Concrete

- The most used construction material:
  - Annual production of cement in Canada: 10Mt
  - Annual production of concrete in Canada: 60Mt

- The carbon emission-intensive material:
  - One ton cement emits 0.8 ton CO$_2$
  - Canadian cement industry emits 8 Mt CO$_2$/year

- Low carbon concrete strategy:
  - Use supplementary cementitious materials (SCM such as Fly ash and slag) to partially replace cement
  - Use carbon dioxide to activate early strength, at the same time sequester CO$_2$ in concrete
Closed System of Calcium Compound: Low carbon concrete
Converting CO$_2$ into CaCO$_3$ by Carbonation Reaction

- After concrete is formed and CO$_2$ gas is injected into the concrete during curing:
  - $3\text{CaO} \cdot \text{SiO}_2 + 3\text{CO}_2 + \mu\text{H}_2\text{O} \rightarrow 3\text{CaO} \cdot 2\text{SiO}_2 \cdot 3\text{H}_2\text{O} + 3\text{CaCO}_3$
  - $2\text{CaO} \cdot \text{SiO}_2 + 2\text{CO}_2 + \mu\text{H}_2\text{O} \rightarrow 3\text{CaO} \cdot 2\text{SiO}_2 \cdot 3\text{H}_2\text{O} + 2\text{CaCO}_3$
  - $\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$
  - $3\text{CaO} \cdot 2\text{SiO}_2 \cdot 3\text{H}_2\text{O} + 3\text{CO}_2 \rightarrow 3\text{CaCO}_3 + 2\text{SiO}_2 \cdot 3\text{H}_2\text{O}$
Concrete Products for CO$_2$ Conversion

Masonry blocks  
Fiber-cement panels  
Prefabricated buildings  
Hollow-core slab  
Concrete pipes
Carbonation Curing Process

Concrete: 75% cement and 25% SCM (supplementary cementitious materials)
Carbonation process: pressure=0.5 bar, time=2-4 h
Carbon dioxide uptake by concrete: 20% of cementitious binder mass
Full Scale Production of Concrete Blocks

Boehmers Blocks in Ontario with 5 autoclaves
Concrete blocks: normal weight, lightweight, high strength
Autoclave process will be replaced by carbonation process
Full Scale Production
CO2 Gas: By-Product of Ethanol Production
Carbonated and Autoclaved Blocks
# Low Carbon Concrete Blocks

<table>
<thead>
<tr>
<th></th>
<th>Conventional block</th>
<th>Low carbon block</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cement (kg)</strong></td>
<td>2.3</td>
<td>1.73</td>
</tr>
<tr>
<td><strong>SCM (kg)</strong></td>
<td>0</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>Stone (kg)</strong></td>
<td>14.5</td>
<td>14.5</td>
</tr>
<tr>
<td><strong>Water (kg)</strong></td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Total mass (kg)</strong></td>
<td>17.9</td>
<td>17.9</td>
</tr>
<tr>
<td><strong>CO₂ emission due to cement (kg)</strong></td>
<td>1.84</td>
<td>1.38</td>
</tr>
<tr>
<td><strong>CO₂ reduction due to SCM (kg)</strong></td>
<td>0</td>
<td>-0.46</td>
</tr>
<tr>
<td><strong>CO₂ reduction due to uptake (kg)</strong></td>
<td>0</td>
<td>-0.46</td>
</tr>
<tr>
<td><strong>Net CO₂ emission per block (kg)</strong></td>
<td>1.84</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>Percent CO₂ reduction</strong></td>
<td>0</td>
<td>75%</td>
</tr>
<tr>
<td><strong>Strength (MPa)</strong></td>
<td>25</td>
<td>33</td>
</tr>
</tbody>
</table>
Benefits of Low Carbon Concrete

- **Environmental:**
  - Carbon emission reduction up to 75% in comparison to conventional products

- **Technical:**
  - Accelerated early strength
  - Improved durability due to the formation of nano-CaCO$_3$ crystals

- **Economical:**
  - Low cement and low embodied energy
  - Steam can be replaced by carbon dioxide
An Emerging Industry for Low Carbon Concrete

- Carboclave Technology, (a spin-off from Boehmers Blocks), Ontario, Canada.
- CarbonCure Technology, Halifax, Canada
- Carbicrete Technology, Montreal, Canada
- Solidia Technology, NJ, USA
Acknowledgment

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- NSERC I2I Grants
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- St Lawrence Cement
- Boehmers Blocks
- Canadian Concrete Masonry Producers Association (CCMPA)