The Sustainable Attributes of Portland Cement Concrete

Lionel Lemay, PE, SE, LEED AP
Sr. Vice President, Sustainable Development
Sustainable Development

“Development that meets the needs of the present generation without compromising the needs of future generations.”

The World Commission on Environment and Development
Triple Bottom Line

Social

Bearable

Equitable

Environment

Sustainable

Viable

Economic
Environmental Impacts
Measuring Green Infrastructure
Cradle to Cradle Perspective

Life Cycle

Material Acquisition
Manufacturing
Construction
Operation
Reuse/Recycling
Material Acquisition Phase

Material Acquisition
Manufacturing
Construction
Operation
Reuse/Recycling
Impact of Extracting Materials

- Extraction of any raw material has impact on the environment.
- Natural Resources Canada compared impacts in research study:
  - Logging (wood)
  - Iron ore mining (steel)
  - Aggregate quarrying (concrete)
- Extracting aggregate for concrete has lower impact than other materials.
## Impact Index

<table>
<thead>
<tr>
<th>Resource Impact Index</th>
<th>Concrete</th>
<th>Limestone Quarrying</th>
<th>1.00</th>
<th>1.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>Iron Ore Mining</td>
<td>2.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>Boreal Timber Harvesting, Coastal Timber Harvesting</td>
<td>2.50</td>
<td>3.25</td>
<td></td>
</tr>
</tbody>
</table>

Source: Natural Resources Canada
Logging for Wood

- Disruption per unit of building material is high
- Renewal takes generations
- Stream damage from landslides is common

Source: Natural Resources Canada
Iron Ore Mining for Steel

- Very deep open pit mining
- Mines are rarely restored
- Duration of disruption may be forever

Source: Natural Resources Canada
Aggregate & Limestone Quarrying

- Closely contained and temporary
- Restored within 1 to 2 years
- Most abundant materials on earth

Source: Natural Resources Canada
Manufacturing Phase

Material Acquisition
Manufacturing
Construction
Operation
Reuse/Recycling
Carbon Dioxide

- Most materials require little processing
- Low energy of production
- Manufactured and harvested locally
- Low transportation energy
- Contributes to local economy

The Mix in Ready Mixed Concrete

- Air: 6%
- Cement: 10%
- Water: 18%
- Sand: 25%
- Gravel: 41%
Does cement manufacturing generate CO₂?

- As with all industrial processes, cement generates CO₂.
- Made from natural minerals:
  - calcium (60%) from limestone
  - silicon (20%)
  - aluminum (10%)
  - iron (10%)
- Heated in large kiln to 1500° C
- Converts raw materials to clinker
- CO₂ generated from two sources:
  - Fossil fuels in burning process
  - Calcination - calcium carbonate broken down to calcium oxide with release of CO₂
U.S. Cement CO₂ Emissions

Does concrete manufacturing produce CO₂?

- Water, sand, stone or gravel and other ingredients make up about 90% of concrete
- Mining sand and gravel, crushing stone, combining the materials and transportation concrete requires very little energy
- Emits a relatively small amount of CO₂
- Amounts of CO₂ embodied in concrete primarily function of cement content
- Structures are built with concrete and not cement
CO₂ Reabsorbed by Concrete

- CO₂ reabsorbed into concrete through carbonation
- 33% to 57% of CO₂ emitted from calcination is reabsorbed through carbonation over 100-year life

How does concrete compare to other building materials?

Concrete has low energy consumption and CO₂ emissions compared to:

- Steel
- Wood
- Asphalt
Concrete vs. Wood Frame

- Thermal mass systems save energy
- Lower CO2 emissions
- Concrete systems reduced energy by 17%

2x12 (R 38) = 6” ICF

Compared 5-story office building

- Steel frame with light frame exterior walls
- Concrete frame with solid concrete exterior walls

Energy of Production

Concrete Frame vs. Steel Frame

Study compared the CO$_2$ emissions of concrete and steel framed buildings

- Concrete frame accounted for 550 kg of CO$_2$ per square meter of floor area
- Steel frame accounted 620 kg of CO$_2$ per square meter of floor area

Concrete vs. Asphalt Pavements

## Concrete vs. Asphalt Pavements

### Annual Savings and Reductions for Major Urban Arterial Highway

<table>
<thead>
<tr>
<th></th>
<th>Results based on driving on concrete vs. asphalt pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum 0.8%</td>
</tr>
<tr>
<td>Fuel Savings (liters)</td>
<td>377,000</td>
</tr>
<tr>
<td>Dollar Savings ($)</td>
<td>338,000</td>
</tr>
<tr>
<td>CO₂ Reductions (t)</td>
<td>1,039</td>
</tr>
</tbody>
</table>
Concrete vs. Asphalt

- LCA on concrete and asphalt roadways
- Construction and maintenance over 50-year life cycle for high volume highway
- Asphalt required 3 times more energy
- Global Warming Potential (CO2 equivalents)
  - Asphalt = 738 t/km
  - Concrete = 674 t/km

What is concrete industry doing?

- Committed to continuous environmental improvement
- P2P Initiative (Prescriptive to Performance Specifications for Concrete)
- The P2P Initiative removes limits on materials
- Allows producers to meet performance requirements
- Minimize environmental impact

www.nrmca.org/P2P
Recycled Industrial Byproducts

- Uses of industrial byproducts
  - Fly ash
  - Blast furnace slag
  - Silica fume
- Supplement a portion cement
- Otherwise end up in landfills
- Called supplementary cementitious materials (SCMs)
- Improves strength and durability
- Reduces CO₂ embodied in concrete
  - Typical values 15% to 40%
  - As much as 70%
Construction Phase

Material Acquisition
Manufacturing
Construction
Operation
Reuse/Recycling
Concrete Construction

- Made specifically for each order
- Little to no waste is generated
- Short transport
- No shipping carton or wrapping
- Leftovers
  - landscaping blocks
  - Traffic barriers
Returned Concrete Options

Batch fresh materials
Reship

Paving at plant

Truck wash, batch plant or discharge after treatment

Solids to landfill

Settling pond

Reclamation
Windrow & Crush
Blocks
Thermal Mass

- Increase thermal lag
  - Off peak demand
  - Lower energy costs
- Lower peak energy
  - Smaller, more efficient HVAC equipment
- Reduce temperature swings
  - Less heating and cooling energy required
High Performance Wall Systems

- Tilt-up Concrete Walls
- Insulating Concrete Forms
- Removable Form Systems
Urban Heat Island Effect

- Residential zones are 3° warmer
- Downtown areas are 7° warmer
- Due to dark-colored roofing and pavement

Source: Lawrence Berkeley National Laboratory
Urban Sprawl

- NASA Thermal Images of Atlanta

Cool Communities

- Use light colored roofing and cladding
- Use light colored pavements
- Landscape shading
- Reduce air temperatures by 5°
- Reduce air conditioning by 18%
Roofing and Cladding

- Concrete roofing and cladding
  - Light colored
  - Highly reflective
- Research shows 40% reduction in cooling energy
Pavement and Landscaping

- Concrete pavement and landscaping
- Article in MIT Technology Review
  - “…blacktopping should be discontinued…”
  - Use light-colored pavements
  - Concrete costs slightly more but has a lower life cycle cost
Concrete Pavement
Reduced Lighting Requirements

- Asphalt requires 24% more poles
- Asphalt costs 24% more
  - Initial costs
  - Maintenance costs
  - Energy costs

Stormwater Management

- Pervious Concrete
  - 15-25% voids
  - Rainwater percolates through the slab
  - Minimizes runoff to surrounding streams and lakes
  - Functions like retention basins
  - Recharges groundwater supplies
Pervious Concrete Applications
## Indoor Air Quality

<table>
<thead>
<tr>
<th>Building Material</th>
<th>VOC Emission (mg/m³h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl flooring</td>
<td>2.3</td>
</tr>
<tr>
<td>Particle board</td>
<td>2.0</td>
</tr>
<tr>
<td>Plywood</td>
<td>1.0</td>
</tr>
<tr>
<td>Acrylic Latex Paint</td>
<td>0.43</td>
</tr>
<tr>
<td>Linoleum</td>
<td>0.22</td>
</tr>
<tr>
<td>Carpet</td>
<td>0.080</td>
</tr>
<tr>
<td>Gypsum board</td>
<td>0.026</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Source: University of Western Ontario
Reduce VOC Emissions

- Use exposed concrete:
  - Decorative floors
  - Textured walls
  - Exposed ceiling
Durability and Versatility

- Most widely used building material
- Extremely durable
  - Doesn’t rot
  - Doesn’t rust
  - Doesn’t burn
- Low maintenance
- 2000 year track record of performance
Reuse/Recycling Phase

Material Acquisition
Manufacturing
Construction
Operation
Reuse/Recycling
Supplementary Cementitious Materials

- Fly ash
  - From coal-fired electrical power plants
- Blast furnace slag
  - From steel manufacturing
- Silica Fume
  - From silicone manufacturing
Key to high performance

- High Performance
  - Improves durability
  - Increases strength
  - Improves constructability

- Environmental Benefits
  - Reduces waste
  - Reduces raw material extraction
  - Reduces energy of production
  - Reduces CO₂
Recycled concrete

- Fills and bases
- Roadways and parking areas
- Driveways and sidewalks
- Shoulders, curbs, gutters
- Landscaping features
- Foundations
- Some Concrete Structures
## Summary

<table>
<thead>
<tr>
<th>Concrete Feature</th>
<th>Environmental Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most ingredients require little processing</td>
<td>Minimizes energy of production</td>
</tr>
<tr>
<td>Most materials harvested and manufactured locally</td>
<td>Minimizes transportation energy</td>
</tr>
<tr>
<td>Building systems combine insulation and thermal mass</td>
<td>Homes and buildings more energy efficient</td>
</tr>
<tr>
<td>Long service life</td>
<td>Minimizes reconstruction, repair and maintenance</td>
</tr>
<tr>
<td>Pavement and exterior cladding are light in color</td>
<td>Minimizes urban heat island effect</td>
</tr>
<tr>
<td>Incorporates recycled industrial byproducts</td>
<td>Reduces the energy required for manufacturing</td>
</tr>
<tr>
<td>Absorbs CO₂ throughout its lifetime through carbonation</td>
<td>Reduces carbon footprint</td>
</tr>
</tbody>
</table>
Thank you

Feel free to contact me with questions or comments at:

Lionel Lemay, PE, SE, LEED AP
Sr. VP, Sustainable Development
NRMCA
Llemay@nrmca.org
(847) 918-7101