Is the market ready for the adoption of alkali-activated cements?

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Zeobond

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Portland Cement Production

Quarried Limestone

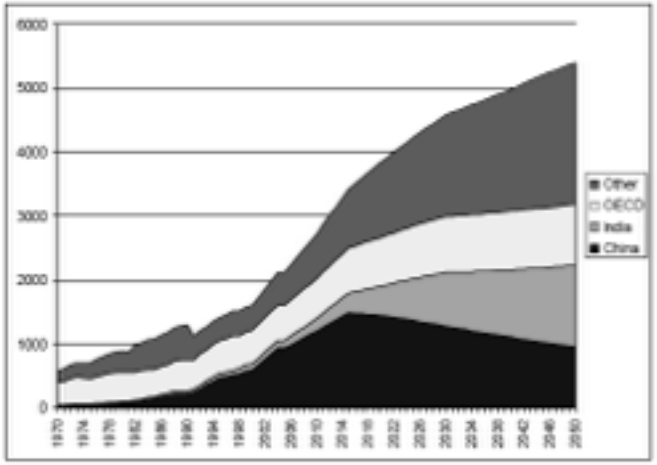
Rotary Cement Kiln

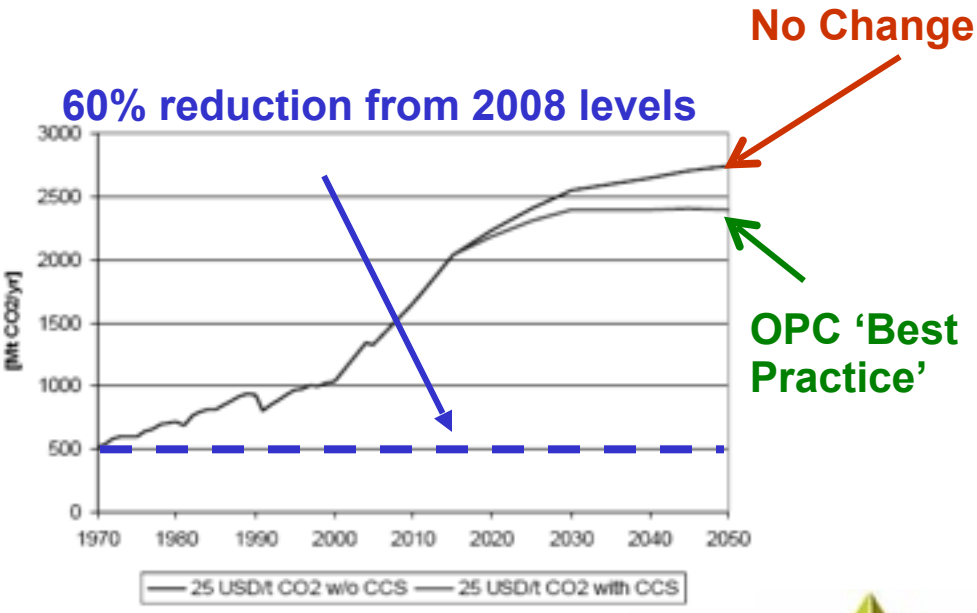
Grinding

Storage

Some facts about Cement

- Cement manufacture makes up 5-8% of all CO_2 (3rd highest)
- Second most used material next to WATER
- **1** ton of CO_2 per **1** ton of cement
- Market to double to 2050





- Alternatives to OPC are required to meet market demand for low CO_2 building materials.

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Cement value chain

- Ownership of limestone assets and permits
- Limestone is available everywhere
- High sunken capital in clinker kilns
- Operating margins relatively high in clinker production and grinding
- Control over supply chain and logistics
- Ownership of sand and aggregate quarries
- Margins relatively low in pre-mixed concrete
- Margins slightly better in precast and concrete placement.

Alkali-Activated Cement: A Simplified View

Metallurgical Slags

Fly Ash

Natural Pozzolans

Cementitious Components

Alkaline Activator

Binder for Concrete

Alkali-Activated Cement Production

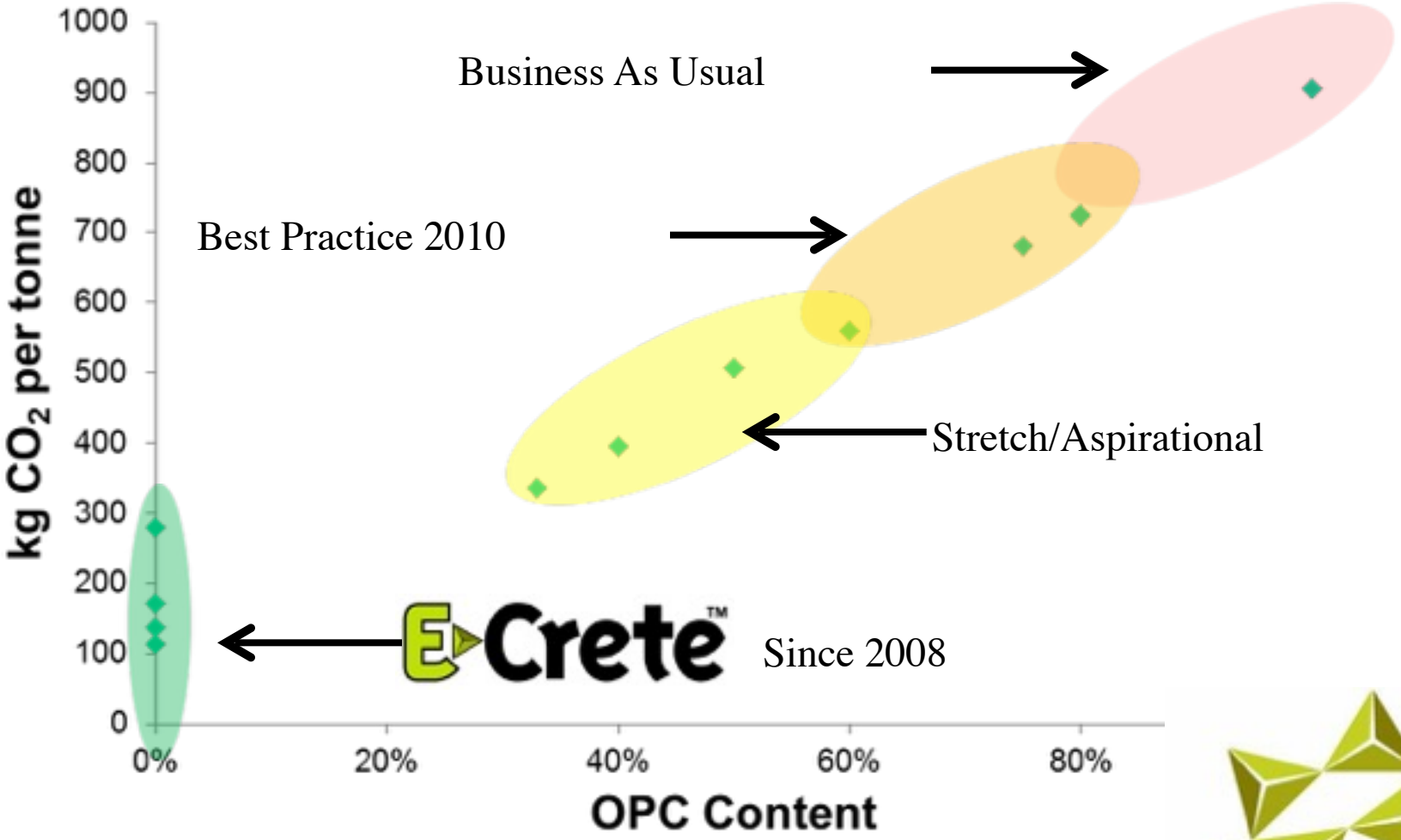
Metallurgical Slags

Fly Ash

Alkali Activator

Grinding

Storage



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History of Alkali-Activation

- Romans used alkali-activated concrete (AAC).
- 1940s - Idea of AAC re-emerged (Purdon).
- Late 1950s - Glukhovsky in Kiev developed alkali-activated binders, followed by Krivenko, who constructed slag AAC structures and a high rise building in Russia in the 1960s.
- Davidovits coined term **geopolymer** in the 1970s.
- Van Deventer made first geopolymer early 1993.
- Today many universities do some geopolymer research, but still little commercial activity.

Drivers for /Obstacles to AAC adoption

• Relative cost of ash/slag	**Driver**/Obstacle
• Waste utilisation	**Driver**
• Cost of activators	Obstacle
• Technical properties	**Partial driver**
• Customer focus on low CO_2	**Main driver**
• Control over the supply chain	**Driver**/Obstacle
• Standards based on OPC	Obstacle
• Questions on durability	Obstacle
• Engineering design methods	Obstacle
• Long track record of OPC	Obstacle
• Desire to innovate	**Driver**

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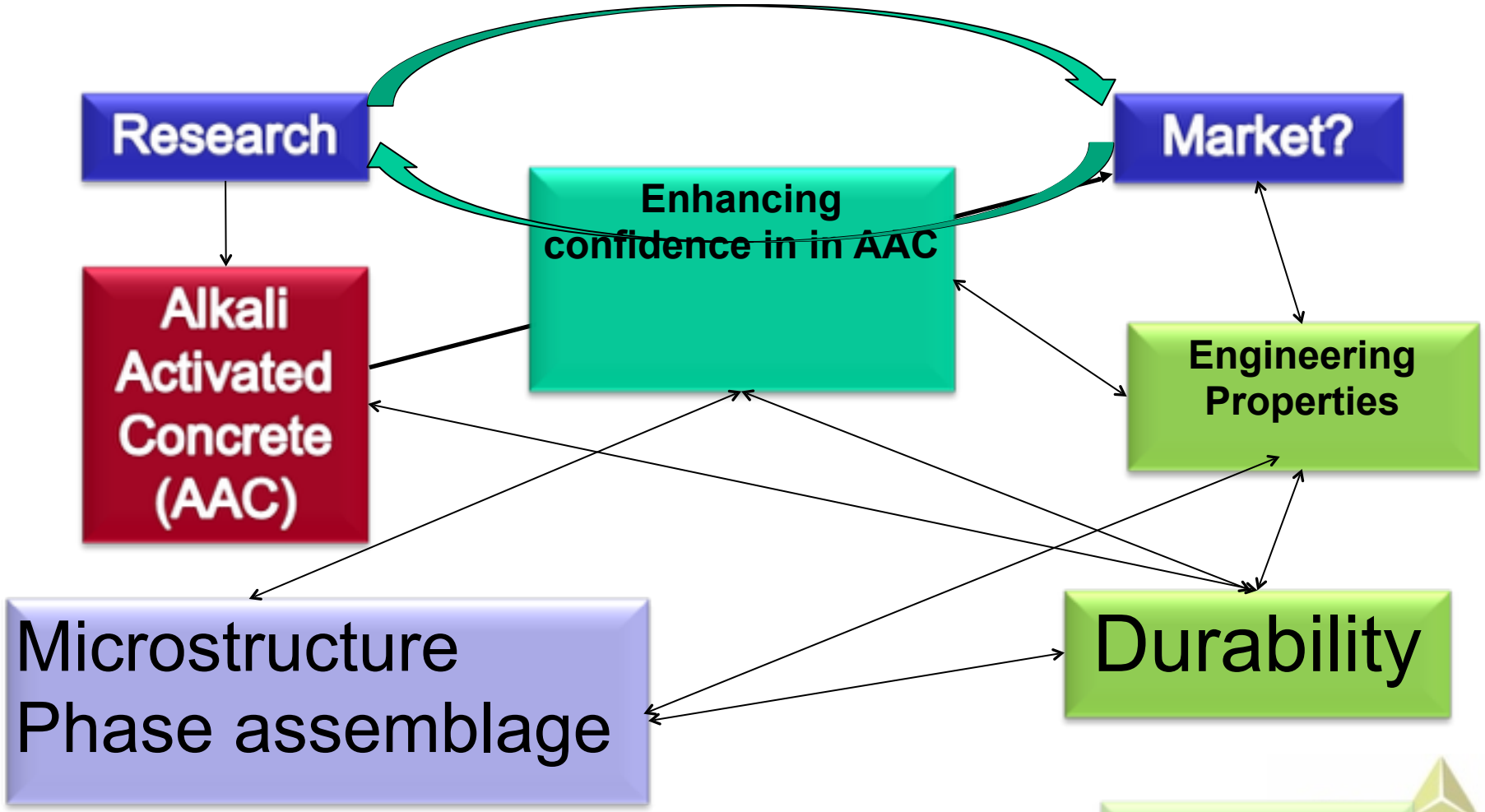
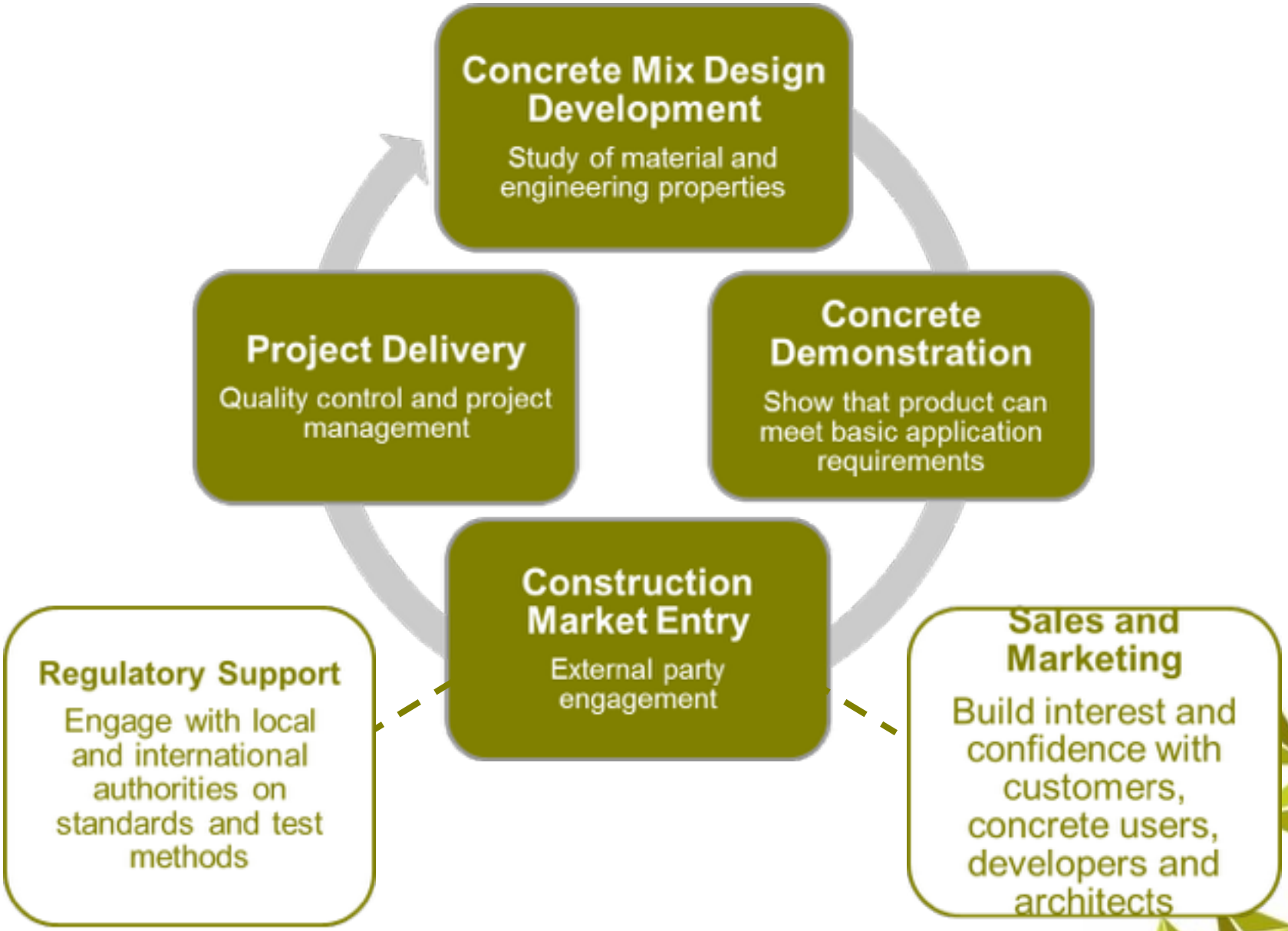
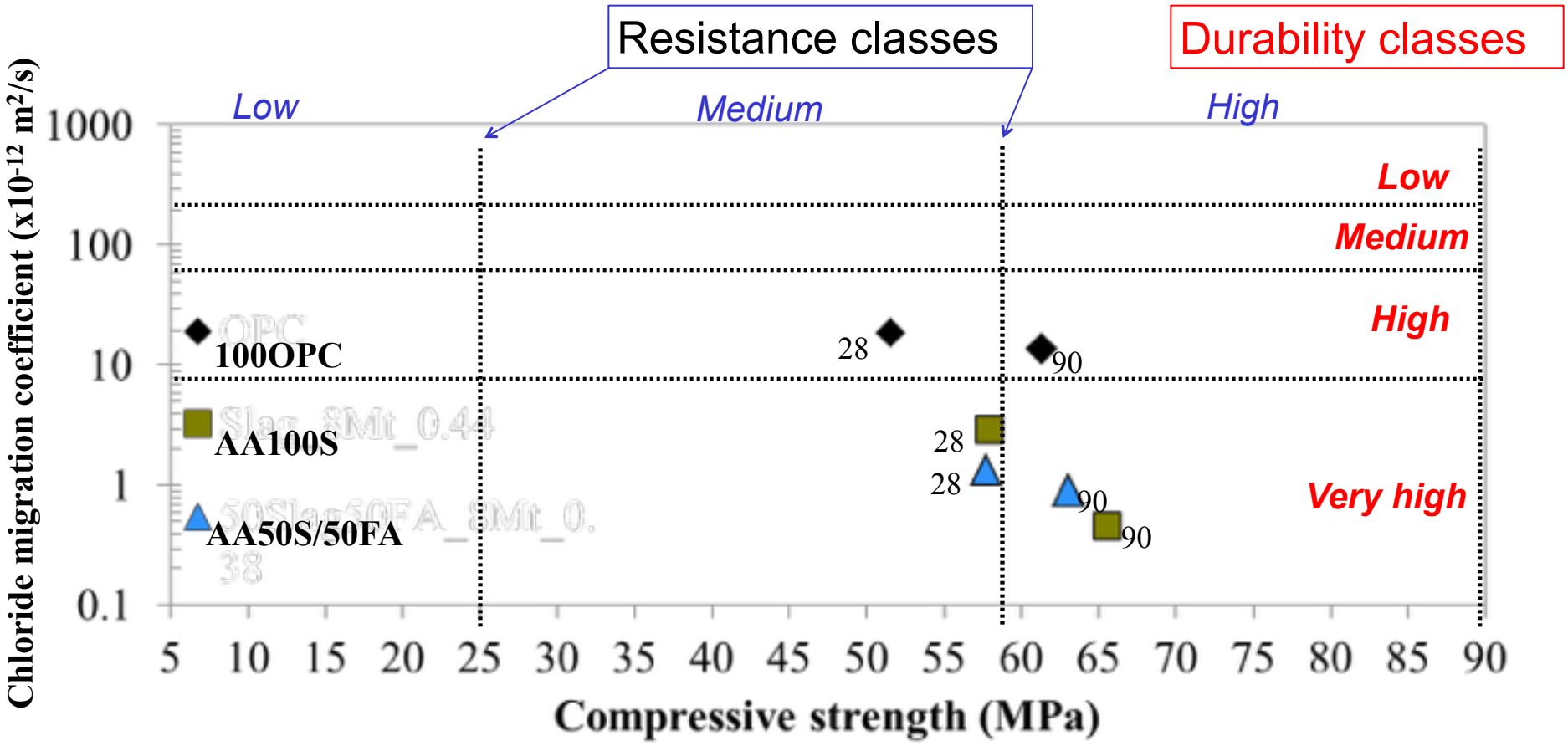
Role of Research in Market Adoption



Market Acceptance and Regulatory Approval



Durability Classes- Chloride Permeability



Baroghel-Bouny V.. 'Conception des bétons pour une durée de vie donnée des ouvrages, Maîtrise de la durabilité vis-à-vis de la corrosion des armatures et de l'alcali réaction, Etat de l'art et Guide pour la mise en œuvre d'une approche performantielle et prédictive sur la base d'indicateurs de durabilité', 2004.

Australian, European, US Standards

Prescriptive approach

Performance based approach

Results are good enough according to approved values

Performance is as good as a prescriptive concrete

Highly corrosive conditions	Porosity (%) (xy standard)	Gas Permeation (10^{-18} m^2) (xy standard)
<30 years	<16	-
30-50 years	<14	
50-100 years	<12	<100
100-120 years	<9	<10

Reference concrete

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Alkali-activated concrete

E-Crete™ rom the Ground Up’

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Footpaths

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Footpath, Westgate Freeway, Melbourne

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E-Crete™ recast Panels

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Thomastown Recreational & Aquatic Centre, Melbourne, Australia

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EcreteTM recast Products

- Manholes, Lids, Bases
- Box Culverts
- Septic Tanks
- Pits
- Floor toppings
- Pavers
- Anti-graffiti panels and Sound-barriers

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Greencast

Salmon Street, Port Melbourne, Bridge Decks

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Swan Street Bridge formwork pour – 17 Sept 09

Scope: 40MPa Retaining Wall
Location: Swan St Bridge, Richmond, Melbourne, Australia **Date:**2009

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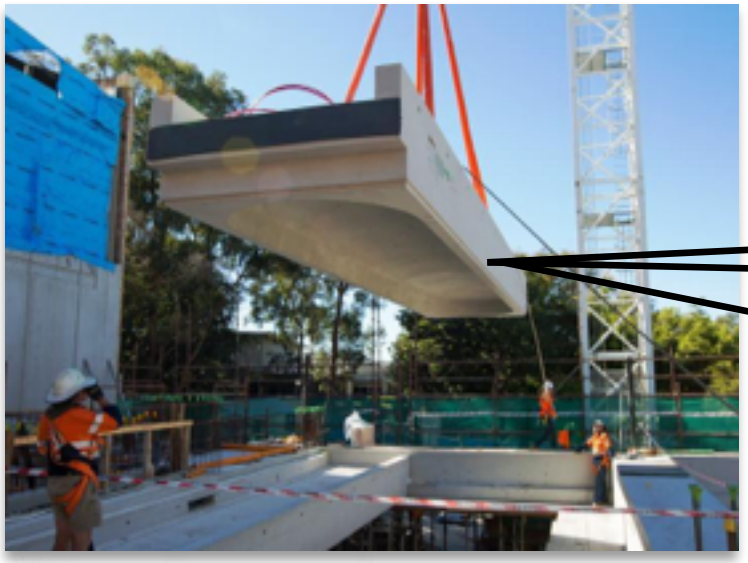
Scope: 40MPa – 33 Structural Beams (10.8m by 2.4m by 9.6m)
Suspended Floor in 5 storey building at University of Queensland, Australia



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Scope: 40MPa Precast Panels – Exposed Aggregate Finish
Location: Melton, Melbourne, Australia **Date:** 2012

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Regional Rail Link project, Melbourne

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Zeobond's Licensee for geopolymer pre-mix concrete

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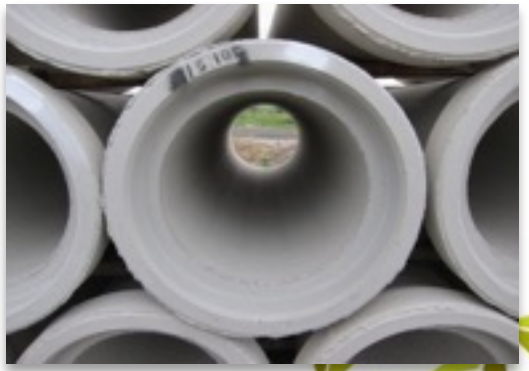
Scope: Reinforced Drainage and Sewerage Pipe, Melbourne, Kilmore, Australia **Started** in 2012

eCP
Low Carbon Concrete Pipe

RCPA
THE AUSTRALIAN PIPE COMPANY





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Sewerage Pipe Project at Werribee, February 2015

eCP
Low Carbon Concrete Pipe

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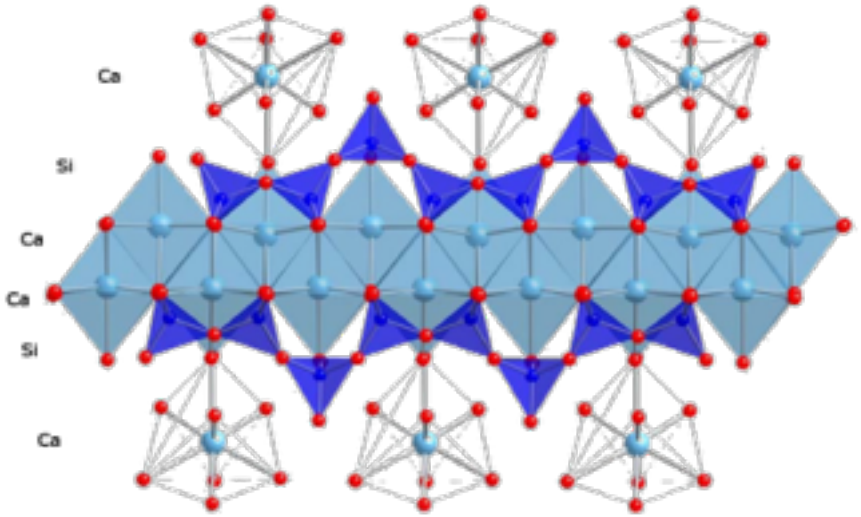
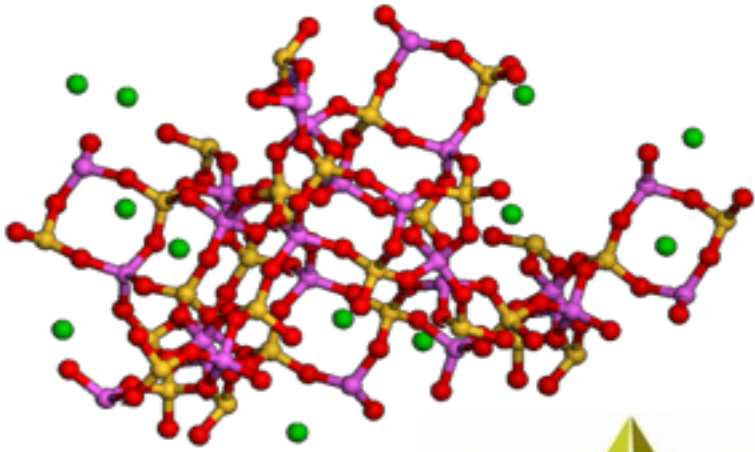
Portland Cement versus Geopolymer

- Hydrated Portland cement
  - Silica chains (“dreierketten”)
  - Break two Si-O-Si bonds to remove a silicon atom
  - Bound water of hydration
- Geopolymer
  - Highly crosslinked gel structure (pseudo-zeolitic)
  - Break four Si-O-(Si,Al) bonds to remove Si or Al
  - Little chemically bound water





C-S-H image from: I.G. Richardson, *Cement and Concrete Research*, **2004**, 34(9): 1733-1777.

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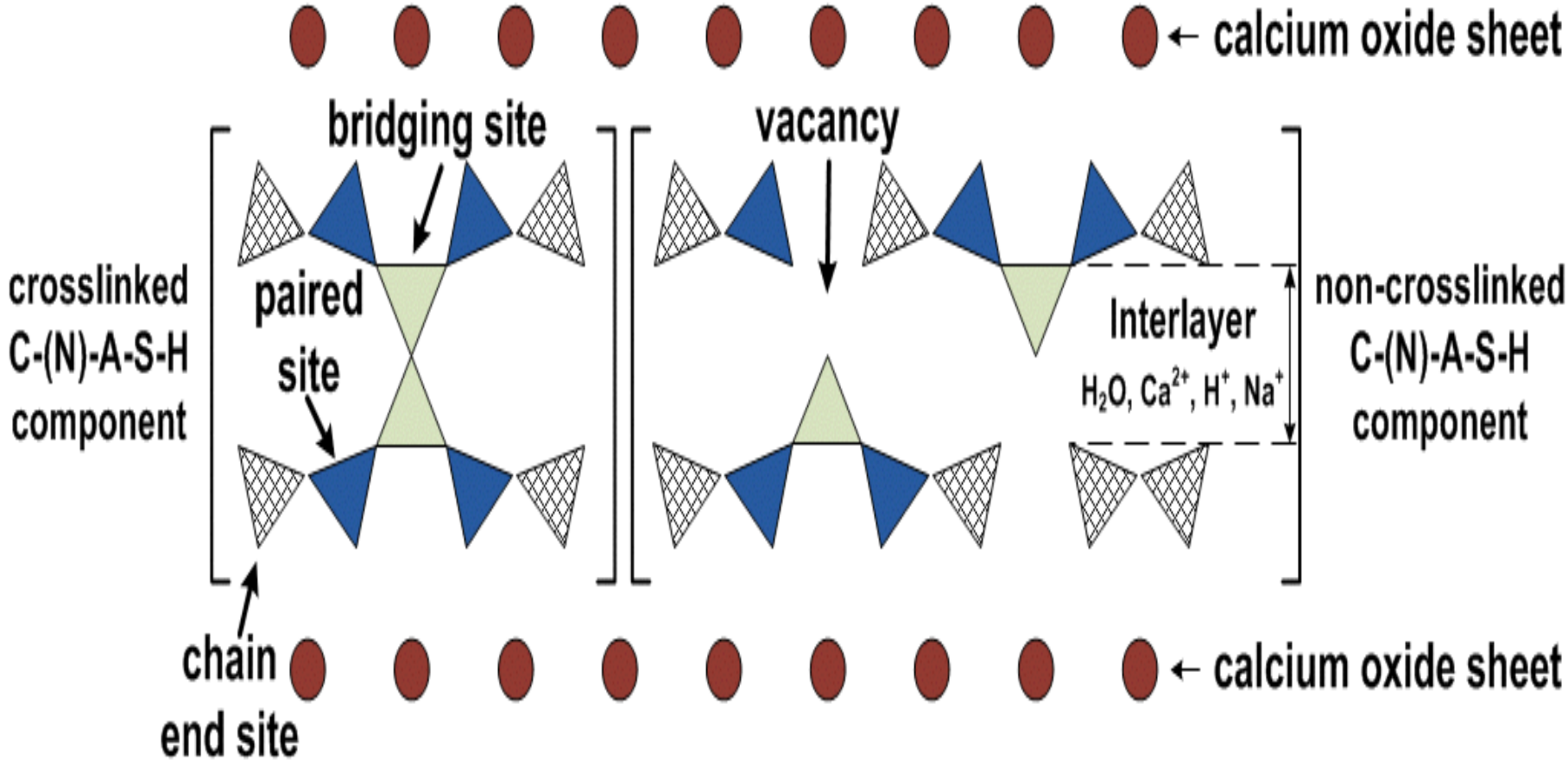
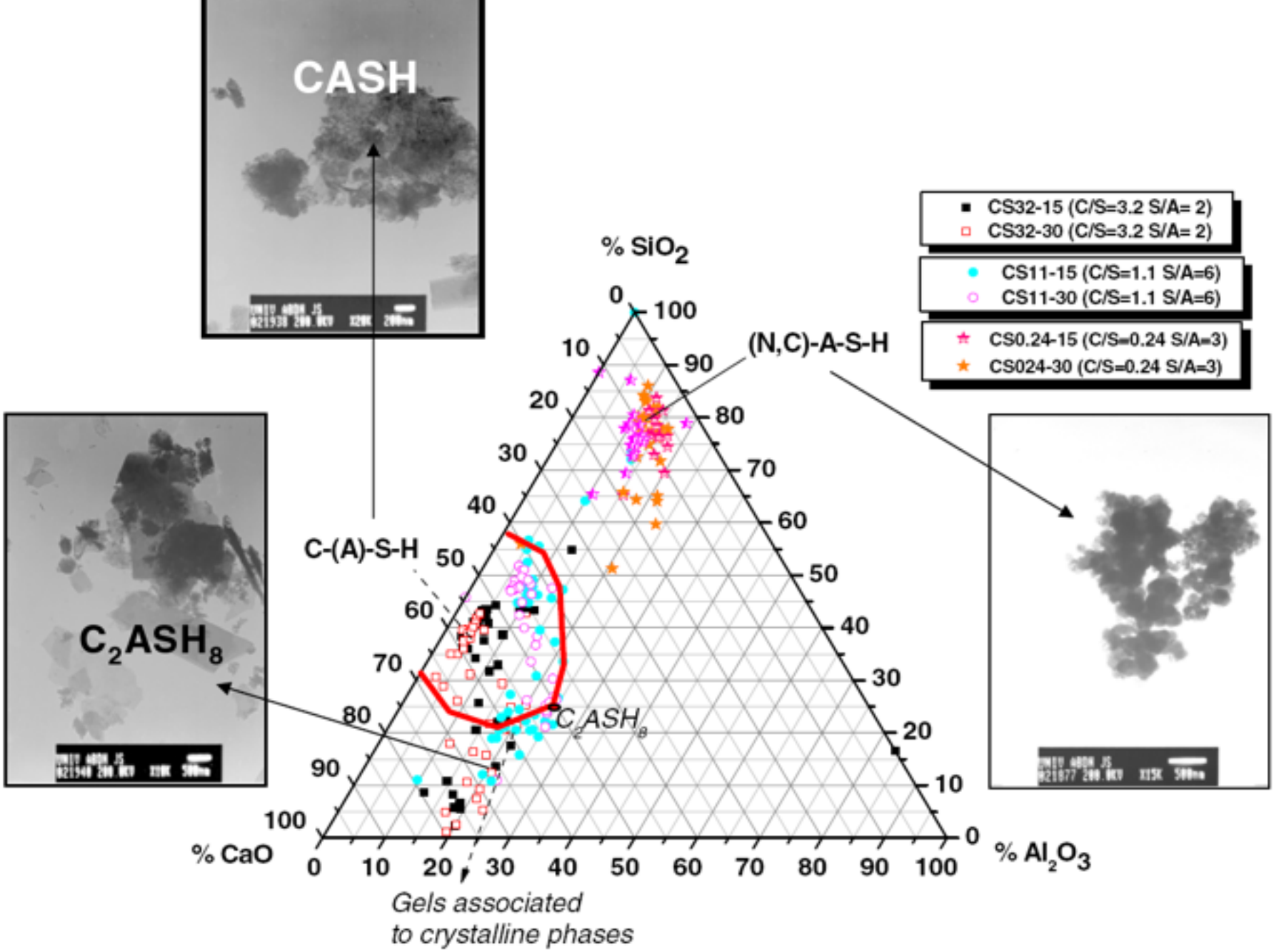
Cross-Linked Substituted Tobermorite Model (CSTM) (Provis & Myers, Sheffield)



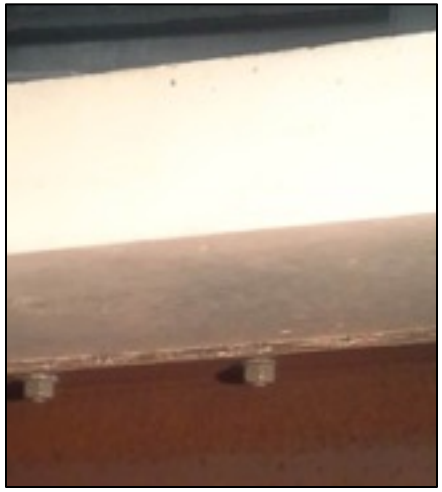


I. García-Lodeiro, A. Palomo, A. Fernández-Jiménez, D.E. Macphee, *Cement & Concrete Research*, **2011**, 41(9):923-931

Structural performance testing

Beam test: Strength at 800KN

Middle of the Bolted steel-AAC beam



50cm from the middle of the Bolted steel-AAC beam

Geopolymer concrete cracked in the middle but not further

No explosion as in usual cement based concrete

Good ductile behaviour of the geopolymer concrete in bending

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