DEVELOPMENT OF banahCEM

A GEOPOLYMER BINDER SYSTEM

Andrew McIntosh

Geopolymer Camp 2012

9 – 11 July 2012
St. Quentin
The principle aims of banah UK Limited are to:

- carry out dedicated research and development in the field of geopolymer technology

- erect a production plant to manufacture geopolymer binders for construction

- develop a centre of excellence in Northern Ireland for novel cements through links with local universities

- reduce the future impact of the construction industry on the earth
THE STORY

In N. Ireland there is a readily available precursor which has been:

• Deposited by Nature
  Successive volcanic episodes in Co Antrim provide precursor

• Discovered by Industry
  Material associated with precursor exploited in 19\textsuperscript{th} and early 20\textsuperscript{th} Century

• Dreaded by Quarrying
  Precursor found in many quarries and is considered a ‘nuisance’ material

• Developed by banah UK Ltd
  Over the last two years this precursor has been used in the development of geopolymer cement
Geopolymer Cement Development

• Search for local sources of aluminosilicate
  • correct mineralogy
Mineralogy of Geopolymer Precursor
Geopolymer Cement Development

- Search for local sources of aluminosilicate
  - correct mineralogy
  - preferably existing quarry site
  - low environmental impact

- Design of geopolymer cement formulation
  - pre-treatment of raw materials
  - alkali content
  - Si:Al ratios
Amorphous Reacted Geopolymer
Geopolymer Cement Development

- Search for local sources of aluminosilicate
  - correct mineralogy
  - preferably existing quarry site
  - low environmental impact

- Design of geopolymer cement formulation
  - pre-treatment of raw materials
  - alkali content
  - Si:Al ratios
  - user friendliness

- Increasing sustainability; reducing costs
  - alternative sources of alkali silicate

- Fitness for purpose
  - testing in various applications
  - third party testing
Geopolymer Cement Development

• High Iron Content of Precursor
  • previous work showed lower strengths for this material
  • Ferro-kaolinite Precursor

• Proposal of a New Geopolymer Class
  • (Na, K, Ca) – (ferro-sialate) molecule

• Replicating Natural Silicate Molecules
  • ‘Getting back to nature’
  • Looking at natural mineralogy for future development
• Two-part cement system

• May be used as a Portland cement replacement

• Ambient temperature setting

• Compressive Strength – 125 MPa +

• Has the following benefits:
  • Low carbon
  • Low environmental impact
  • Acid resistance
  • Sulfate resistance
  • Heat resistance
  • Consistent performance due to quality of raw materials
Compressive Strength of Geopolymer Concrete

**banahCEM™**

**Compressive Strength of Geopolymer Concrete**
Freeze-Thaw Testing of Geopolymer Concrete

- **High Slump**
  - 50 Cycles
  - Control

- **Low Slump**
  - 50 Cycles
  - Control

*Compressive Strength (N/mm²)*
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Strength Development

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>% of 28 day Strength</th>
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<tbody>
<tr>
<td>0</td>
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<td>160</td>
<td>80%</td>
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<tr>
<td>180</td>
<td>90%</td>
</tr>
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</table>

- banahCEM Strength Development
- Typical CEM I Strength Development
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Isothermal Conduction Calorimetry

Sample 2.5

Rate of Heat Production
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Isothermal Conduction Calorimetry

Sample 2.5

Total Heat Production over first 72 Hours
Accelerated Ageing of Geopolymers


- Ageing at 95°C produced dramatic acceleration of ageing effects
- Strength Loss of 60% of cured value
- Linked to phase changes – development of Zeolites
- Metakaolin based geopolymers unsuitable for construction

From Publication mentioned above
Accelerated Ageing of Geopolymer

- Samples of binder and mortar cast and cured for 28 days
- Stored at 95°C in a sealed container and tested for compressive strength and crystalline structure at intervals
- Slight decrease in compressive strength observed
- **NO** increase in crystalline structure observed
- **NO** decrease in compressive strength over 2 years at ambient temperatures.
Figure 1: XRD pattern (8-70° 2theta) showing no difference in XRD trace between two samples
Shrinkage of 35MPa concrete at 200 hours:

- Uncovered from casting = -1650 μstrains
- Covered for two days = -980 μstrains
- With additive, uncovered = -330 μstrains
- With additive, covered for three days = -50 μstrains
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Environmental Impact

CO₂ Emissions
• Portland Cement – typically 880 kg per tonne of product*
  * sales of BCA members in 2007. Supplied by sustainableconcrete.org.uk

• BanahCEM – approximately 96 kg per tonne of product

‘Hole-in-the-ground’ Factor
• CEM I – 2.05 tonnes raw material for 1 tonne product
  • 1.65 tonnes limestone; 0.4 tonnes clay

  British Geological Survey, Cement Raw Materials, November 2005

• BanahCEM – 1.23 tonnes raw material for 1 tonne product
  • 0.77 tonnes geological precursor
  • 0.46 tonnes for alkali-silicate component
banah CEM
Production Plant
In summary, banah UK Ltd

- has developed a viable geopolymer binder for use in niche applications
- is finalising plans for a plant capable of 100,000 tonnes/yr
- will be looking to partner with interested parties to see the implementation of geopolymer binders
- will be pressing forward in the design and supply of a revolutionary geopolymer block design
- will continue in the research and development of geopolymer technology in construction
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