ADVANCES IN ALTERNATIVE CEMENTITIOUS BINDERS

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Acknowledgements

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Participants of the International Summit on Cement Hydration Kinetics and Modeling*

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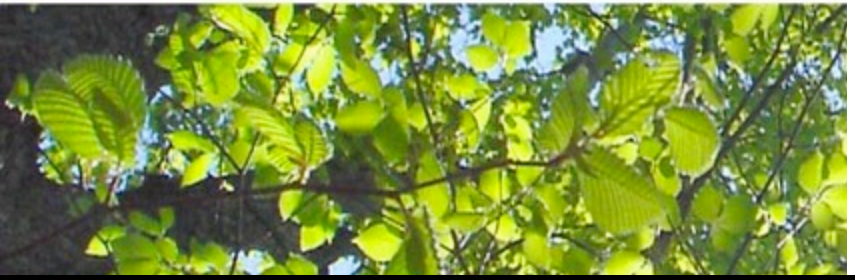
* The International Summit on Cement Hydration Kinetics and Modeling was held on July 27, 28 and 29, 2009 at Laval University, Quebec, Quebec City, Canada.

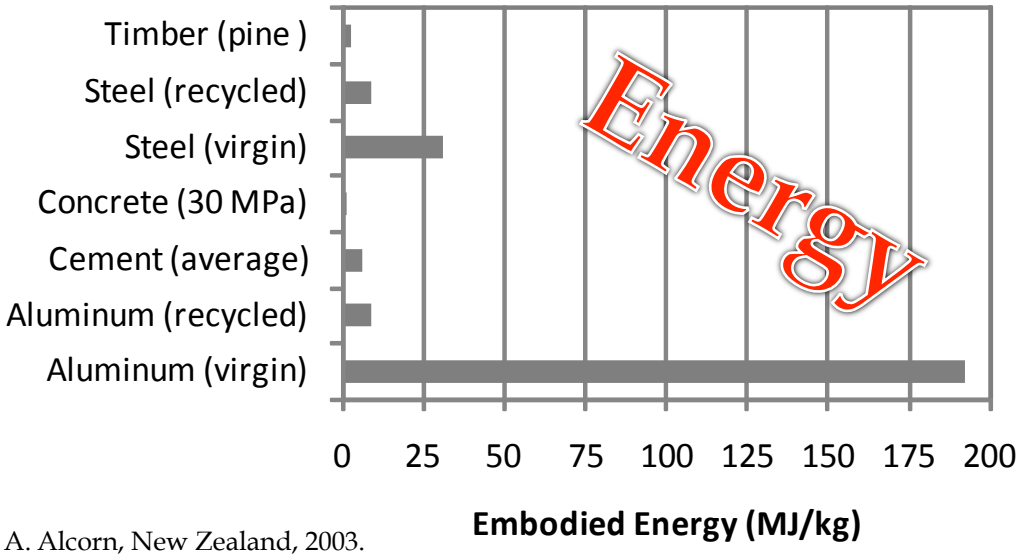
Roadmap 2030
identified 17 sub-topics

- **Design and Structural System**
  - Structural concrete
  - Reinforced concrete
  - Modeling and measurement
  - High-performance concrete
  - Technology transfer
  - Fire-, blast-, and earthquake-resistant
  - Cross-cutting innovations
- **Constituent Materials**
  - **New materials**
  - Performance measurement and prediction
  - Reuse and recycling
- **Concrete Production, Delivery and Placement**
  - Information and control
  - Production, Delivery, and Placement
  - Test methods and sensors
  - Energy and environment
- **Repair and Rehabilitation**
  - **New repair materials**
  - Assessment tools and modeling/measurement techniques
  - Repair field process technologies

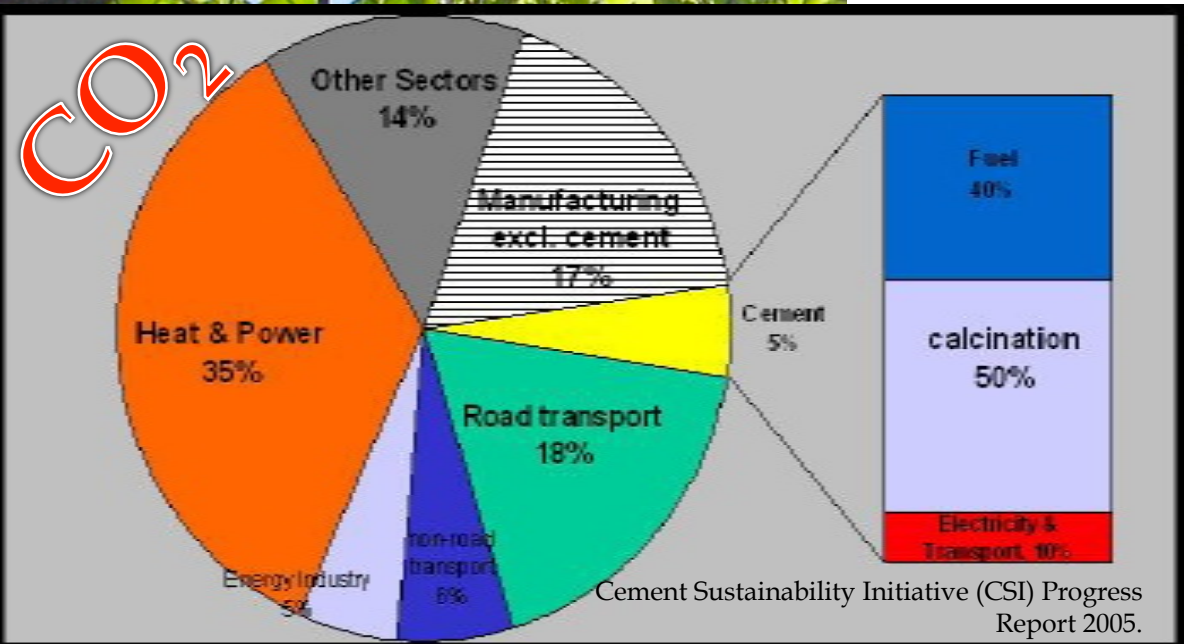
Why new materials?

Environmental motivations

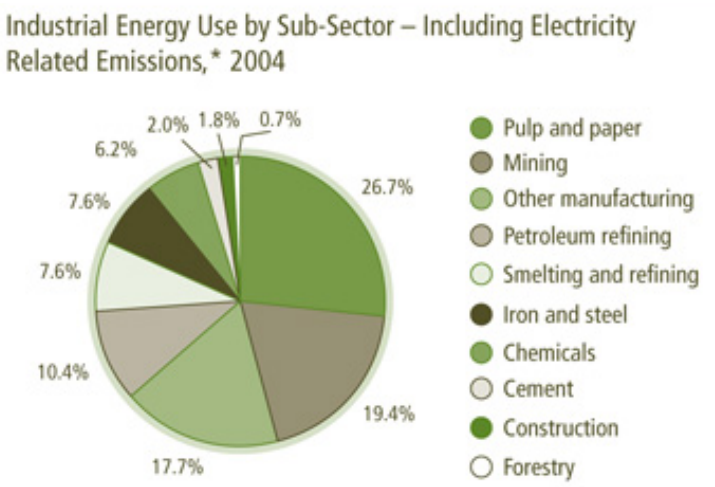




A. Alcorn, New Zealand, 2003.



Cement Sustainability Initiative (CSI) Progress Report 2005.



NRC (Canada)

Why new materials?

Performance considerations

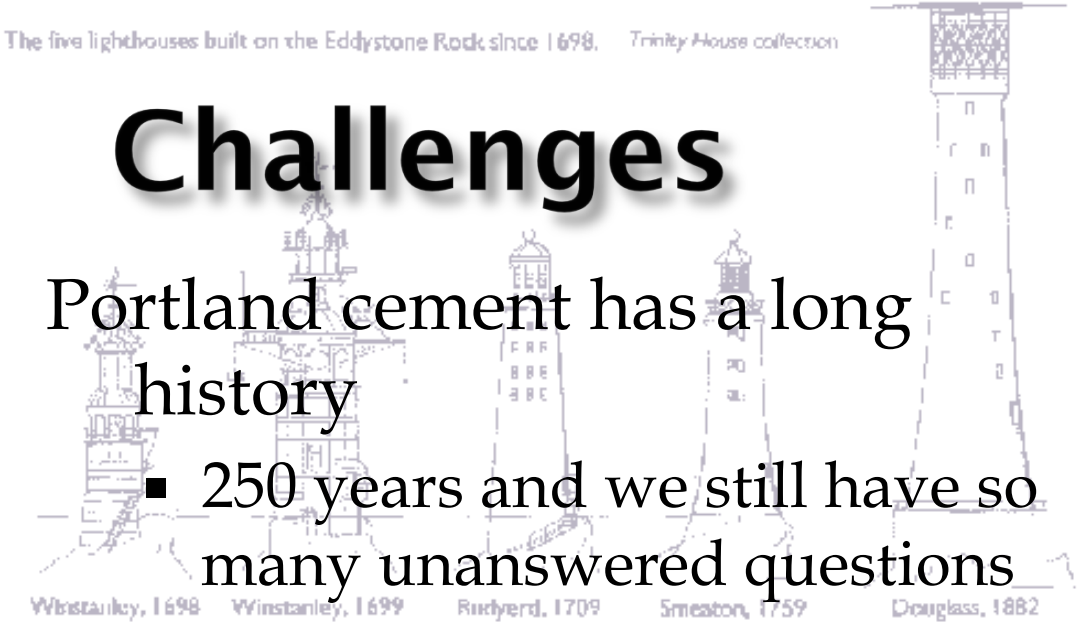
- Rapid repair
- Acid resistance
- Sulfate resistance

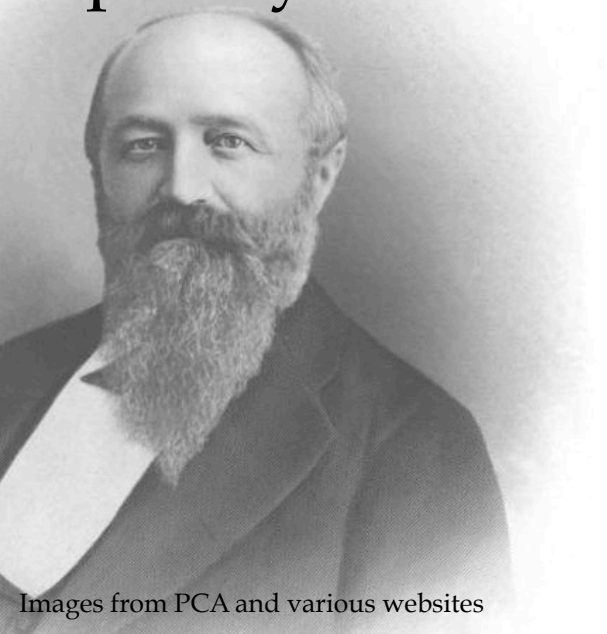
Challenges

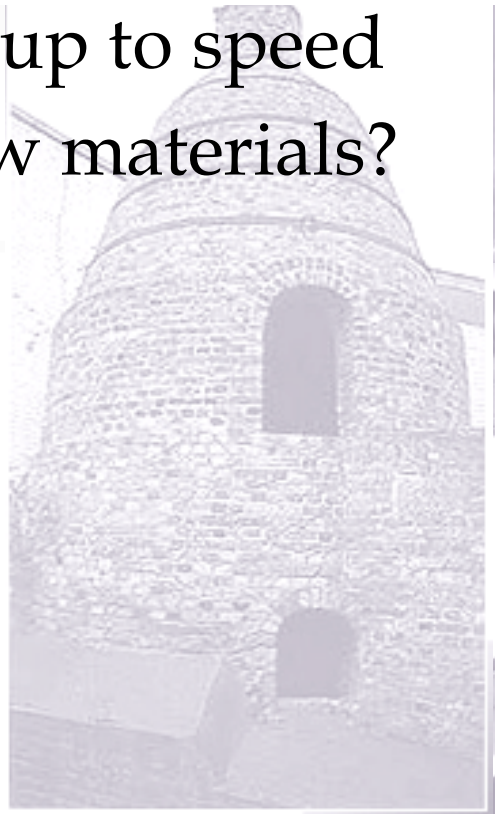
Portland cement has a long history

- 250 years and we still have so many unanswered questions

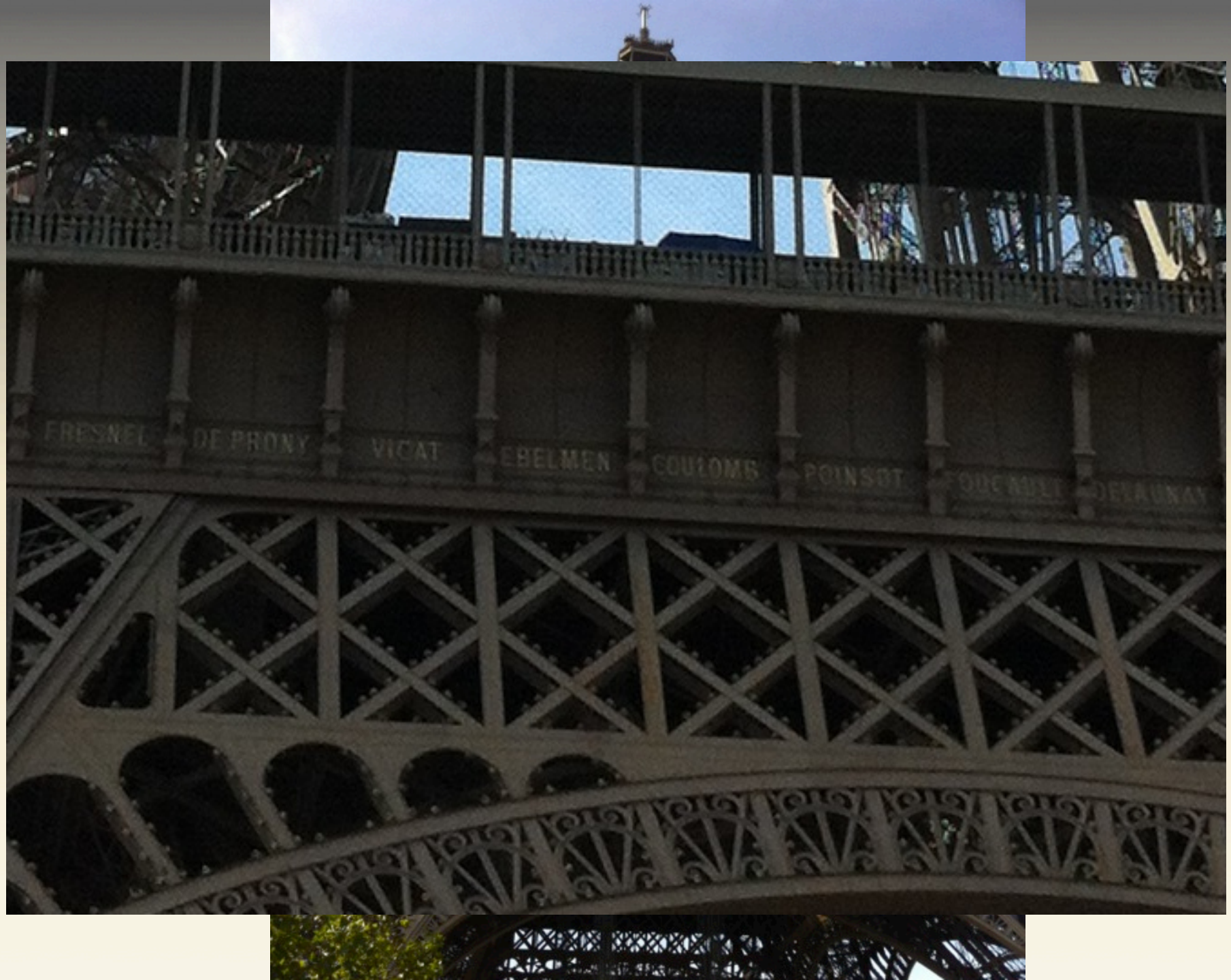
How can we get up to speed quickly with new materials?





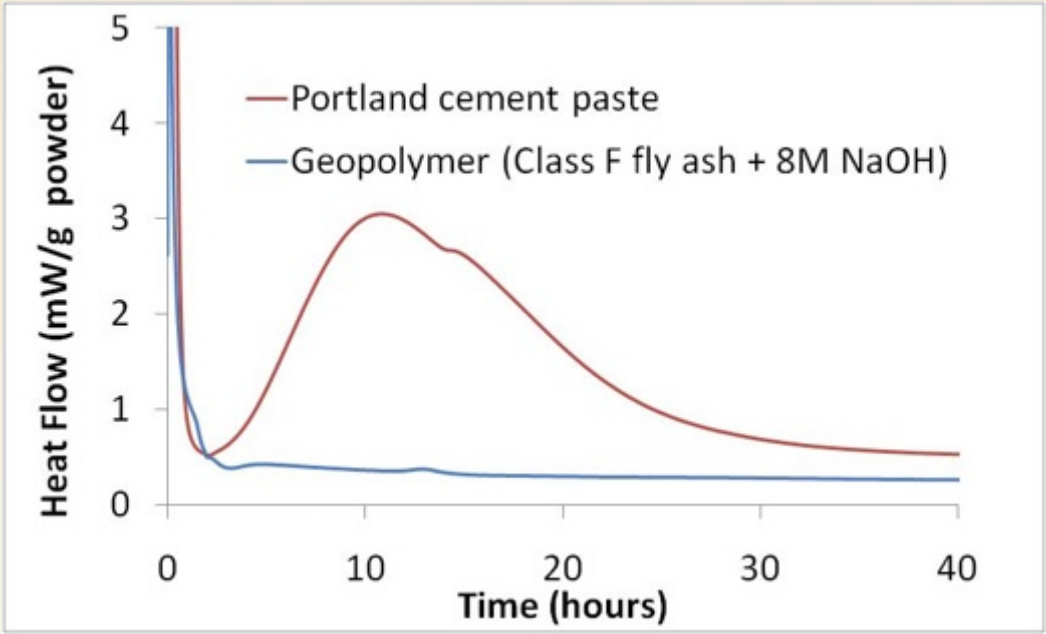


Images from PCA and various websites


FRESNEL
DE PRONY
VICAT
EBELMEN
COULOMB
POINSOT

Borrow from Portland Cement

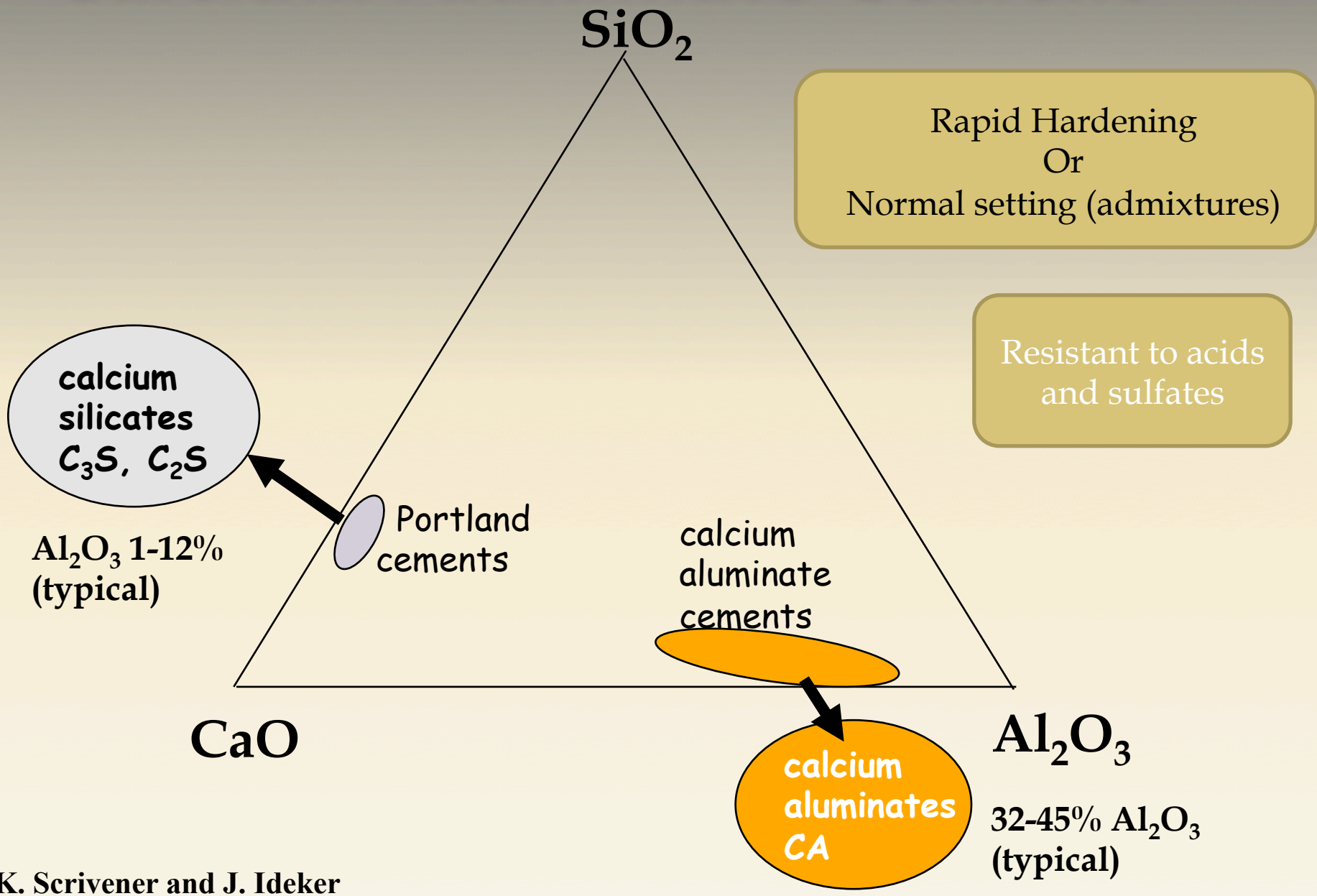
- We can often apply the same tools used to analyze portland cement to the new materials
  - Experimental analysis techniques
  - Kinetic models
- Doesn't always work…



“New” Cements

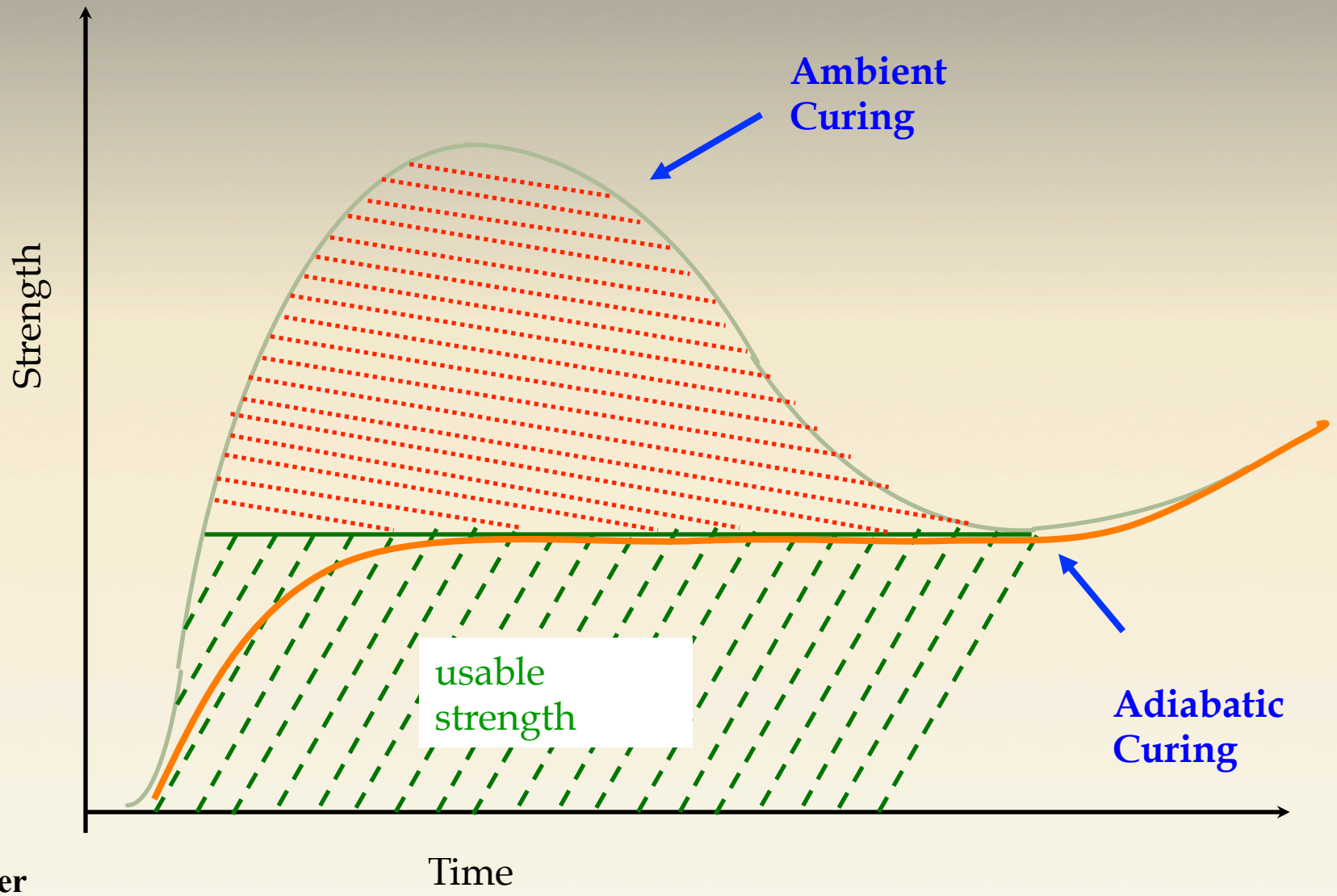
- Calcium aluminate cements
- Calcium sulfoaluminate cements
- Super-sulfated cements
- Alkali-activated binders

Calcium Aluminate Cement



K. Scrivener and J. Ideker

Calcium Aluminate Cements



J. Ideker

Calcium Aluminate Cements

- Portland cement analysis methods apply
- Very similar questions to portland cement:
  - Mechanical property development with admixtures used to control setting and strength
  - Dimensional stability
  - Interactions with supplementary cementitious materials
- Challenges:
  - Predictable performance
  - Cost!

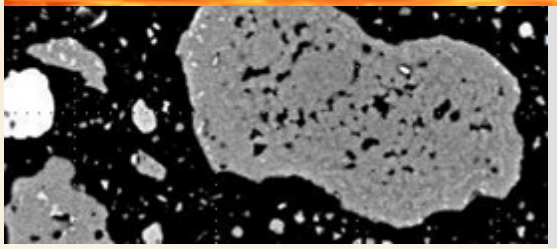
Calcium Sulfoaluminate Belite Cement

In the kiln: $3CaCO_3 + SiO_2 \rightarrow Ca_3SiO_5 + 3CO_2$

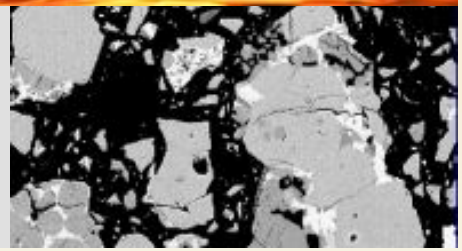
Calcium carbonate (limestone) + Silica → C_3S (alite) + Carbon dioxide gas

CSAB Cements	CaO Content	Portland Cement
$C_4A_3\hat{S}$ ←	36.7% — 73.7%	→ C_3S
C_2S		C_2S
$C\hat{S}H_2/C\hat{S}$		C_3A
C_4AF (optional)		C_4AF
C_2AS (optional)		$C\hat{S}H_2$

1250°C — **Kiln Temp.** — **1450°C**

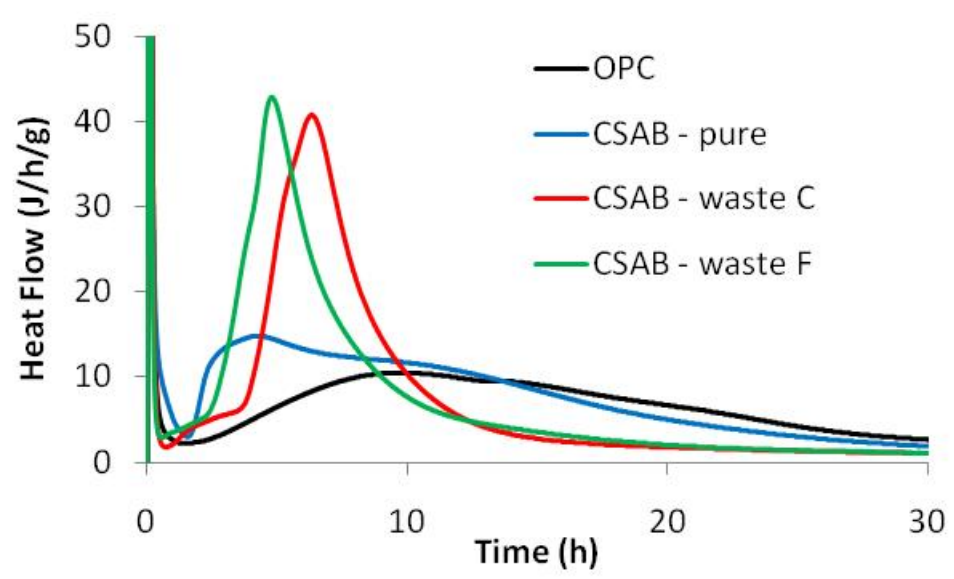


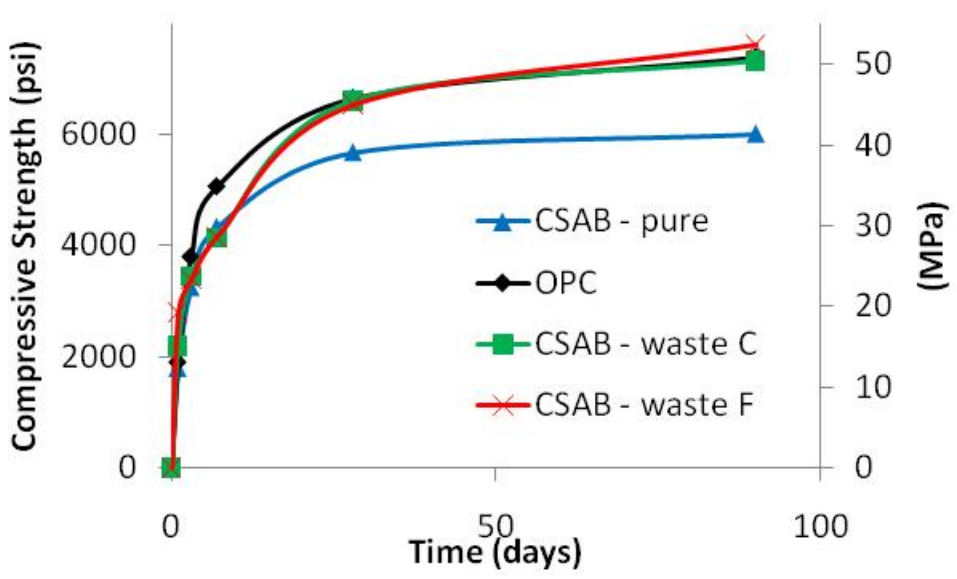
Grinding Energy



CSAB Cement

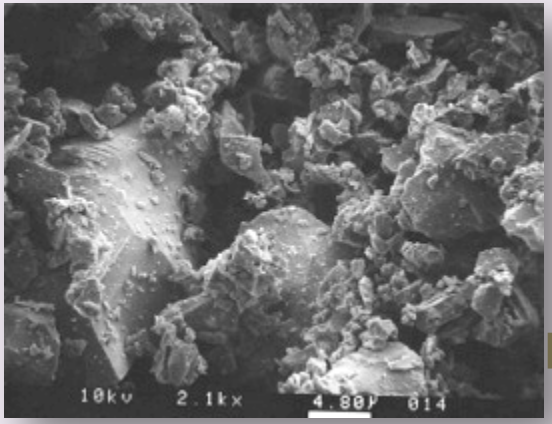
- Portland cement analysis methods apply
- Challenges
  - No standard compositions
  - Dimensional stability
  - Durability





Supersulfated Cements

Slag (70-90%)



High CaO, MgO, and Al_2O_3 content (~14%)

Calcium sulfate (10-20%)

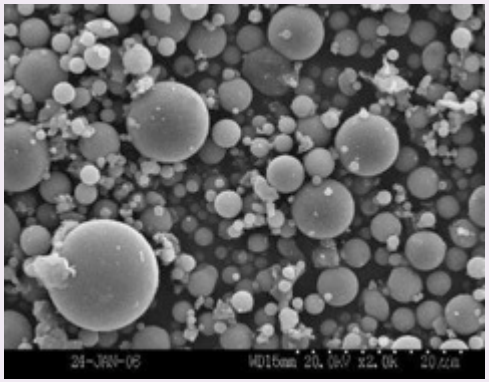
Alkali source (<5%)

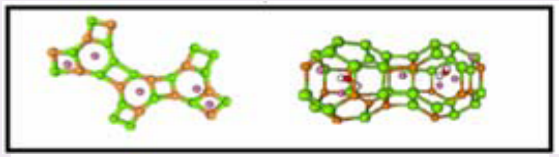
Images from PCA, EPA, and various websites

Supersulfated Cements

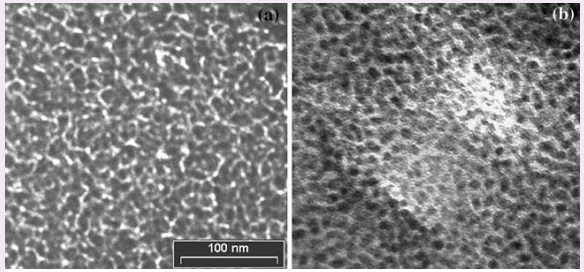
- Portland cement analysis methods apply
- Challenges
  - Slow strength gain
  - Understanding sensitivity to composition
  - Carbonation

Alkali-Activated Binders





Examples of Inorganic Polymer Network Structures (where the pink/red atoms are aluminum and silicon, green are oxygen, and purple are alkali cations (from Duxson *et al.* 2007)



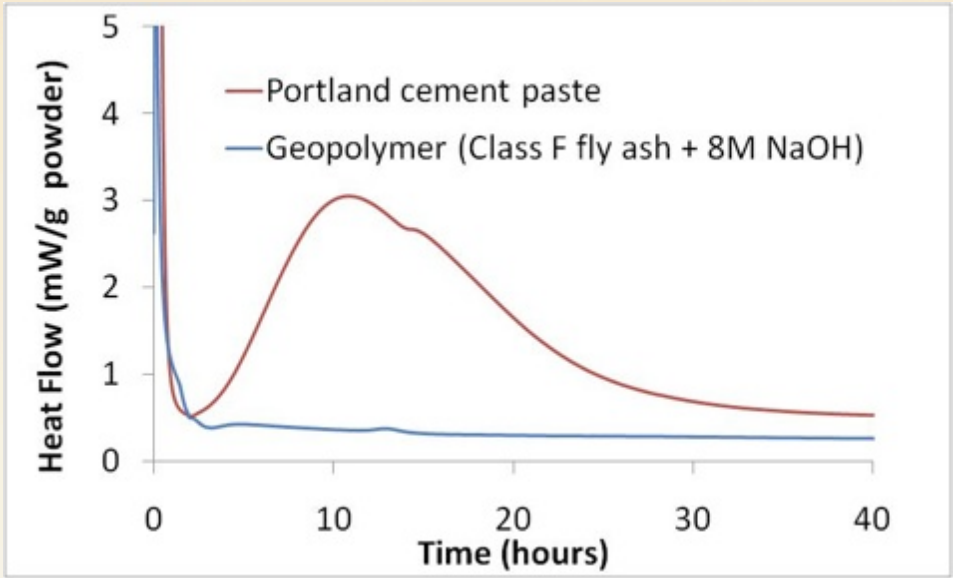
TEM brightfield images of IP binders made from metakaolin (a) and fly ash (b) (from Duxson *et al.* 2007)

Images from PCA and various websites

Alkali-Activated Binders

- Portland cement analysis methods do not all directly apply

- Challenges
  - Raw materials and proportioning
  - Performance predictability
  - Curing control
  - Durability
  - Admixtures for workability



Summary

- There are many portland cement alternatives
- None are positioned to take over significant market share in the very near future
- Although benefits stand to be gained in environmental impacts and/or durability…
- Significant work remains to understand:
  - Raw material selection for maximum performance and minimum cost
  - Binder composition-performance relationships
  - Reaction mechanisms and admixture effects
  - Long term volume stability and durability