State of the Art - Concrete

Innovations in the World’s Most Common Building Material

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What is it?

- Water
- Aggregate (Sand, Gravel, Etc.)
- Cement
A Brief History

First developed by the Egyptians, guarded as a military secret*

Utilized by Romans in a variety of structures

1817 – Louis Vicat patents his recipe for “artificial stone”

1824 – Joseph Aspdin invents Portland Cement

1849 – Joseph Monier develops reinforced concrete

*Lafarge: Concrete Reborn. 2009 Press Kit
Benefits of Concrete

- **Durability** – Life spans for concrete buildings can be up to triple that for buildings of other materials.

- **Insulator** – Has a relatively high thermal mass which allows for operating energy efficiency and reduced heating and cooling costs. Also an acoustic insulator that allows for the absorption of sound (i.e. highway tunnels)

- **Reflectivity** – Assists in reducing heat-island effect

- **Locally Produced** – Typically mixed within 300 miles of its intended site and made to order
Where is it used?

Every year, over 7 billion cubic meters of concrete are produced.
Drawbacks of Concrete

- Cement requires heating limestone and other ingredients to 2,640 degrees F (1,450 degrees C)

- 1.6 tons of raw material (i.e. limestone, clay, shale, etc.) to produce 1 ton of cement

- Anywhere from 7 – 12% of the world’s annual CO2 emissions are related to concrete manufacture (90% of that is related to cement production)
Innovation in Concrete

- Use of volcanic ash, blast furnace slag, fly ash and silica fume as a partial substitute for cement.

<table>
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<tr>
<th>Replacement Factor for Raw Materials</th>
<th>CO2 reduction</th>
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<tbody>
<tr>
<td>15%</td>
<td>250 million tons</td>
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<tr>
<td>50%</td>
<td>800 million tons</td>
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- Magnesium = Carbon Offset

Equivalent of removing ¼ of all cars from the road
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THE PROCESS

CO₂ → CAPTURE → USE → BUILDING MATERIAL

- CO₂ from flue gas (industrial emitters)
  - Use raw flue gas – no concentration required

- CO₂ captured and converted to a solid
  - Calcium Carbonate novel cement

- Used to make a range of building material products

Source: Calera website (www.calera.com)
Drawbacks of Concrete

Concrete is subject to cracking

- Heating during setting process
- Constant freeze/thaw cycles
- De-icing salts on roads and bridges

- Natural disasters
- Mechanical loading
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**Self-Healing Concrete**

- Memory Polymers – A shape memory polymer is embedded in the concrete. Upon cracking, the polymers are heated which activate them to form their original shape, effectively pulling the crack closed.

- Microencapsulation – capsules filled with a repairing solution are incorporated into concrete mixture. As a crack spreads it ruptures the capsule which releases the healing agent. The agent then flows into the crack, reacting with the catalyst and forming a gel which prevents further spreading.

- Bacterial – Mineral producing bacteria are placed into the concrete mixture. When exposed to water, the bacteria produces a material (i.e. calcium carbonate) which acts as a bio-cement to fill cracks.
The annual costs to repair, strengthen and protect concrete is estimated to be $18 - $21 billion.*

Corrosion in bridges and highways creates $8.3 billion of annual maintenance expenditure for the federal government.**

*https://www.icri.org/PUBLICATIONS/2008/PDFs/marapr08/CRBMarApr08_Goodwin.pdf
Drawbacks of Concrete

Typically seen as a Cradle to Grave product
(Most used concrete ends up in landfills)
Innovation in Concrete

Waldspirale Darmstadt, built in 2009 with concrete using recycled, crushed concrete from previous demolitions.

Pervious pavement made using recycled concrete aggregate
Questions?

The Wilshire on Grand
New Guinness World Record for “Longest Continuous Concrete Pour”
Set February 16, 2014
References

- “Recycling Concrete” - World Business Council for Sustainable Development
- “Self-Healing Concrete with a microencapsulated healing agent” – Pelletier, Brown, Shukla and Bose. University of Rhode Island
- Corrosion Costs and Preventive Strategies in the United States. NACE. 2002
- Self Healing Concrete – A Sustainable Future. Simon Dunn. Cardiff University.