Equivalent Performance with Half the Clinker Content using PLC and SCM

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University of New Brunswick

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Lafarge North America

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Portland Cement Manufacture

CaCO₃ (limestone)
2SiO₂•Al₂O₃ (clay, shale)
Fe₂O₃ (iron oxide)
SiO₂ (silica sand)

Calcination: CaCO₃ → CaO + CO₂
~ 0.50 ton CO₂ per 1.0 ton of clinker

Fuel: ~ 0.25 to 0.65 ton CO₂ per ton of clinker

~ 1450°C or 2640°F

Kiln

Heat

CO₂

3CaO•SiO₂
2CaO•SiO₂
3CaO•Al₂O₃
4CaO•Al₂O₃•Fe₂O₃

Finished cement

interground

CaO•SO₃•2H₂O

Gypsum + Clinker
Portland Limestone Cement Manufacture

CaCO₃ (limestone)
2SiO₂•Al₂O₃ (clay, shale)
Fe₂O₃ (iron oxide)
SiO₂ (silica sand)

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~ 0.50 ton CO₂ per 1.0 ton of clinker

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Kiln ~ 1450°C or 2640°F

CaCO₃ (Limestone)
CaSO₄•2H₂O + Gypsum + Clinker

Finished cement interground

\{ 3\text{CaO} \cdot \text{SiO}_2 \\
2\text{CaO} \cdot \text{SiO}_2 \\
3\text{CaO} \cdot \text{Al}_2\text{O}_3 \\
4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3 \}
Cement production accounts for **approximately 7% to 8% of CO₂ globally** *(Mehta, 1998)* ...

... and approximately 2.8% of CO₂ emissions in Canada *(Neitzert, 1997)*

Calcination: $CaCO_3 \rightarrow CaO + CO_2 \uparrow$ (gas)  

Energy: $C + O_2 \rightarrow CO_2 \uparrow$ (gas)

www.cement.ca
PLC - Historical Timeline

- 20% limestone cement in Germany (1965)
- French Standards allow limestone additions
- Canadian Standards allow 5% in Type GU
- 15% (+/- 5%) in Germany
- Up to 20% in U.K.
- Up to 20% in CEM II-A or 35% in CEM II-B
- Up to 5% in all Canadian Cements
- ASTM C 150 allows up to 5%
- AASHTO allows up to 5%
- Up to 15% in Canada (except sulfate-resisting)
Cement types commercialized in Europe (according to Cembureau)
• Portland limestone cement was the major cement type produced in Europe in 2004.
### CSA A3001-08 Types of Hydraulic Cement Permitted

<table>
<thead>
<tr>
<th>Portland cement type</th>
<th>Blended hydraulic cement type*</th>
<th>Portland-limestone cement type†‡</th>
<th>Name§</th>
</tr>
</thead>
<tbody>
<tr>
<td>GU</td>
<td>GUb</td>
<td>GUL</td>
<td>General use cement</td>
</tr>
<tr>
<td>MS</td>
<td>MSb</td>
<td>–</td>
<td>Moderate sulphate-resistant cement</td>
</tr>
<tr>
<td>MH</td>
<td>MHb</td>
<td>MHL</td>
<td>Moderate heat of hydration cement</td>
</tr>
<tr>
<td>HE</td>
<td>HEb</td>
<td>HEL</td>
<td>High early-strength cement</td>
</tr>
<tr>
<td>LH</td>
<td>LHb</td>
<td>LHL</td>
<td>Low heat of hydration cement</td>
</tr>
<tr>
<td>HS</td>
<td>HSb</td>
<td>–</td>
<td>High sulphate-resistant cement</td>
</tr>
</tbody>
</table>

*The suffix “b” indicates that the product is a blended hydraulic cement.
†The suffix “L” indicates that the product is portland-limestone cement.
‡Portland-limestone cements should not be used in an environment subjected to sulphate exposure as defined in Table 3 of CAN/CSA-A23.1.

PLC is produced to provide equivalent performance to PC in Canada
So requirements for Type GUL (up to 15% limestone) same as Type GU (< 5%)

### CSA A23-09 Use of Portland Cement in Concrete

- Portland limestone cement is permitted for use in all classes of concrete except for sulfate exposure classes (S-1, S-2, S-3)
### CSA A3001-08 Requirements for Portland Limestone Cement

<table>
<thead>
<tr>
<th>Composition [% per mass]</th>
<th>L.O.I. limit [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinker</td>
<td>Limestone</td>
</tr>
<tr>
<td>85</td>
<td>15</td>
</tr>
</tbody>
</table>

**Limestone Cement requirements:**
- $\text{CaCO}_3 \geq 75\%$ (calculated from $\text{CaO}$)
- Clay $\leq 1.20/100g$ (determined by methylene blue test)
- Total organic carbon: TOC $\leq 0.50\%$ by mass
Beneficial Effects of Limestone Addition

- Limestone (primarily CaCO$_3$) chemically reacts with C$_3$A to form carboaluminates—at least at replacements of 5-10%.

\[
C_3A + C\overline{C} + xH \xrightarrow{hydration} C_3A \cdot C\overline{C} \cdot H_x
\]

- Finer limestone particles fill the voids between clinker particles improving the grain packing of cement.

- Fine limestone particles as nucleation sites for hydration products at early hydration ages accelerating the hydration and consequently improving the early strength.

Limestone is not totally inert!
CaSO₄

+ CSH + CH + FH₃ + pore solution

ettringite

monosulfate

Ms-ss

C₄AH₁₃

Hemicarbonate

Monocarbonate

Reduced porosity

Increased porosity

CaCO₃

calcite

Hertford, 2008
**Effect of Limestone on Strength**

_Hawkins, 1986_

Four cements with “constant” Blaine

<table>
<thead>
<tr>
<th>L/stone (%)</th>
<th>0</th>
<th>2</th>
<th>5</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blaine (m²/kg)</td>
<td>371</td>
<td>351</td>
<td>346</td>
<td>364</td>
</tr>
<tr>
<td>&lt; 325 (%)</td>
<td>90.0</td>
<td>85.5</td>
<td>81.0</td>
<td>82.4</td>
</tr>
</tbody>
</table>

Four cements with “constant” < 325 mesh

<table>
<thead>
<tr>
<th>L/stone (%)</th>
<th>0</th>
<th>2</th>
<th>5</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blaine (m²/kg)</td>
<td>390</td>
<td>387</td>
<td>433</td>
<td>470</td>
</tr>
<tr>
<td>&lt; 325 (%)</td>
<td>94.7</td>
<td>91.9</td>
<td>91.2</td>
<td>91.6</td>
</tr>
</tbody>
</table>

![Compressive Strength Graph](Image)
Effect of Fineness on Performance

![Graph showing the effect of fineness on performance.](image)

W/CM = 0.49 - 0.51

Testing in Canada indicates that the Blaine of PLC needs to be increased by approx 100 – 120 m²/kg compared with PC to obtain equivalent performance.

Blaine (m²/kg)

Compressive Strength (MPa)

Compressive Strength (psi)

PC
PLC with 12% Limestone

1 day
7 days
28 days
56 days
Tests carried out with Canadian materials -

- Portland-limestone cements (PLC) were produced in different grinding circuits with various clinkers ($C_3A$ from 4.5 to 12%) and limestones.
- Amount of limestone varied between 3 and 19% (to keep within limits, the real CSA PLC max. will be ~13%).
- Standard mortar tests and chemical analyses were performed on the different PLCs.
- Concrete with various w/cm ratio’s 0.35 to 0.80 were produced. The cement contents in the mixed varied between 225 and 420 kg/m$^3$
- Concrete tests with different PLC’s (10 to 22 %LS) and various amounts of slag (15, 25, 30%) and fly ash (20%) were performed
- Slump, slump retention and air were measured
- Durability tests were performed, e.g. RCP, freeze/thaw, salt scaling, shrinkage, sulfate resistance, and ASR
- Testing conducted by cement companies and universities
- Concrete laboratory tests and field trials undertaken by one of the cement companies presented in this paper
## Example Test Program – Cement Company #2

<table>
<thead>
<tr>
<th>Total Cementing Material</th>
<th>Cement Type</th>
<th>SCM</th>
<th>Fresh properties &amp; strength</th>
<th>Freeze-Thaw</th>
<th>Deicer Salt Scaling</th>
<th>RCPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 kg/m³ (400 pcy)</td>
<td>PC PLC-12%</td>
<td>0%</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>355 kg/m³ (600 pcy)</td>
<td>PC PLC-12%</td>
<td>0%</td>
<td>20% Fly Ash 35% Slag</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>410 kg/m³ (700 pcy)</td>
<td>PC PLC-12%</td>
<td>0%</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
To achieve equivalent performance PLC is ground to a higher fineness.
Fineness in PLC: Clinker vs. Limestone

- Also clinker in PLC is ground finer than clinker in PC.

- Limestone fineness in the interground product is significantly finer than the clinker fraction.

- \( D_{50} \) Limestone: 7 to 10 \( \mu m \)

- \( D_{50} \) Clinker: 15 \( \mu m \)
### Company 2: Time of Set, w/cm = 0.45

<table>
<thead>
<tr>
<th></th>
<th>ASTM C403 Set Time (hr:min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC0</td>
<td>5:40</td>
</tr>
<tr>
<td>PC12</td>
<td>4:50</td>
</tr>
<tr>
<td>PC0+20% FA</td>
<td>6:20</td>
</tr>
<tr>
<td>PC12+20% FA</td>
<td>5:45</td>
</tr>
<tr>
<td>PC0+35% Slag</td>
<td>7:05</td>
</tr>
<tr>
<td>PC12+35% Slag</td>
<td>5:45</td>
</tr>
</tbody>
</table>

- Slumps: 100-120 mm
- Air: 5.3-6.0 %
- Only mix with measurable bleeding = PC0
Company 2 Second Test Grind – Strength Results – w/cm = 0.40 & 0.80 (no SCM)

- **W/CM = 0.40**
  - Compressive Strength (MPa)
  - Compressive Strength (psi)
  - Age (days)

- **W/CM = 0.78 - 0.80**
  - Compressive Strength (MPa)
  - Compressive Strength (psi)
  - Age (days)
Company 2 Second Test Grind – Strength Results – w/cm = 0.45 & SCM

Strength at 1 day

Strength at 7 days

Compressive Strength (MPa)

Compressive Strength (psi)

Supplementary Cement Materials

PC
PLC - 12%

No SCM 35% Slag 20% Fly Ash

Supplementary Cement Materials

No SCM 35% Slag 20% Fly Ash
Company 2 Second Test Grind – Strength Results – w/cm = 0.45 & SCM

Strength at 28 days
Strength at 56 days

Compressive Strength (MPa)
Compressive Strength (psi)

No SCM  35% Slag  20% Fly Ash
Supplementary Cement Materials

No SCM  35% Slag  20% Fly Ash
Supplementary Cement Materials
Company 2 Second Test Grind – Durability Tests – w/cm = 0.40, 0.45 & SCM

Freeze-Thaw Resistance (ASTM C 666)

Scaling Resistance (ASTM C 672)

Chloride Permeability at 28 days

Chloride Permeability at 56 days
Company 2 Second Test Grind – Durability Tests – ASR & Sulfate Resistance

ASR Testing

Sulfate Resistance Testing

AMBT  Accelerated Mortar Bar Test, ASTM C 1260
CPT  Concrete Prism Test, ASTM C 1293
ACPT  Accelerated Concrete Prism Test

ASTM C 1012 Mortar bars immersed in 5% Na₂SO₄ solution
Field Trials

- Exshaw Cement Plant, AB
- Brookfield Cement Plant, NS
- Gatineau Concrete Plant, QC
PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

Objective:

• Field test performance of PLC concrete with various levels of SCM in an exterior flatwork application.
• Control sections with Type GU + SCM

Eight Concrete Mixes:

<table>
<thead>
<tr>
<th>Cement</th>
<th>SCM Replacement Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Type GU</td>
<td>X</td>
</tr>
<tr>
<td>Type GUL</td>
<td>X</td>
</tr>
</tbody>
</table>

Cementing Materials:

• Type GU with 3.5% limestone (PC)
• Type GUL with 12% Limestone (PLC)
• Blended SCM = 2/3 Slag + 1/3 Fly Ash
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<tr>
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<th>SCM Replacement Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Type GU</td>
<td>92</td>
</tr>
<tr>
<td>Type GUL</td>
<td>84</td>
</tr>
</tbody>
</table>

Clinker content (% of total cementitious)

Cementing Materials:
• Type GU with 3.5% limestone (PC)
• Type GUL with 12% Limestone (PLC)
• Blended SCM = 2/3 Slag + 1/3 Fly Ash
PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

Fresh concrete properties:
- Slump
- Air
- Temperature
- Density

Hardened concrete properties on site-cast specimens:
- Strength
- RCPT
- Hardened Air-Void Parameters
- Freeze-thaw (ASTM C 666: Proc. A)
- Salt Scaling (ASTM C 672 & BNQ Method)

Properties of 35-Day-Old Cores:
- Strength
- RCPT
- Chloride diffusion coefficient
## PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

### Properties of Plastic Concrete

<table>
<thead>
<tr>
<th>SCM (%)</th>
<th>Cement Type</th>
<th>W/CM</th>
<th>Slump (mm)</th>
<th>Air (%)</th>
<th>Temp (°C)</th>
<th>Unit Wt. (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>PC</td>
<td>0.45</td>
<td>100</td>
<td>6.8</td>
<td>18.8</td>
<td>2317</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>0.44</td>
<td>80</td>
<td>6.0</td>
<td>17.5</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>PC</td>
<td>0.44</td>
<td>75</td>
<td>6.2</td>
<td>18.1</td>
<td>2317</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>0.45</td>
<td>100</td>
<td>6.6</td>
<td>16.3</td>
<td>2328</td>
</tr>
<tr>
<td>40</td>
<td>PC</td>
<td>0.44</td>
<td>95</td>
<td>6.8</td>
<td>16.5</td>
<td>2303</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>0.44</td>
<td>80</td>
<td>6.0</td>
<td>15.5</td>
<td>2331</td>
</tr>
<tr>
<td>50</td>
<td>PC</td>
<td>0.44</td>
<td>95</td>
<td>6.8</td>
<td>15.0</td>
<td>2300</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>0.44</td>
<td>95</td>
<td>6.5</td>
<td>14.5</td>
<td>2309</td>
</tr>
</tbody>
</table>
PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

- Vibrating Screed
- Bullfloat
- Broom Finish
- Insulated Tarps (except slab 5)
PLC Trial Pour – Cylinder Strengths

3-Day Strength

<table>
<thead>
<tr>
<th>SCM</th>
<th>PC</th>
<th>PLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>24.22</td>
<td>21.72</td>
</tr>
<tr>
<td>25%</td>
<td>21.72</td>
<td>20.71</td>
</tr>
<tr>
<td>40%</td>
<td>20.71</td>
<td>18.91</td>
</tr>
<tr>
<td>50%</td>
<td>18.91</td>
<td>15.32</td>
</tr>
</tbody>
</table>

7-Day Strength

<table>
<thead>
<tr>
<th>SCM</th>
<th>PC</th>
<th>PLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>30.23</td>
<td>30.05</td>
</tr>
<tr>
<td>25%</td>
<td>29.82</td>
<td>29.62</td>
</tr>
<tr>
<td>40%</td>
<td>30.31</td>
<td>31.11</td>
</tr>
<tr>
<td>50%</td>
<td>29.42</td>
<td>28.87</td>
</tr>
</tbody>
</table>

28-Day Strength

<table>
<thead>
<tr>
<th>SCM</th>
<th>PC</th>
<th>PLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>41.34</td>
<td>41.30</td>
</tr>
<tr>
<td>25%</td>
<td>45.44</td>
<td>45.47</td>
</tr>
<tr>
<td>40%</td>
<td>48.64</td>
<td>48.13</td>
</tr>
<tr>
<td>50%</td>
<td>48.74</td>
<td>46.56</td>
</tr>
</tbody>
</table>

56-Day Strength

<table>
<thead>
<tr>
<th>SCM</th>
<th>PC</th>
<th>PLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>41.30</td>
<td>41.34</td>
</tr>
<tr>
<td>25%</td>
<td>45.56</td>
<td>46.00</td>
</tr>
<tr>
<td>40%</td>
<td>48.63</td>
<td>48.73</td>
</tr>
<tr>
<td>50%</td>
<td>48.76</td>
<td>46.55</td>
</tr>
</tbody>
</table>
PLC Trial Pour – Core Strengths at 35 Days

- Core Strength at 35 Days:
  - 0% SCM: 39.7, 35.3
  - 25% SCM: 35.7, 35.5
  - 40% SCM: 42.3, 43.2
  - 50% SCM: 37.6, 39.4

- Graph showing strength in MPa vs. SCM percentages (0%, 25%, 40%, 50%).
PLC Trial Pour – RCPT Results

Charge Passed (Coulombs) vs. SCM Replacement Level (%) for PC and PLC at 28 and 56 days.

- PC at 28 days
- PLC at 28 days
- PC at 56 days
- PLC at 56 days
### RCPT Results for Cores taken at 35 Days

<table>
<thead>
<tr>
<th>Cement</th>
<th>Charge Passed in 6 Hours (Coulombs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0% SCM</td>
</tr>
<tr>
<td>PC</td>
<td>2395</td>
</tr>
<tr>
<td>PLC</td>
<td>2345</td>
</tr>
</tbody>
</table>

### Chloride Diffusion Coefficients Determined on Cores taken at 35 Days

<table>
<thead>
<tr>
<th>Cement</th>
<th>Charge Passed in 6 Hours (Coulombs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0% SCM</td>
</tr>
<tr>
<td>PC</td>
<td>15.0</td>
</tr>
<tr>
<td>PLC</td>
<td>11.9</td>
</tr>
</tbody>
</table>
Chloride Profiles for Cores taken at 35 Days and Immersed in NaCl for 42 Days

- PC - 0% SCM
- PLC - 0% SCM
- PC - 25% SCM
- PLC - 25% SCM
- PC - 50% SCM
- PLC - 50% SCM

Chloride (% by mass of concrete)

Depth (mm)
PLC Trial Pour – Scaling Test Results

**BNQ Test Method**

- **PC**
- **PLC**

<table>
<thead>
<tr>
<th>Mass Loss (g/m²)</th>
<th>0% SCM</th>
<th>25% SCM</th>
<th>40% SCM</th>
<th>50% SCM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PC</strong></td>
<td>39</td>
<td>114</td>
<td>127</td>
<td>142</td>
</tr>
<tr>
<td><strong>PLC</strong></td>
<td>497</td>
<td>273</td>
<td>106</td>
<td>380</td>
</tr>
</tbody>
</table>

**ASTM C 672**

- **PC**
- **PLC**

<table>
<thead>
<tr>
<th>Mass Loss (g/m²)</th>
<th>0% SCM</th>
<th>25% SCM</th>
<th>40% SCM</th>
<th>50% SCM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PC</strong></td>
<td>40</td>
<td>10</td>
<td>80</td>
<td>400</td>
</tr>
<tr>
<td><strong>PLC</strong></td>
<td>10</td>
<td>30</td>
<td>230</td>
<td>320</td>
</tr>
</tbody>
</table>
### PLC Trial Pour – Other Test Results

<table>
<thead>
<tr>
<th>SCM (%)</th>
<th>Cement Type</th>
<th>Air Void Parameters</th>
<th>Durability Factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Air (%)</td>
<td>L (mm)</td>
</tr>
<tr>
<td>0</td>
<td>PC</td>
<td>5.3</td>
<td>173</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>5.6</td>
<td>187</td>
</tr>
<tr>
<td>25</td>
<td>PC</td>
<td>4.9</td>
<td>148</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>5.4</td>
<td>149</td>
</tr>
<tr>
<td>40</td>
<td>PC</td>
<td>5.6</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>5.3</td>
<td>165</td>
</tr>
<tr>
<td>50</td>
<td>PC</td>
<td>5.6</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>PLC</td>
<td>6.6</td>
<td>147</td>
</tr>
</tbody>
</table>
PLC Trial Pour – Conclusions

- No observable differences between plastic properties, placing and finishing of concrete with PC or PLC at a given level of SCM.
- No significant difference between strength and permeability of concrete with PC or PLC at a given level of SCM.
- No consistent trends in salt scaling resistance of PC concrete compared with PLC concrete at a given level of SCM.
- Long-term strength and permeability improved as level of SCM increased.
- Resistance to salt scaling reduced as SCM level increased, especially at 50% SCM.
Exshaw Cement Plant, Alberta

- Sept 2009
- Paving, Curbs & pumped concrete
- PC & PLC cements
- 15, 25 & 30% fly ash
Brookfield Cement Plant, Nova Scotia

- Oct 2009
- Paving
- Blended PC & PLC cements containing 15% slag
- 15 & 20% fly ash
Field Trials - 2009

Exshaw Cement Plant, Alberta

- Strength
- Salt Scaling
- Chloride Permeability

Brookfield Cement Plant, Nova Scotia

Specimens cast from both sites for laboratory testing:

- Strength
- Salt Scaling
- Chloride Permeability
CO₂ Reducitons

PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October, 2008

- 355 kg/m³ (590 pcy) cementing materials
- Type GU with no SCM - 92% clinker in cementing material
- Type GUL with 40 to 50% SCM – 50 to 42% clinker in cementing material
- **CO₂ reduced by approx 1 tonne per 6-m³ truck (1 ton per 8-yd³ truck)**
- But can’t use 40 – 50% SCM in every application
- Type GUL with 25% SCM – 63% clinker in cementing material
- **CO₂ reduced by approx ¾ tonne per 6-m³ truck (¾ ton per 8-yd³ truck)**
Brookfield Cement Plant, Nova Scotia

- 386 kg/m³ (643 pcy) cementing materials
- Type GU - 91% clinker in cementing material
- Type GULb (15% slag + 12% limestone) – 68% clinker
- CO₂ reduced by approx ½ tonne per 6-m³ truck (½ ton per 8-yd³ truck)
- Type GULb can be used as a base cement for nearly all cases – with further incorporation of SCM at the concrete plant depending on the application

Approx 25% reduction in clinker (& CO₂ emissions)
Overall Summary

- Portland-limestone cements with up to 15% limestone, when optimized for equal early-age strength, can be used in concrete together with fly ash and slag at the levels typically added at the concrete plant.
- Optimization of PLC requires higher Blaine fineness to get equal grinding of the harder clinker fraction.
- Canadian Standards now permit the use of portland limestone cements with up to 15% interground limestone.
- This provides an opportunity to reduce in CO$_2$ emissions by ~10%, while providing similar technical performance to current GU cements.
- PLC performs well with normal levels of slag or fly ash replacements (providing further opportunities to reduce CO$_2$ emissions).
Questions?