Novacem
Carbon negative cement

Novacem – A novel cement for the construction industry

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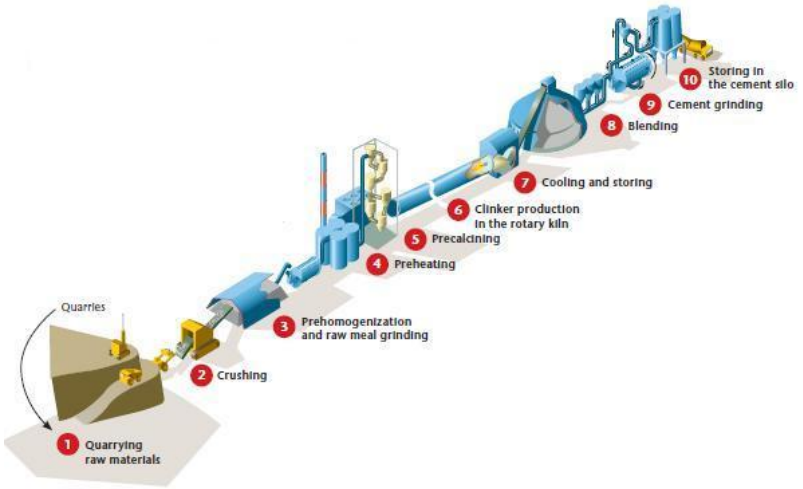
Cement is a vital construction material but with a recognised CO_2 problem

- Cement is a vital construction material. Cement volumes are around 2.6 billion tn and are forecast to reach 4.4 billion tn by 2050. Average emissions are 800 kg CO_2/tn cement while emissions of CSI cement companies average 650 kg CO_2/tn cement.
- In 2009 a Technology Roadmap was created by the IEA and WBCSD. Further improvements in energy efficiency, alternative fuels and clinker substitution were estimated to reduce 15% of industry's carbon emissions (i.e. 0.36 Gt out of 2.34 Gt CO_2 of baseline emissions)
- The Roadmap identified carbon capture and storage (CCS) as a breakthrough technology but it was estimated that even if it could effectively be developed its implementation would considerably increase capital and operational costs.



Novacem is a radical alternative to Portland cement

Novacem overview

- Spin-out from Imperial College funded by Imperial Innovations, the Royal Society Enterprise Fund, the London Technology Fund and Laing O'Rourke.
- Cement based on magnesium oxide, magnesium carbonates and pozzolans. Produced from magnesium silicates with reserves of over 20,000 billion tonnes.
- CO_2 emissions reduced up to 900 kg per tonne of Portland cement replaced.
- Working in collaboration with various partners, including Lafarge and Laing O'Rourke.

Novacem has three fundamental differences in embodied carbon compared to current cement production

Embodied carbon: Novacem vs. current ordinary Portland cement production

Current cement production*

1. Carbonate feedstock: limestone is dug up and processed. Typically **400kg of CO_2** released from limestone per tonne of cement.
2. High temp process (1,450°C) requires fossil fuel. Typically **400kg of CO_2** created from fuel per tonne of cement.
3. **No absorption of CO_2 in cement production.**

Total typical emissions of **+800kg** CO_2/tn cement

vs.

Novacem

1. Non-carbonate feedstock (uses magnesium silicates) so **no CO_2 from the raw material**.
2. Lower temperature process (700°C) can better utilise biomass fuel. **0-420kg CO_2** created per tonne of cement, depending on fuel mix used and choice of feedstock.
3. Cement composition includes a carbonate created during production process by absorbing CO_2. **30-100 kg CO_2** absorbed per tonne of cement.

Total typical emissions of **-100kg to +320kg** CO_2/tn cement

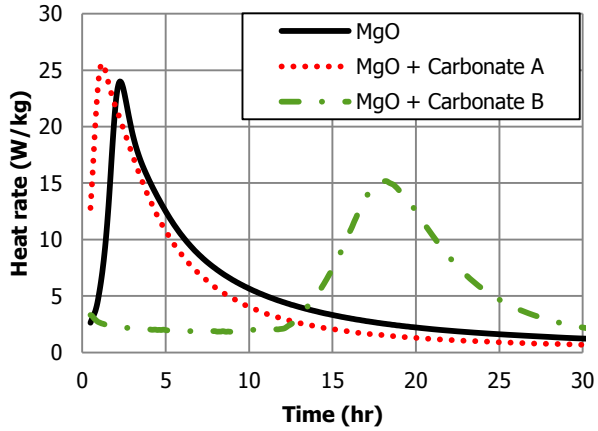
* Global weighted average figures from International Energy Agency 2007

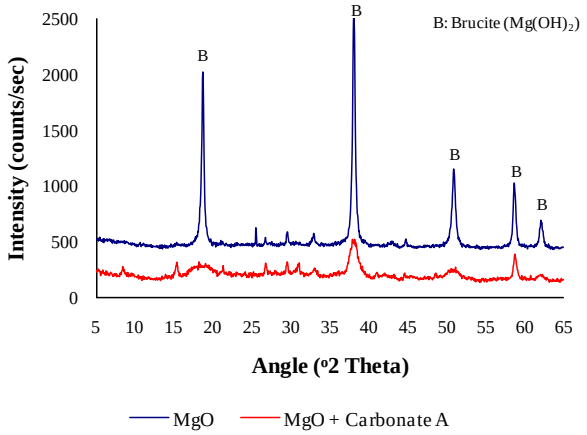
Initial concept of Novacem cement

- MgO based-cements were first discovered in 1867 by Sorel. They were normally a mixture between MgO and a soluble salt ($MgCl_2$, $MgSO_4$ or soluble phosphates) and they were used in niche applications due to durability problems and/or high production costs.
- The Novacem cement concept was initially based on utilising the high CO_2 absorption capacity of magnesium oxide in order to develop a new class of cements.
- However, in order to compete with Portland cement there were two major problems that we had to solve:
  - How do you accelerate strength development and reach performance parity?
  - How do you develop a manufacturing process that is low carbon, low cost and scalable?

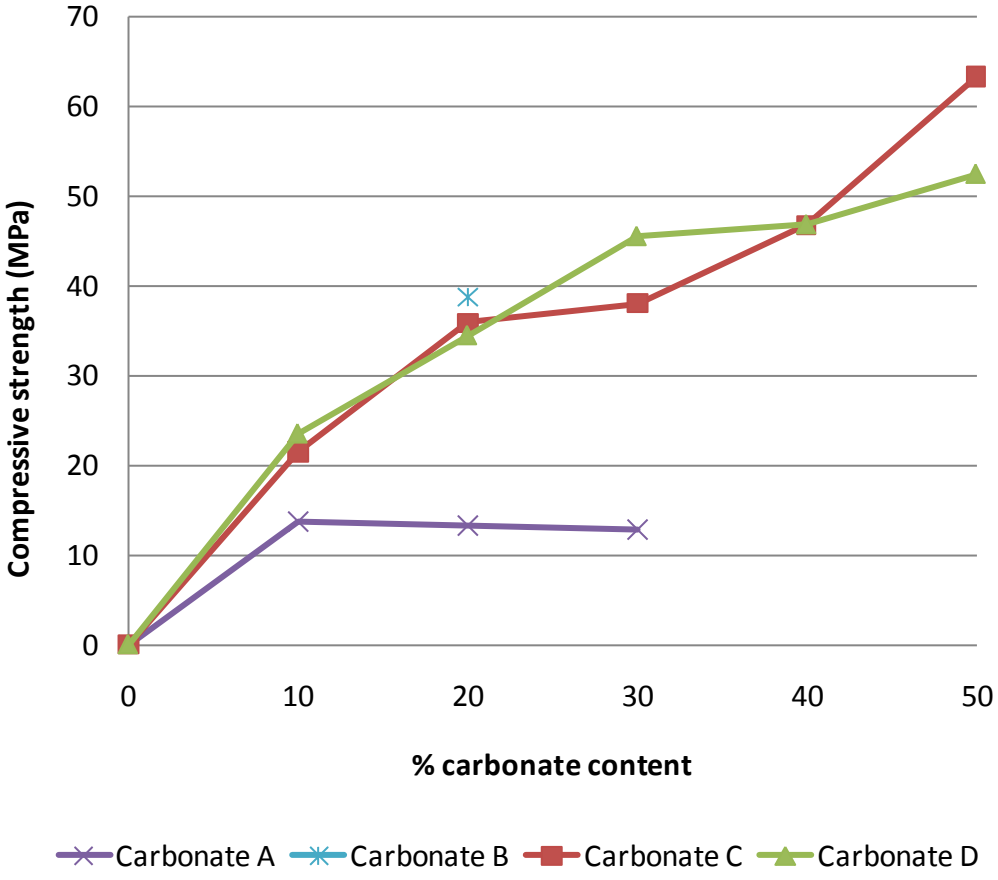
MgO-carbonate systems as the basis of Novacem cement

- Initial work concentrated on the acceleration of MgO carbonation in order to aid strength development.
- It was found that blends of MgO and hydrated magnesium carbonates carbonated significantly faster that pure MgO.
- The use of these carbonates modified the hydration rate and mechanism of MgO and led to the production of semi-amorphous and nano-sized $Mg(OH)_2$ crystals.
- This allowed the development of a MgO-magnesium carbonate cement system which could develop strength through hydration rather than carbonation.





MgO-carbonate cements achieve considerable mechanical properties



The type of hydrated carbonate influences the hydration kinetics of MgO.

This influences the carbonate content of the cement and the mechanical properties.

Mechanical properties can be further improved by reducing the high water/cement ratio used (w/c 0.58).

Novacem composition is now based on a combination of MgO, SiO_2 and hydrated magnesium carbonates

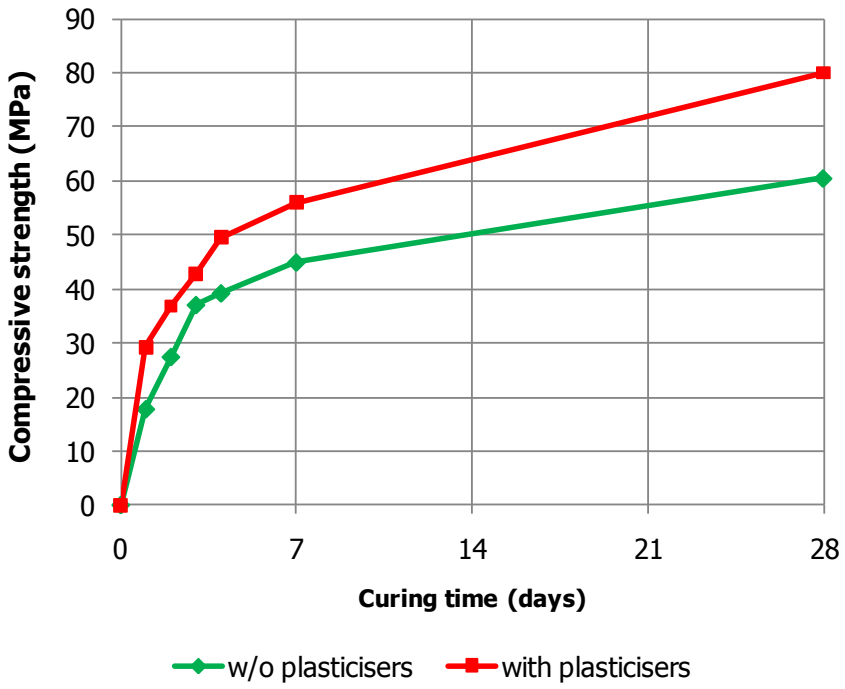
- Novacem cement composition is a unique blend of MgO, SiO_2 and hydrated magnesium carbonates

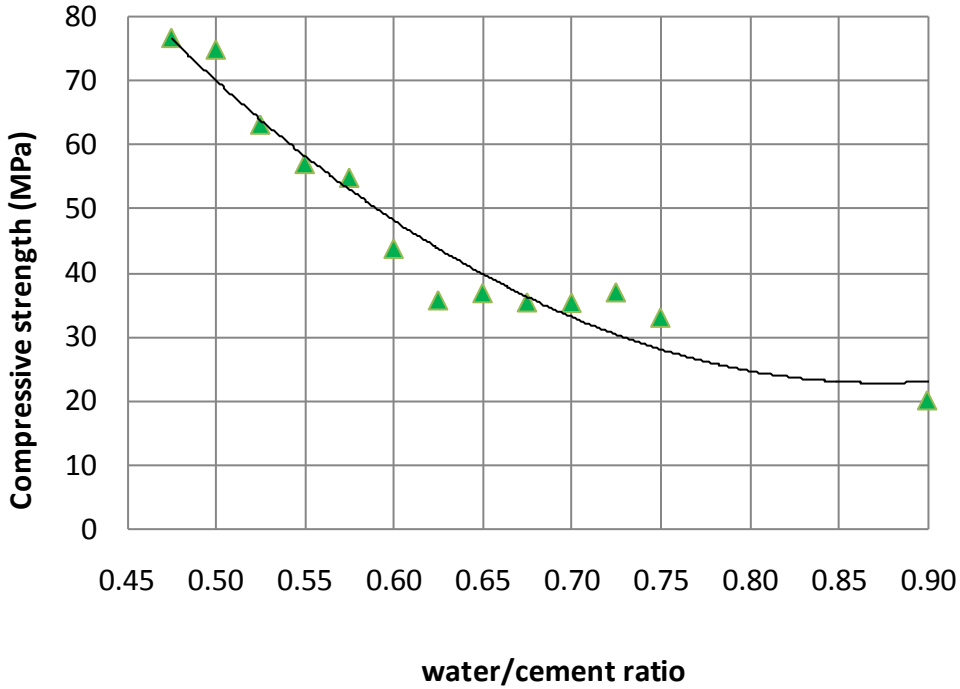
  $x\ MgCO_3 \bullet y\ Mg(OH)_2 \bullet z\ H_2O$ (i.e. $4MgCO_3.Mg(OH)_2.4H_2O$)

- Early strength development is due to MgO hydration reaction while later strength is due to pozzolanic reactions and the formation of magnesium silicate hydrates.
- The addition of the hydrated magnesium carbonates has two important advantages:
  - Improves mechanical strength to the cement system by modifying the cement hydration chemistry
  - The carbonates are net sinks of CO_2 so the cement can achieve a carbon negative footprint during the production stage

Performance characteristics of Novacem cement

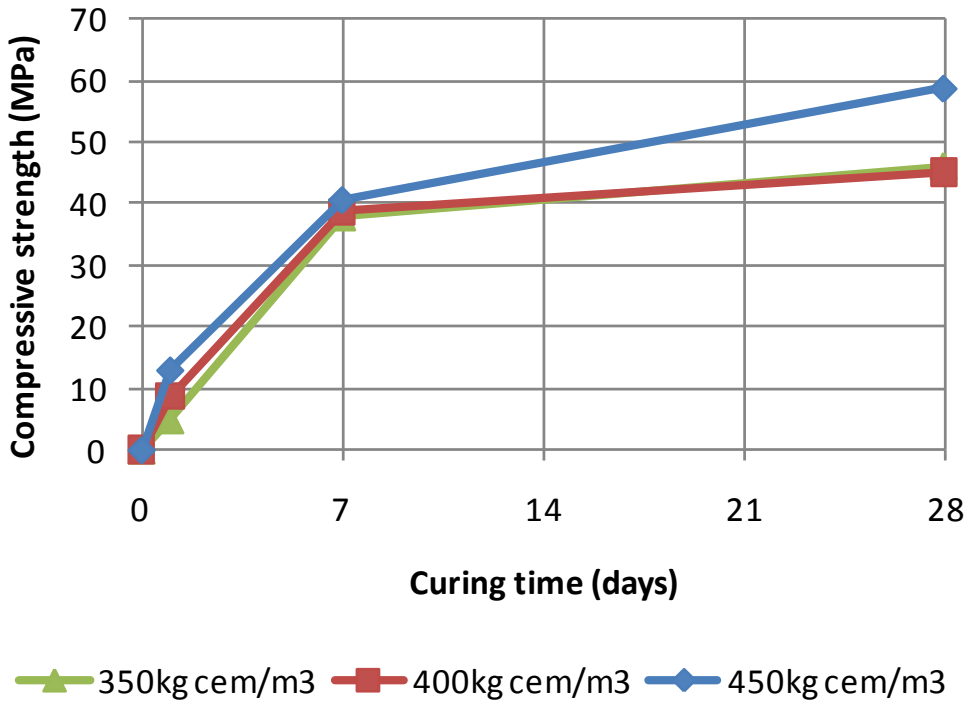
Over 70% of 28 day strength is achieved after 7 days curing. Higher water/cement ratios than PC are still needed to make Novacem cement. Plasticisers are required at water to cement ratios lower than 0.58.





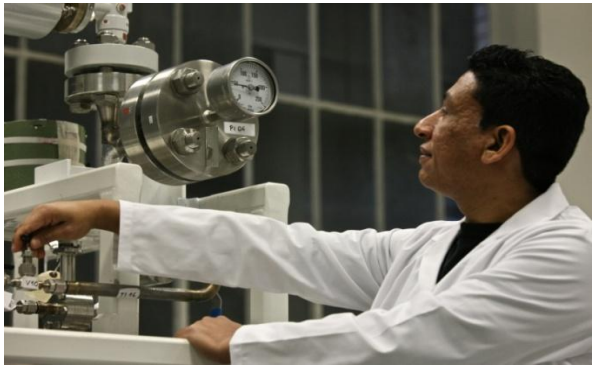
Performance characteristics of Novacem concrete

Concrete trials were undertaken with Laing O'Rourke. Samples achieved 40-60 MPa strength which is in line with Portland cement concrete.



Novacem's production process is using a non-carbonate based feedstock

- The production of low carbon Novacem cement is based on the carbonation of magnesium silicate minerals.
- A batch pilot plant was developed through Novacem's £1.5m collaborative TSB project in conjunction with partners Laing O'Rourke, Rio Tinto Minerals, WSP Group and Imperial College.
- Pilot plant installed in January 2010 and began operating reliably in May 2010. The plant was successfully upgraded in late 2010 to increase plant capacity and operate in a batch-continuous mode.



Summary

- **Performance:** continuous improvement aiming at full performance parity – more testing needed to prove durability and long term performance
- **Process:** good progress in building a pilot plant and converting it from batch to batch-continuous operation
- **Raw material:** much clearer understanding; reserves much higher than previously thought but significant work is remaining to understand reserves at a local level

Thank you!

These slides were used as visual aids accompanying an oral presentation by Novacem staff. As such they are not a complete record of the presentation.

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