LMC 2001- present

Professor Karen Scrivener, FREng
1980-1984 PhD Imperial College

Development of Microstructure during the Hydration of Portland Cement
Backscattered Electron Imaging
What is relevance?
1995-2001 LCR, Lafarge: Head of Calcium Aluminate Research

Acadia to Industry

UK to France
March 2001: Laboratory of Construction Materials EPFL
How to be relevant in Academia?
Creation of NANOCEM

- May 2002: first meeting, 6 partners, Paris
- Unsuccessful bid for EU network of excellence
- March 2003: Decision to form independent consortium
- May 2004: signature of consortium agreement

Continuing activity - indefinite duration
An Industrial Academic Partnership for Fundamental Research on Cementitious Materials
Industrial Partners

€s
For Core research programme

Academic Partners

Partner research projects
Industrial - academic dialog

**Academia**

- Long term advance of knowledge
- Integration of knowledge into new products and processes

**Industry**

- Interpretation of knowledge and clarification of possible progress areas

**Areas where lack of understanding or quantitative measurement blocks progress**
Industrial partners

LafargeHolcim
HEIDELBERGCEMENT
CRH
aalborg portland
TITAN
SCG
Sika
gcp applied technologies
CHRYSO
EPFL
Academic partners
What does this mean for LMC?
Personnel of LMC: ~10 PhD students; 4 postdocs
1 senior researcher; 4 technical staff, visitors
Our approach

Quantitative Microstructural Characterisation

Microstructural Modelling
Research areas

Hydration

“Green” cement and concrete

Specialist binders

Durability

Transport properties

Sulfate attack

Carbonation

ASR
Microstructure lies at the heart of the link between composition and performance.

- **Composition, Mixing, Time, Temperature, RH, etc.**
- **Microstructure**
- **Thermodynamics**
- **Kinetics**
- **Performance**
  - Rheology, setting
  - Hardening Cracking
  - Durability
Microstructural analysis methods

XRD
Electron Microscopy - SEM/TEM
Proton NMR
MIP, TGA, etc
Microstructural analysis methods

- Sample preparation
- Calorimetry
- Chemical shrinkage
- XRD
- Electron Microscopy
  - SEM/TEM
- Proton NMR
- MIP, TGA, etc

Written mostly by the students doing the experiments
5th Doctoral school LC3
Characterisation methods of blended cements
23rd – 26th April 2019
EPFL, Lausanne
Switzerland
MOOC launched September 2017

- Includes lectures and practical demonstrations:
- All available on U tube
Nowadays global warming is biggest challenge facing us
830 Billion Tons carbon dioxide!
-This is the CO2-budget remaining to be emitted if we want to keep global warming at a maximum of 2 Degrees Celsius temperature increase.

- Emissions in 2017: 36.79 billion tonnes
- At this rate we will exceed this amount in 23 years – 2041!
- Even if we cut emissions by 50% tomorrow it will be exceeded in 46 years
- We do not have 100 years to wait for Nanotechnology to deliver!
- WE NEED TO ACT NOW
Cement Based Materials: cannot be replaced by alternatives

Cementitious materials make up ~50\% of everything we produce. In the light of this, CO\textsubscript{2} emissions of 5-10\% very good.
What is available on earth?

- Na\textsubscript{2}O
- K\textsubscript{2}O
- Fe\textsubscript{2}O\textsubscript{3}
- MgO
- CaO
- SiO\textsubscript{2}
- Al\textsubscript{2}O\textsubscript{3}

- Too soluble
- Too low mobility in alkaline solutions
- The most useful

30 year old concrete

Slag cement blend
Hydraulic minerals in system CaO-SiO$_2$-Al$_2$O$_3$ 

BUT, what sources of minerals are there which contain Al$_2$O$_3$ $>$ SiO$_2$? 

Bauxite – localised, under increasing demand for Aluminium production, EXPENSIVE 

Even if all current bauxite production diverted would still only replace 10-15% of current demand.

CaO $>$ less CO$_2$
Portland based cements will continue to dominate

Blended cements are the most realistic option to reduce CO$_2$ and extend resources
Availability of SCMs

Classic SCMs – fly ash and slag are only around 15% of current cement production, will drop to < 10% in near future.
LC$^3$ is a family of cements, the figure refers to the clinker content.

- 50% less clinker
- 30% less CO$_2$
- Similar strength
- Better chloride resistance
- ASR resistant
Huge amounts of suitable clays presently stockpiled as waste
Trial productions in Cuba and India

Housing materials produced in factories by unskilled workers with no special training at 1:1 replacement

7 tonnes CO2 saved
Potential impact of LC$^3$ technology

<table>
<thead>
<tr>
<th>Year</th>
<th>Global cement production (Billion tons/year)</th>
<th>Clinker factor, global average (%)</th>
<th>Global SCM volume (Billion tones/year)</th>
<th>Global CO$_2$ reduction (Million tones/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2.6</td>
<td>79</td>
<td>0.5</td>
<td></td>
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<tr>
<td>2050 (CSI study)</td>
<td>4.4</td>
<td>73</td>
<td>1.2</td>
<td>200</td>
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</tbody>
</table>

IEA: International Energy Agency study for
CSI: Cement Sustainability Initiative
of WBCSD: World Business Council for Sustainable Development

Global potential of LC$^3$
\[ \Delta = 400 \text{ million tonnes per yr} \]

> whole of CO$_2$ emissions of France
But LMC is much more than LC3
### 40 PhD Theses

<table>
<thead>
<tr>
<th>Lucie Baillon</th>
<th>Patrick Juillard</th>
<th>Amelie Bazzoni</th>
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<tr>
<td>Severine Lamberet</td>
<td>Ruzena Chamrova</td>
<td>Mo Zalzale</td>
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<td>Mohsen Ben Haha</td>
<td>Aude Chabrelie</td>
<td>John Rossen*</td>
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<td>Xinyu Zhang</td>
<td>Carolina Prieto</td>
<td>Arnaud Muller</td>
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<td>Prakash Mathur</td>
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<td>Belay Dinesa*</td>
<td>Emelie l’Hopital*</td>
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<td>Ines Jaoudi</td>
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<td>Cyrille Dunant</td>
<td>Alain Giorla</td>
<td>Frank Bullerjahn</td>
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<tr>
<td>Vanessa Kocaba</td>
<td>Mathieu Antoni</td>
<td>* with Barbara Lothenbach</td>
</tr>
</tbody>
</table>

*with Barbara Lothenbach
MXG 2nd floor
Take stairs up one floor
More than 100 journal publications

More than 20 nationalities

Coming soon......

“the book”
Many Thanks

Especially to Lab staff: Philippe Simonin; Lionel Sofia
Secretarial staff: Maude Schneider; Anne Sandra Hofer
and their predecessors
Nanocem organizer: Marie Alix Dalang
Funders

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- Nanocem
- European Union
- Federal Office for Dam Surveillance
- Kerneos Aluminate Technologies
- Holcim
- Heidelberg
- SCG
- GCC
- Grace
- Cemsuisse