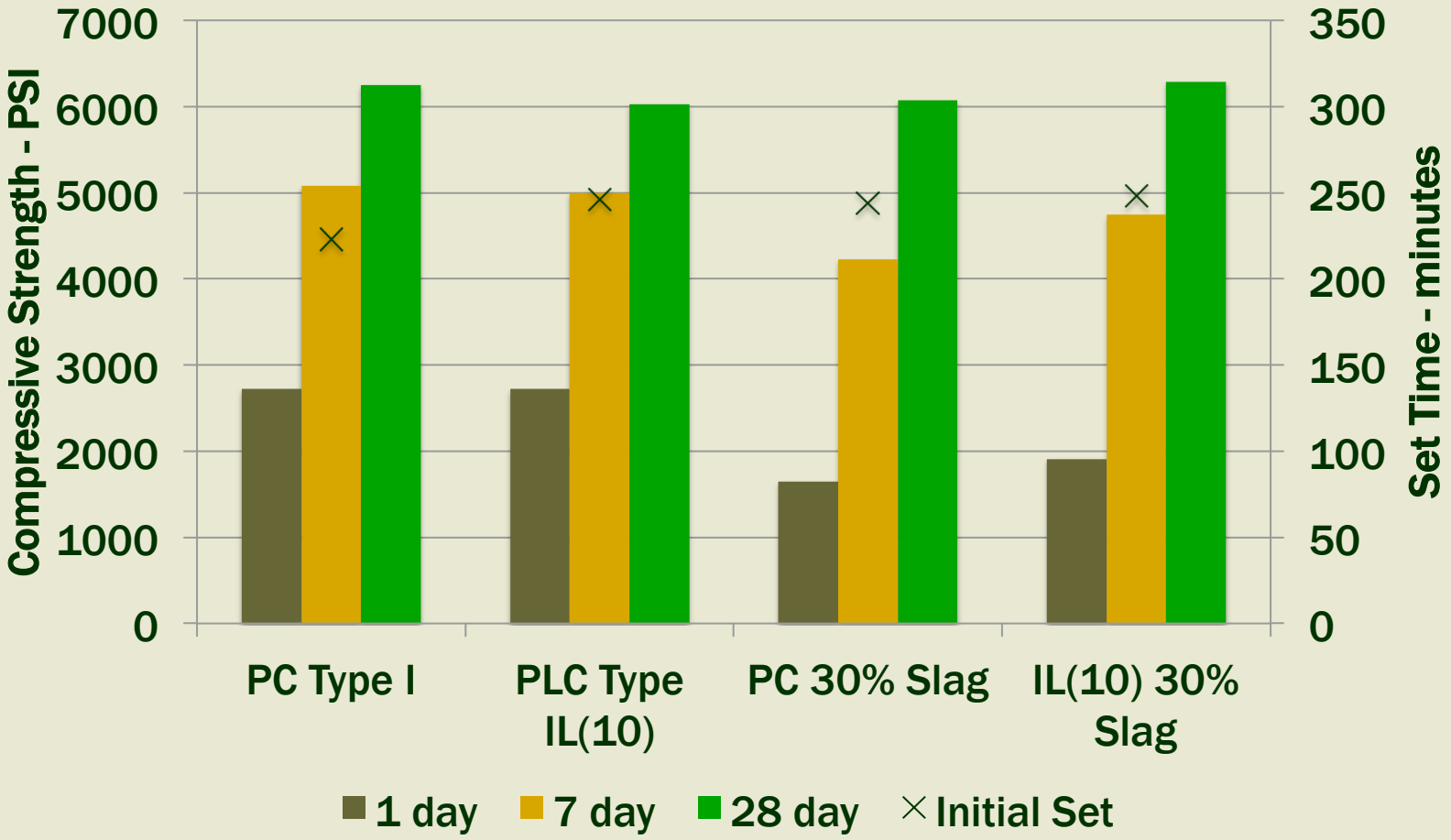
- Comparable performance to Type I portland cement
  - Without SCMs
  - With SCMs
- Reduced environmental footprint
  - Raw materials
  - Energy
  - Greenhouse gas

Environmental Benefits

	10%	15%
Energy Reduction*		
Fuel (million BTU)	443,000	664,000
Electricity (kWh)	6,970,000	10,440,000
Emissions Reduction*		
SO_2 (lb)	581,000	870,000
NO_X (lb)	580,000	870,000
CO (lb)	104,000	155,000
CO_2 (ton)	189,000	283,000
Total hydrocarbon, THC (lb)	14,300	21,400

* Per million tons cement

Set Time – Compressive Strength



Relative Resistance to Chloride Ion Penetration ASTM C1202

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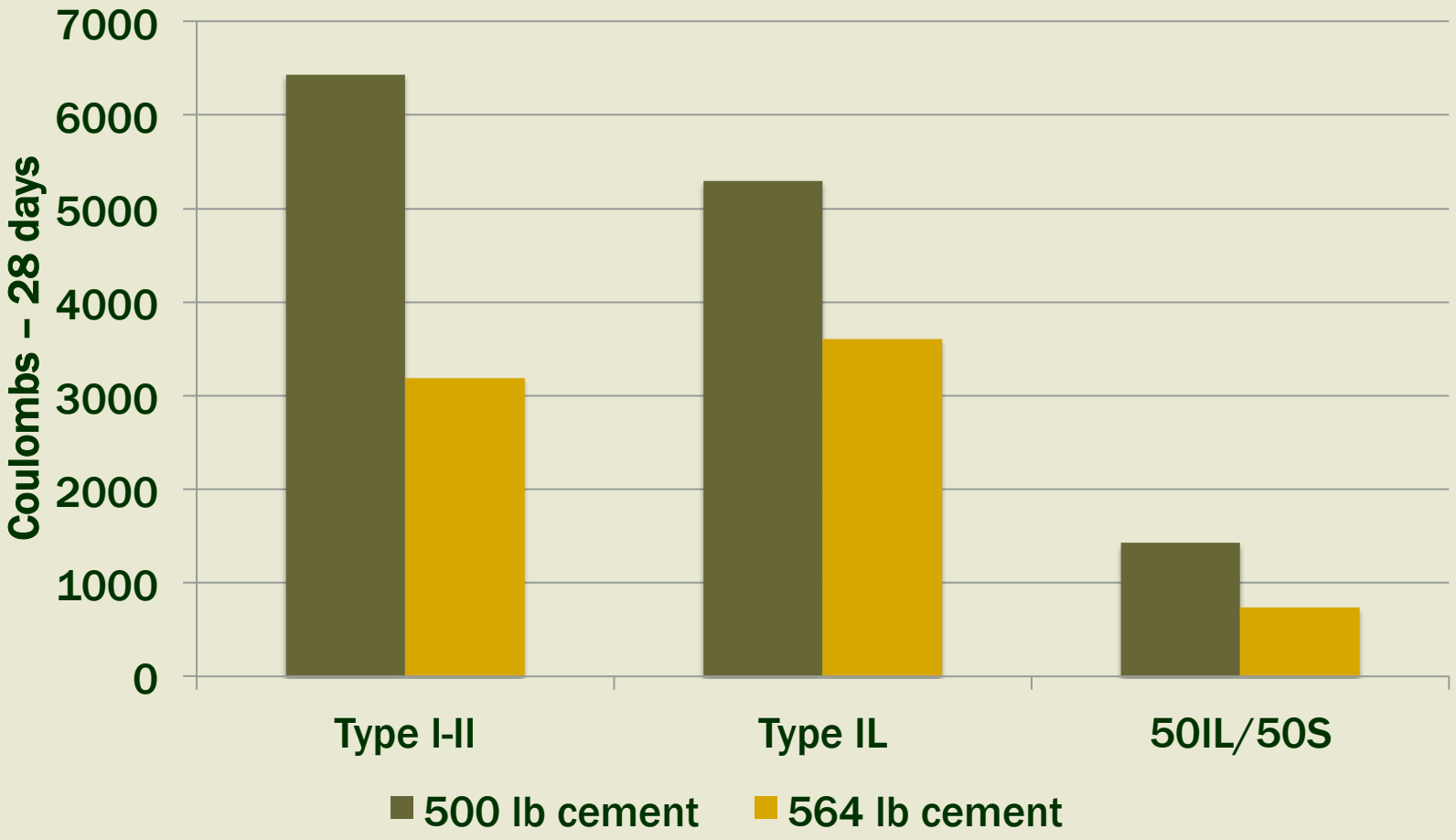
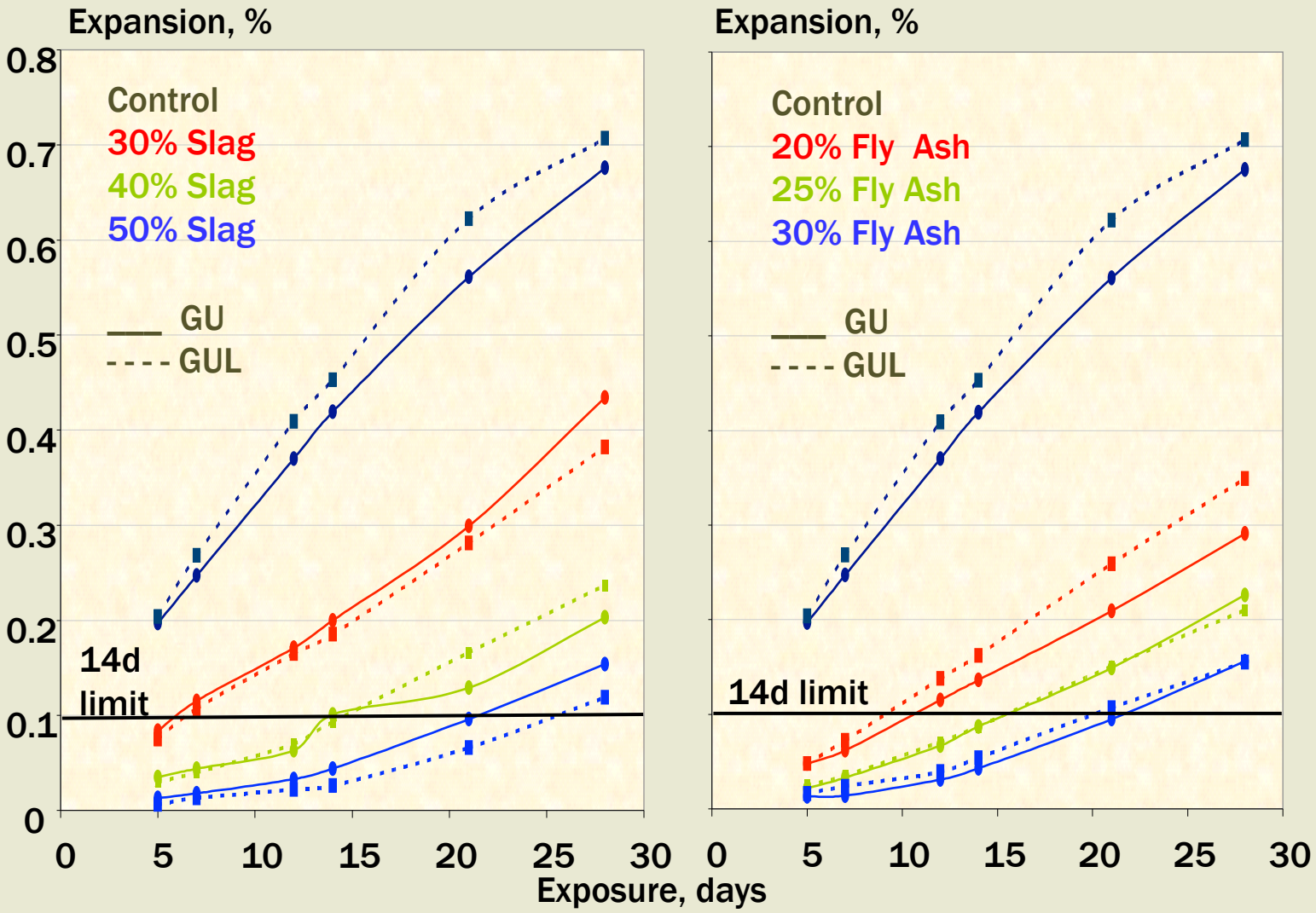


ASR – Accelerated Mortar Bar Test (C1567)



F ash

PLC – Sulfate Resistance

- C595/M240 does not permit more than 5% limestone in MS or HS blended cements
  - Potential for thaumasite form of sulfate attack – deterioration of CSH matrix exposed to sulfates and carbonates in wet cool conditions
  - Research indicates that appropriate use of slag cement, Class F fly ash, or metakaolin can effectively mitigate the potential for the thaumasite form of sulfate attack
  - CSA A3001 permits blended cements to contain 5% to 15% limestone if:
    - They also contain at least 40% slag, 25% Class F fly ash, 15% metakaolin, or a combination of 5% silica fume and either 25% slag or 20% Class F fly ash
    - ASTM C1012 bars stored at 5°C must have expansions of less than 0.10% at 18 m (with a supplemental limit of 0.10% at 24 m if the increase in expansion between 12 and 18 m exceeds 0.03%)

Summary of Today's Discussion

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- Slag cement used with portland cement will reduce the environmental footprint of concrete and can enhance key performance characteristics, including strength and durability
- Portland-limestone cement, Type IL will reduce the environmental footprint of concrete and can provide comparable characteristics to a Type I portland cement
- Concrete mixtures containing slag cement and Type IL or blended Type IT(S)(L) will further reduce environmental impact and can provide desired strength and durability performance

Summary of Today's Discussion

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- Use of slag cement, Class F fly ash, metakaolin, or combinations of silica fume and slag cement or Class F fly ash with Type IL cements or in Type IT cements that contain more than 5% limestone is a potential means of addressing potential for thaumasite form of sulfate attack

Observations/Recommendations

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- Under ASTM and AASHTO terminology Type IL cements are considered binary blended cements. Therefore mixtures of Type IL cement with SCM's are by definition ternary systems. A specification that prohibits ternary systems in effect precludes the use of a very effective option for providing durable concrete and minimizing environmental impact
- Consider incorporating ternary systems in state specifications
- Include performance-based options in specifications

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Thank You!

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