A promising essential technology travelling from Cuba to India via Switzerland: The case of the LC$^3$ project
Outline

- Critical role of cement and concrete to development
- Realistic options to lower environmental impact and increase supply
- The project
- The essential lessons learnt
Construction and Development

- According to UN Millennium Goals in 2010 there was a need to build decent houses for 828 million people.
- In addition to houses, the entire built environment and the infrastructure needs to be enlarged, maintained and improved.
- The World Bank identifies that in poor countries, less than 30% of the population have access to sanitation, and only 60% have a safe water supply.
- To cope with these social demands, we need to assure the supply of a cheap mineral binder (cement) for the entire world.
- Since we cannot shrink the build environment, there are limitations to dematerialize the construction industry.
- Therefore, the production of cheap mineral binder must grow to fulfil the expectations of a growing population.
Cement consumption and development

Sce: Cembureau & world bank (2005)
Demand for cement is forecast to rise: to meet the demands of a developing world

60% of consumption in China, which consumes 6 times more per head than India by 2050 demand in India forecast to overtake China
Concrete is the only viable solution to …

- … continue to reduce the environmental footprint **AND** satisfy the growing demand for construction materials at the same time
- … increase production with a more efficient use of resources

There are many construction materials which are well adapted to many circumstances, but concrete is by far the most used and has a relative low CO₂ emission compared to others

- *(a)* 34 GT of total resource consumption
- *(b)* 30 GT of CO₂ emitted by this consumption

<table>
<thead>
<tr>
<th>Material</th>
<th>Per year</th>
<th>A = % of a</th>
<th>CO₂e / yr</th>
<th>B = % of b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>17.1 GT</td>
<td>50.2%</td>
<td>2.6 GT</td>
<td>8.5%</td>
</tr>
<tr>
<td>Steel*</td>
<td>0.74 GT</td>
<td>2.4%</td>
<td>2.3 GT</td>
<td>8.1%</td>
</tr>
<tr>
<td>Timber</td>
<td>2.2 GT</td>
<td>6.5%</td>
<td>5.1 GT**</td>
<td>17%**</td>
</tr>
</tbody>
</table>

Figures for 2005 assembled by Dr Phil Purnell, U. Leeds, UK
Options for improvement
The resources of the earth mean we do not have a lot of options!

The composition of the Earth’s Crust limits the possible chemistries, but the limited range mean we can explore all options.
What about the different oxides

- Na$_2$O
- K$_2$O
- Fe$_2$O$_3$
- MgO
- CaO
- SiO$_2$
- Al$_2$O$_3$

   - Too soluble
   - Too low mobility in alkaline solutions
   - The most useful
Most promising approach – reducing the clinker factor

- **Process optimisation**
- **↓ CO₂**
- **↓ clinker factor**

SCMs – Supplementary Cementitious Materials

- Clinker
- Gypsum
- Cement
- Limestone
- Fly ash
- Slag
- Natural pozzolan

Often by-products or wastes from other industries
Increase in clinker substitution
But supplies limited

Figures from ~2013

- Used in cement
- Reserve

Fly ash: significant volumes with low performance
Availability of suitable clays, yellow and pale green regions, and others
Global potential of LC^3

<table>
<thead>
<tr>
<th></th>
<th>Global cement production</th>
<th>Clinker factor, global average</th>
<th>Global SCM volume</th>
<th>Global CO₂ reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Billion tons/year</td>
<td>%</td>
<td>Billion tonnes/year</td>
<td>Million tonnes/year</td>
</tr>
<tr>
<td>2006</td>
<td>2.6</td>
<td>79</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>2050 (CSI study)</td>
<td>4.4</td>
<td>73</td>
<td>1.2</td>
<td>200</td>
</tr>
</tbody>
</table>

Δ = 300 million tonnes per yr ~ whole of CO₂ emissions of France
Collaboration with Cuba through two rounds of SNSF(SDC) funding
The original idea

Understanding clay activation and pozzolanic reactivity
XRD: Cuban Clay

Position [°2Theta]

Ref.

1000°C
900°C
800°C
700°C
600°C
500°C
**Phase 1:**
2005 - 2009

**Phase 2:**
2009 - 2012

**Future objectives**
- Realise high levels of substitution with local materials

Electron microscopy enables us to understand why with 60% substitution we can get >90% of pure cement strength at 7 days.

*Calcined cuban soil can be a good substitute for cement*

![Graph showing evolution of compressive mechanical strengths](image)

- Support production
- Realise high levels of substitution with local materials
- Verify durability of materials
• 118 tonnes of original material with 18% moisture content were fed to the kiln
• 65 tons of calcined material were obtained
Elements cast at ECOT
It works for many clays!

<table>
<thead>
<tr>
<th>Kaolinite content (%)</th>
<th>Burgess</th>
<th>India1</th>
<th>Thai</th>
<th>India3</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td></td>
<td></td>
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<tr>
<td>80</td>
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<td>50</td>
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<tr>
<td>20</td>
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</table>
LC$^3$ project

- Entry phase 2012-mid 2014
- 4,03 Mio CHF from 1st June 2014 until 31st May 2017
LCC project funds

- CH / Global: 1'500'000 SDC funding, 1'500'000 External funds
- India: 1'000'000 SDC funding, 3 researchers
- Cuba: 2'000'000 SDC funding, 10 researchers
- 3 researchers
- 10 researchers
- 6 researchers
Potential impact of LCC is worldwide

However we cannot work everywhere at once
- Choice of India as main focus for work
- Brazil Thailand China associated countries
- Exploration of contacts in South Africa

Communication on global basis
- Publications in primary journals
- International conferences
- Technology transfer
Why focus in India?

- Size of the Indian market, and growth potential;
- Commitment of the Indian Government to CO₂ reduction;
- Availability and limitations of current technology (fly ash);
- Availability of a combination of research and field experience
  - IITs: Delhi, Madras, Bombay
  - TARA field applications
  - Recognised international actor
- Adaptability of the industry
  - 30-70% blended cements (Fly ash) in 15 years
Pilot Production used in concrete products
Overall aim, strategy

LCC is recognized as a cement suitable for general construction and measures for establishment in the market as a mainstream cement type initiated.
The essentials

- Need for enthusiastic partners on the ground
- Efficient cooperations take time
- First ideas were too complex
- People cannot pay extra for “green”, especially in countries where growth in demand will be highest
- In the cement business scale gives HUGE economies in terms of cost and emissions
  - Portland cement clinker is a highly optimised product
  - Better to then blend with other materials
- Need to work at many levels
  - Scientific understanding
  - Field experience
  - Major cement producers
  - Small producers
Thank you