Geopolymer Concrete: A Sustainable Cement based Concrete for the Future

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Global Materials Consumption

Production of 1 ton cement = 1 ton of CO$_2$
After fossil fuels, Portland cement is the largest emitter
Cements

Portland Cement invented in 1824, wide usage in the early 1900’s (80 years of incubation)

Other Cements:

- Supersulphated cements
- Calcium aluminate cements
- Calcium sulfoaluminate cements
- Magnesium oxy-carbonate cements
- Limestone Calcined Clay Cement (LC³)
- Geopolymer
## Carbon Emissions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Emission Factor</th>
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<tbody>
<tr>
<td>Coarse Aggregates - Granite/Hornfels</td>
<td>45.9 kg CO(_2)-e/tonne</td>
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<tr>
<td>Coarse Aggregates - Basalt</td>
<td>35.7 kg CO(_2)-e/tonne</td>
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<tr>
<td>Fine Aggregates</td>
<td>13.9 kg CO(_2)-e/tonne</td>
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<tr>
<td>Cement</td>
<td>820.0 kg CO(_2)-e/tonne</td>
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<tr>
<td>Fly Ash (F-type)</td>
<td>27.0 kg CO(_2)-e/tonne</td>
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<tr>
<td>GGBFS</td>
<td>143.0 kg CO(_2)-e/tonne</td>
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<tr>
<td>Concrete Batching</td>
<td>3.3 kg CO(_2)-e/m(^3)</td>
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<tr>
<td>Concrete Transport</td>
<td>9.4 kg CO(_2)-e/m(^3)</td>
</tr>
<tr>
<td>On Site Construction Activities</td>
<td>9.0 kg CO(_2)-e/m(^3)</td>
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</tbody>
</table>
Concrete Carbon Emissions

**CO₂ Emissions Breakdown**

<table>
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<tr>
<th>t CO₂-e/m³</th>
<th>25MPa</th>
<th>32MPa</th>
<th>40MPa</th>
<th>50MPa</th>
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<tbody>
<tr>
<td>GP Cement</td>
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<td>Construction Activities</td>
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Cement Use in Different Countries
Cement Use Projections

China
India
Other Developing Countries
OECD

Cement Production (GT/year)

Year

1990 2000 2010 2020 2030 2040 2050
Challenges in Meeting the Extra Cement Demand

• **Build New Cement Factories?**
  Factory for 1 M tons cement/year production
  – Capital = US$200 Million
  – Employ <150 people
  – Burn 100 kg fuel/ton of cement

• **Alternate Low Carbon Materials**
  – Fly Ash 780 MT/year – 54% usage
  – Blast Furnace Slag 400 MT/year
  – Steel slag 350 MT/year
Geopolymer Concrete

- **1 Part Main Binder** (eg. 400 kg/m³)
  - Comprised of various combinations of fly ash and slag; eg. 0.5 Fly Ash; 0.5 Slag
- **0.08 Activator** (eg. 32 kg/m³)
  - sodium metasilicate powder
- **0.35 Water** (eg. 140 kg/m³)
- **Coarse Aggregates** (1100 kg/m³)
- **Fine Aggregates** (740 kg/m³)

40 MPa

80% reduction in CO₂ Emissions from OPC

CO₂-e from OPC is 4th largest after oil, gas and coal
SEM Images

(a) Hardened Portland Cement

(b) Geopolymer
Disadvantages of OPC

– Carbon emissions
– Fire resistance
– Acid resistance
– Corrosion of reinforcements
– Poor tensile strength/Cracking
– Shrinkage
– Creep
Geopolymer

Mechanical performance: very similar

• Elastic modulus
• Compressive strength
• Tensile strength
• Poisson's ratio
• Shrinkage
• Creep
Geopolymer: Special Applications

- Low carbon concrete
- Fire resistant concrete
- Acid resistant concrete
- Fibre reinforced composites
- Pavements
Geopolymer: Drawbacks

- Alkaline materials (handling, OHS)
- pH buffer capacity / Rate of carbonation
- Increased porosity, reo corrosion
- Curing temperatures/ Moist curing with high slag
- Efflorescence
- Abrasion/Erosion resistance
Drivers for Geopolymer use in Projects

- Low Carbon Initiatives
  - Green Flagship Projects eg. GCI Building

- Technical Demands
  - Fire/Acid/Crack Resistance

- Availability of Source Materials
  - Fly Ash/Slag

- Geopolymer Use
Conclusions

• Geopolymer is an alternative technology to meet the additional future cement demands
  – No capital investments
  – Carbon emission reductions (80%)

• Geopolymer may meet certain technical requirements where the conventional concrete has problems
  – Fire resistance (eg. tunnel segments)
  – Acid resistance (eg. sewer pipes)
  – Low shrinkage (eg. aircraft pavements)