DEVELOPMENT OF banahCEM

A GEOPOLYMER BINDER SYSTEM

Andrew McIntosh

Geopolymer Camp 2013

8 – 10 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 and European universities
- reduce the future impact of the construction industry on the earth

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THE STORY

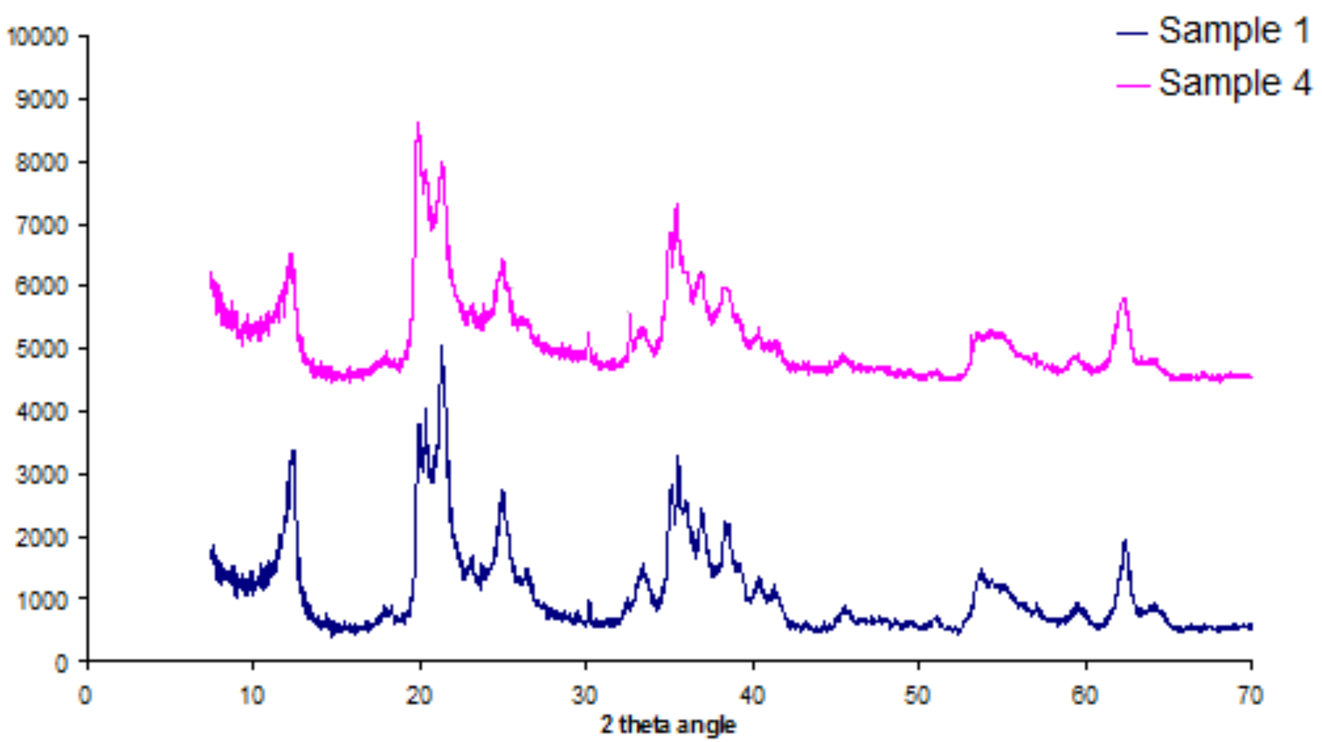
In N. Ireland there is a readily available precursor which has been:

- Deposited by Nature
  Successive volcanic episodes in Co Antrim provide precursor
- Discovered by Industry
  Material associated with precursor exploited in 19th and early 20th 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



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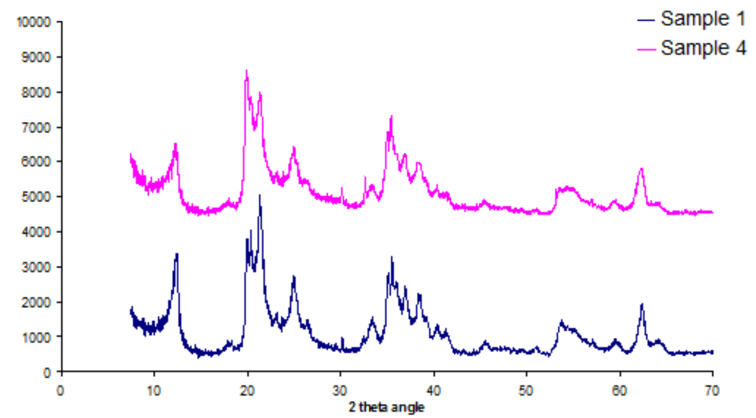
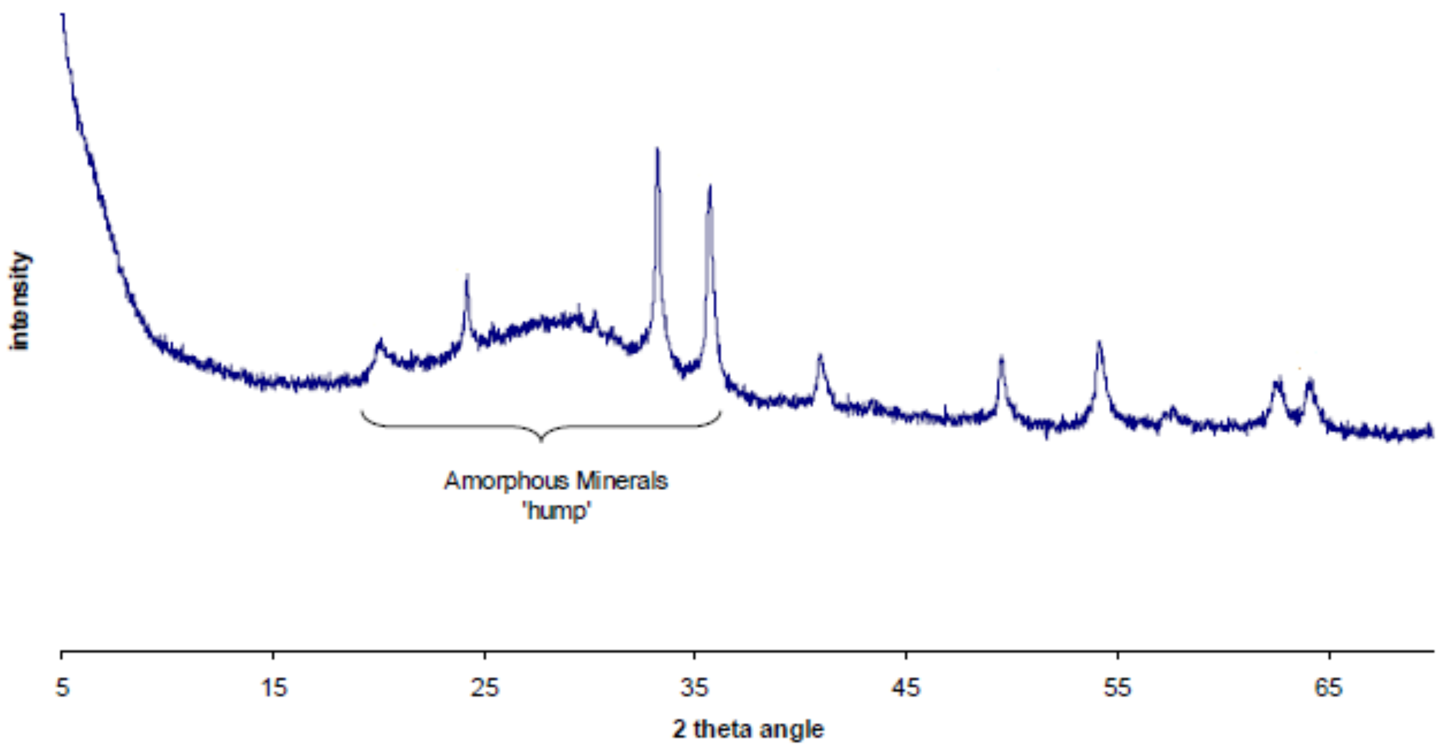
Geopolymer Cement Development

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

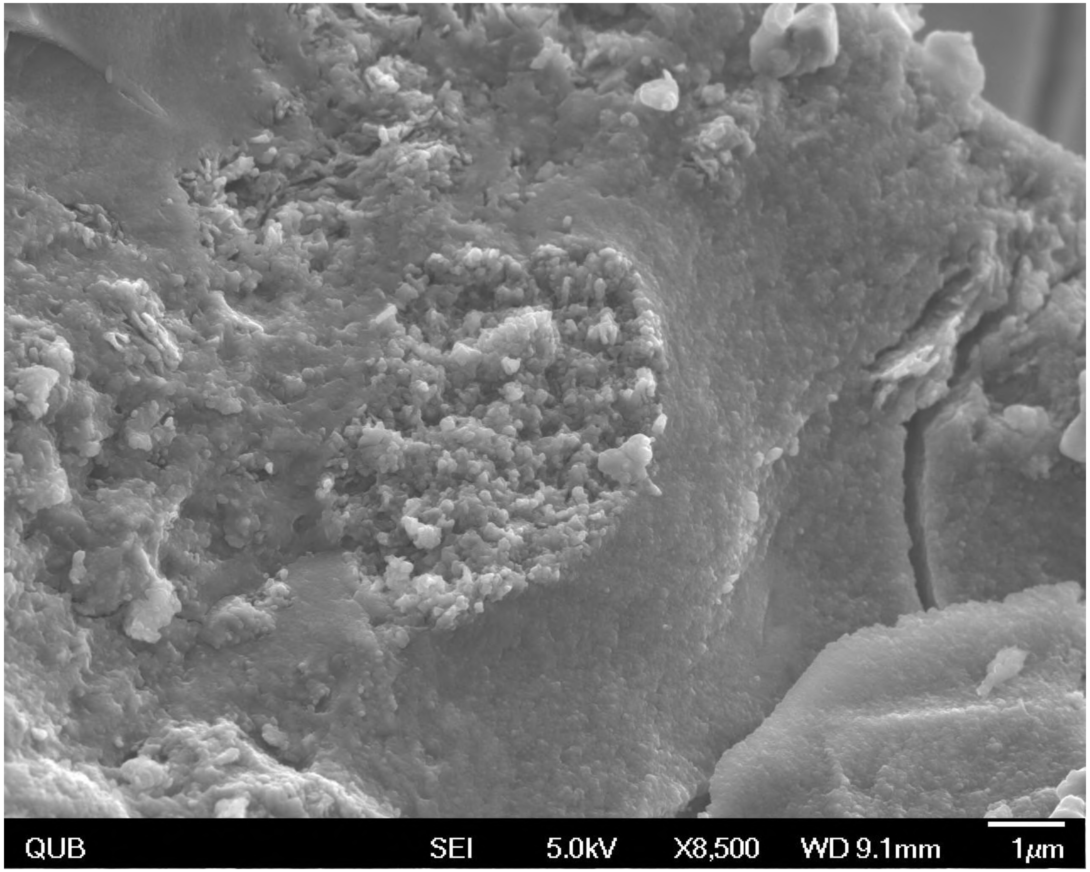
- Design of geopolymer cement formulation
  - pre-treatment of raw materials
  - alkali content
  - Si:Al ratios



Amorphous Reacted Geopolymer



Amorphous Reacted Geopolymer



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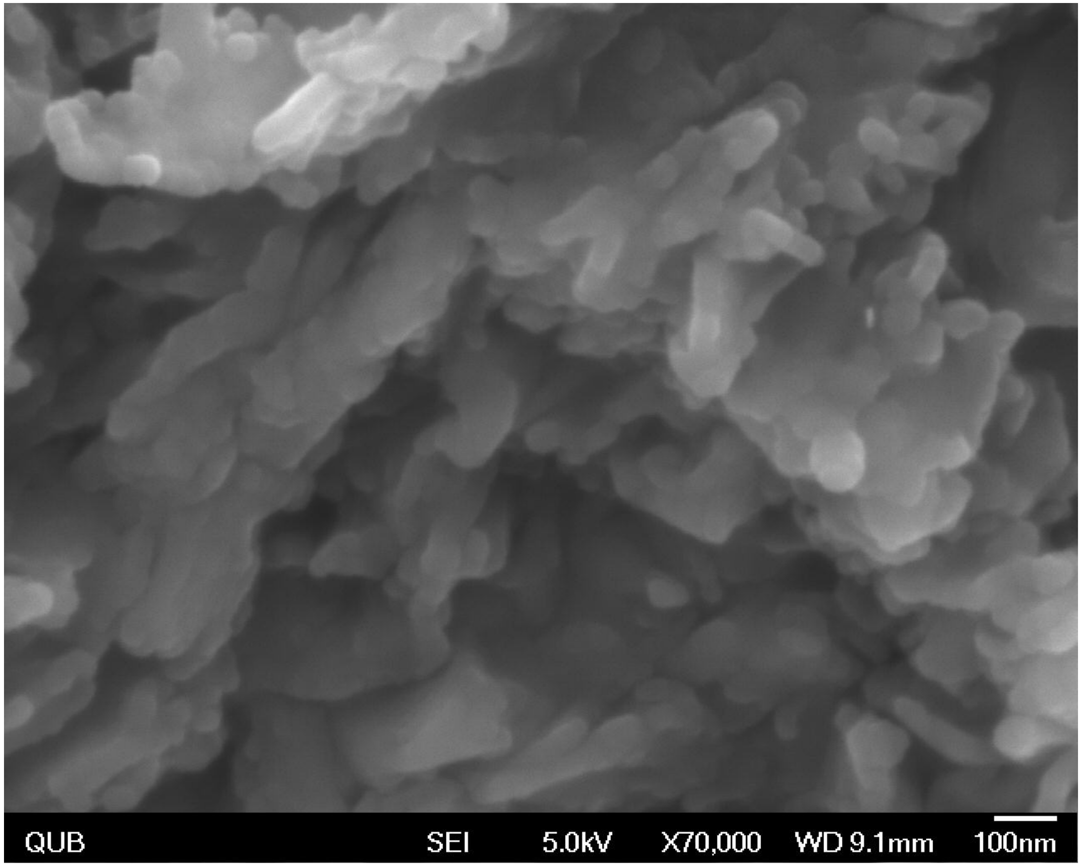
Amorphous Reacted Geopolymer



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Geopolymer Cement Development

- Search for local sources of aluminosilicate
    - correct mineralogy
    - preferably existing quarry site
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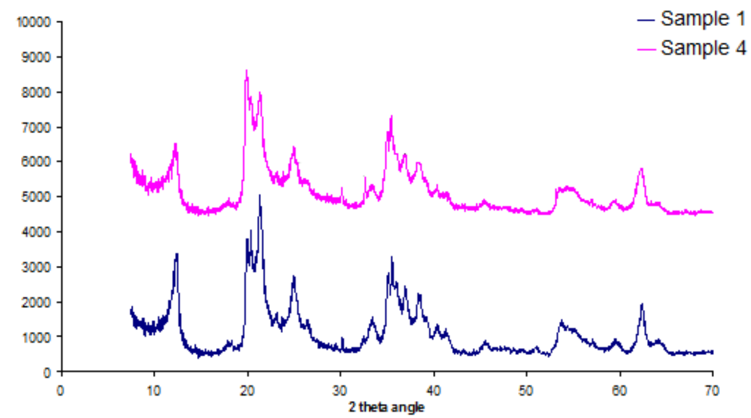
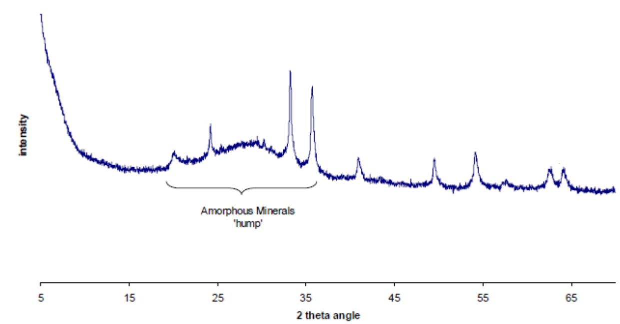
- Design of geopolymer cement formulation
    - pre-treatment of raw materials
    - alkali content
    - Si:Al ratios
    - user friendliness

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

- Fitness for purpose
    - testing in various applications
    - third party testing





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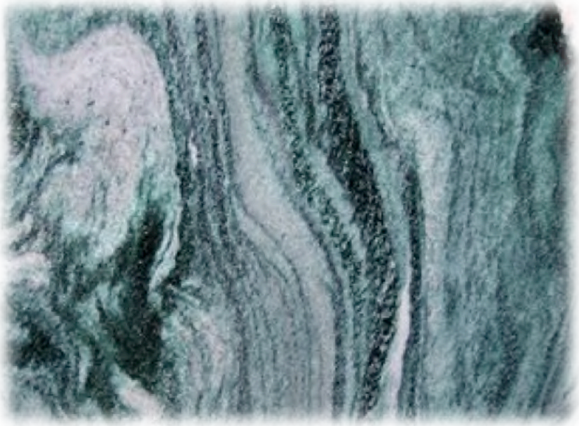
Geopolymer Cement Development

- 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



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- 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
    - Fire resistance
    - Consistent performance due to quality of raw materials

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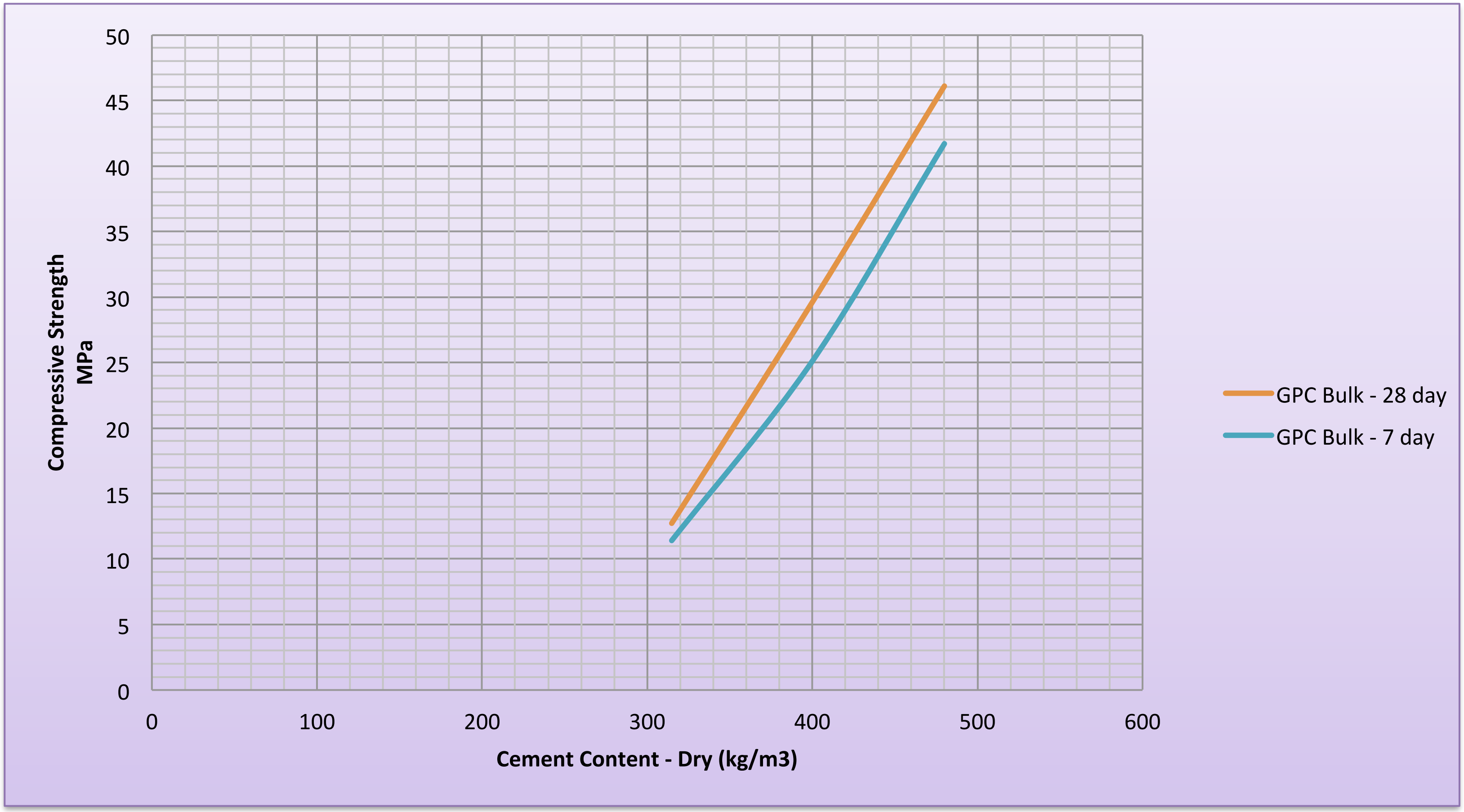
Compressive Strength of Geopolymer Concrete



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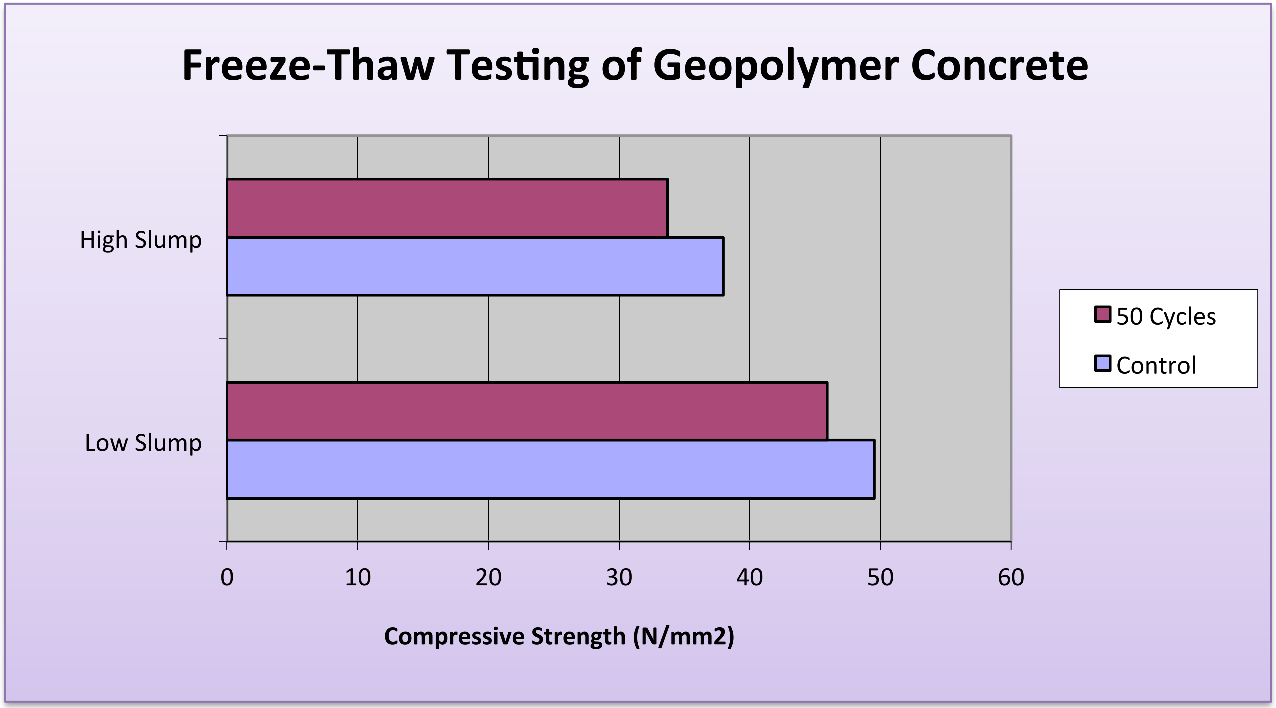
Freeze/Thaw Testing



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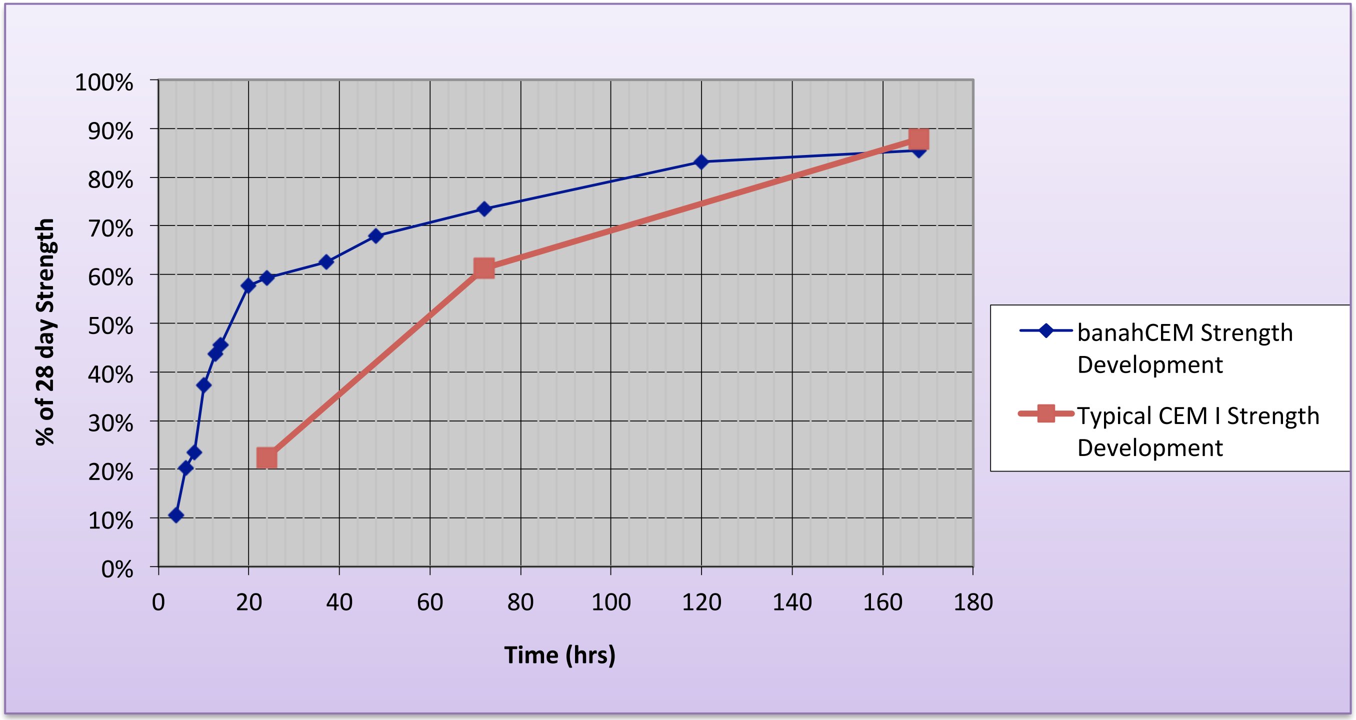
Strength Development



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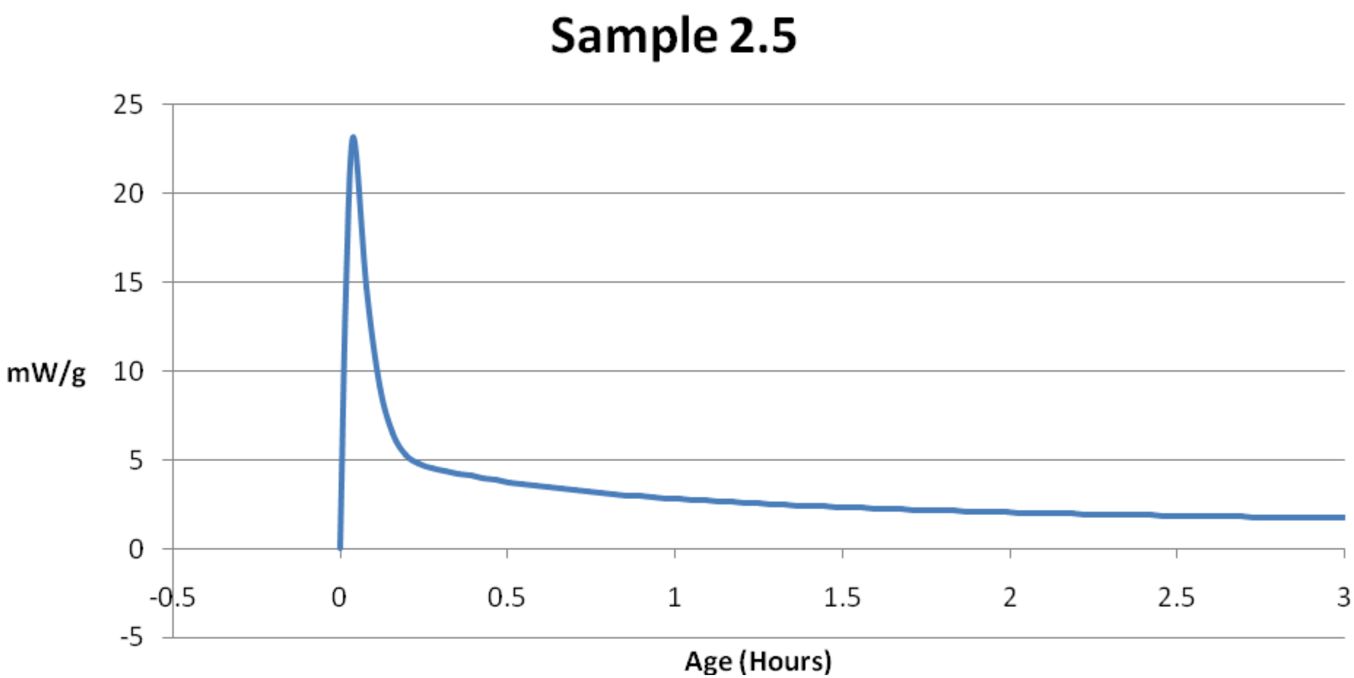
Isothermal Conduction Calorimetry



Rate of Heat Production

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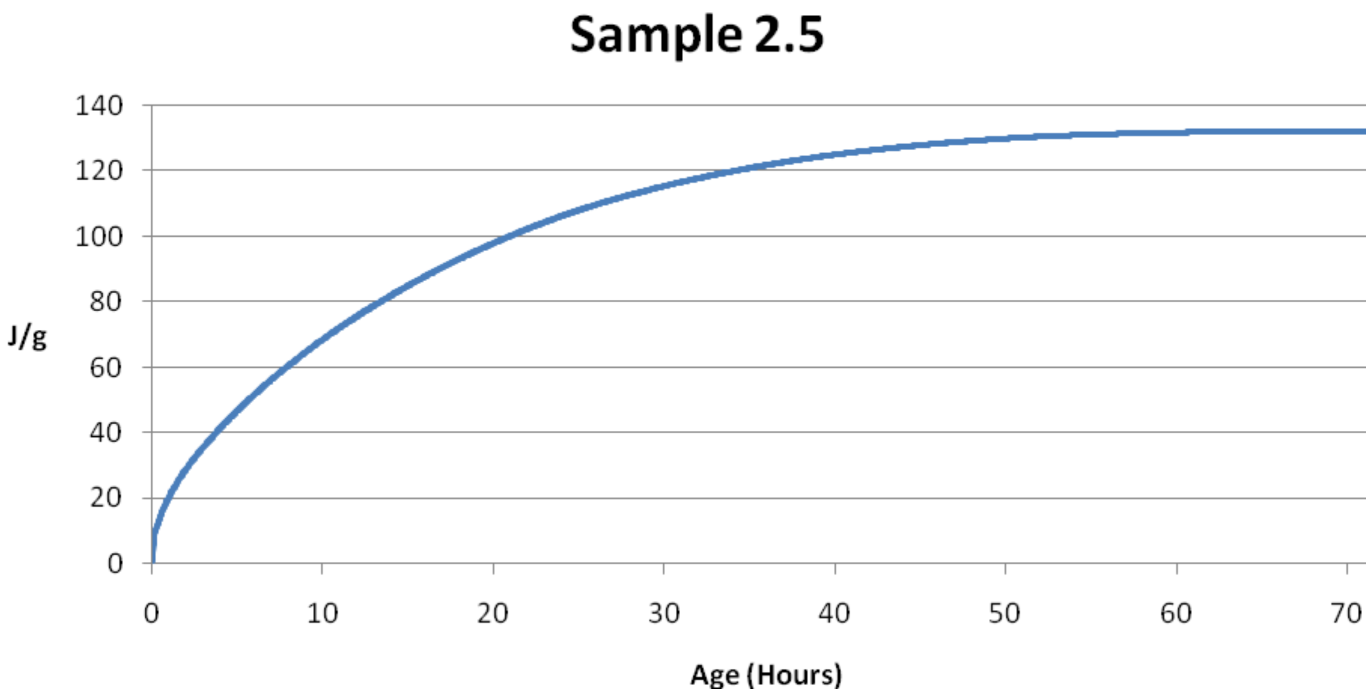
Isothermal Conduction Calorimetry



Total Heat Production over first 72 Hours

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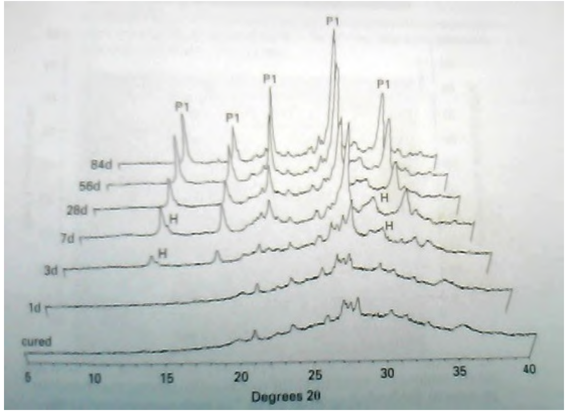
Accelerated Ageing of Geopolymers

R.R. Lloyd, Accelerated ageing of geopolymers, in Provis, J.L. and van Deventer, J.S.J. (Eds.) *Geopolymers: Structures, processing, properties and industrial applications*, Woodhead Publishing, Abingdon UK, 2009, pp. 139-166.

- 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

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Accelerated Ageing of Geopolymer

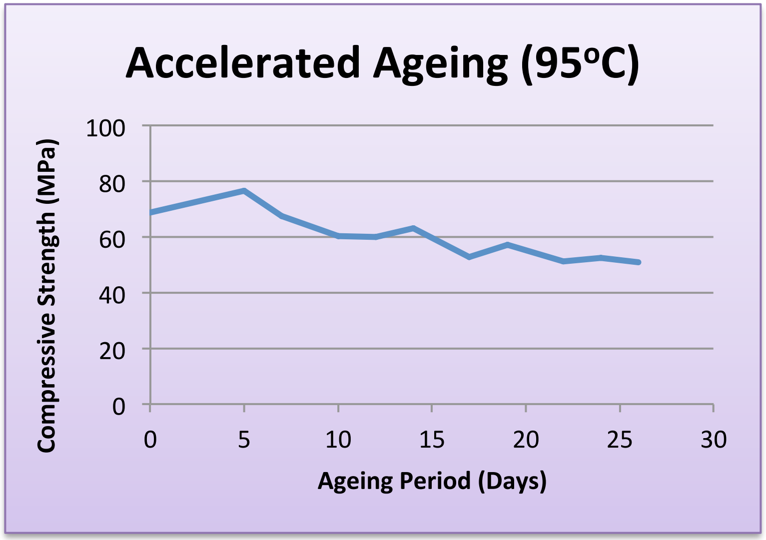
- Samples of binder and mortar cast and cured for 28 days

- 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.



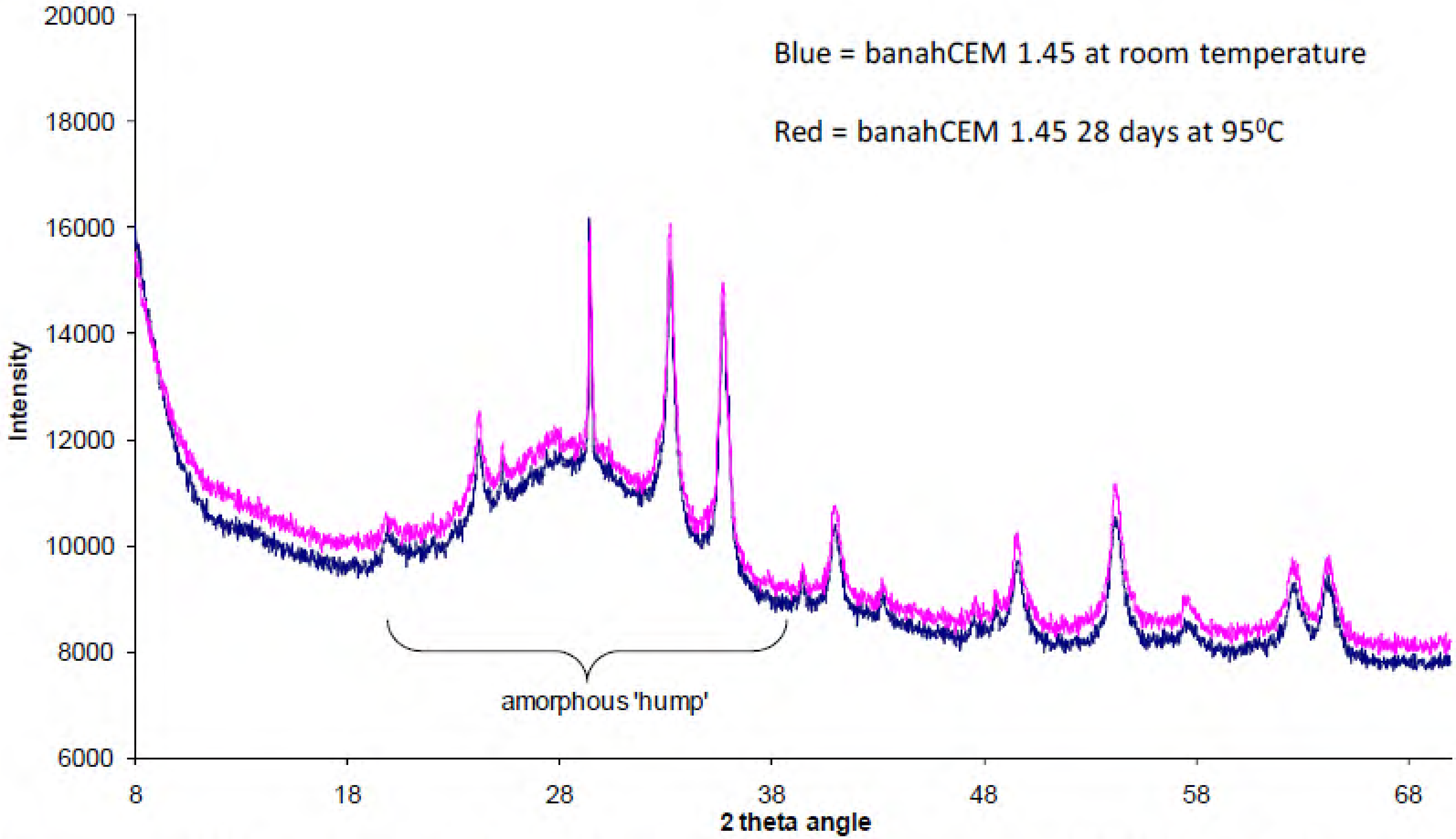


Figure 1: XRD pattern (8-70^0 2theta) showing no difference in XRD trace between two samples

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Shrinkage

Shrinkage of 35MPa concrete at 200 hours:

Uncovered from casting = -1650 µstrains

Covered for two days = -980 µstrains

With additive, uncovered = -330 µstains

With additive, covered for three days = -50 µstrains

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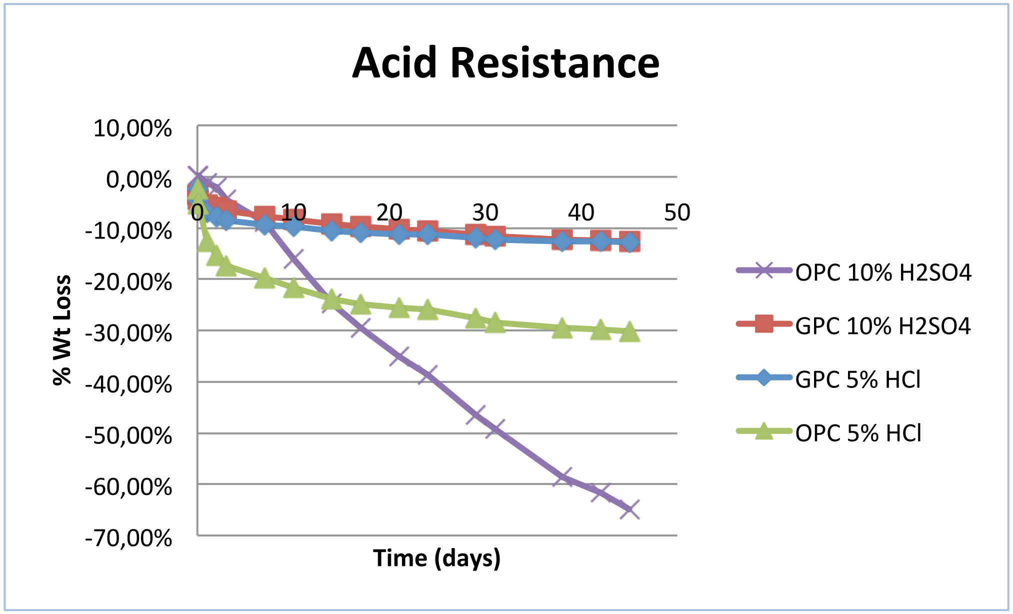
Acid / Sulfate Resistance

Initial comparison tests with OPC:



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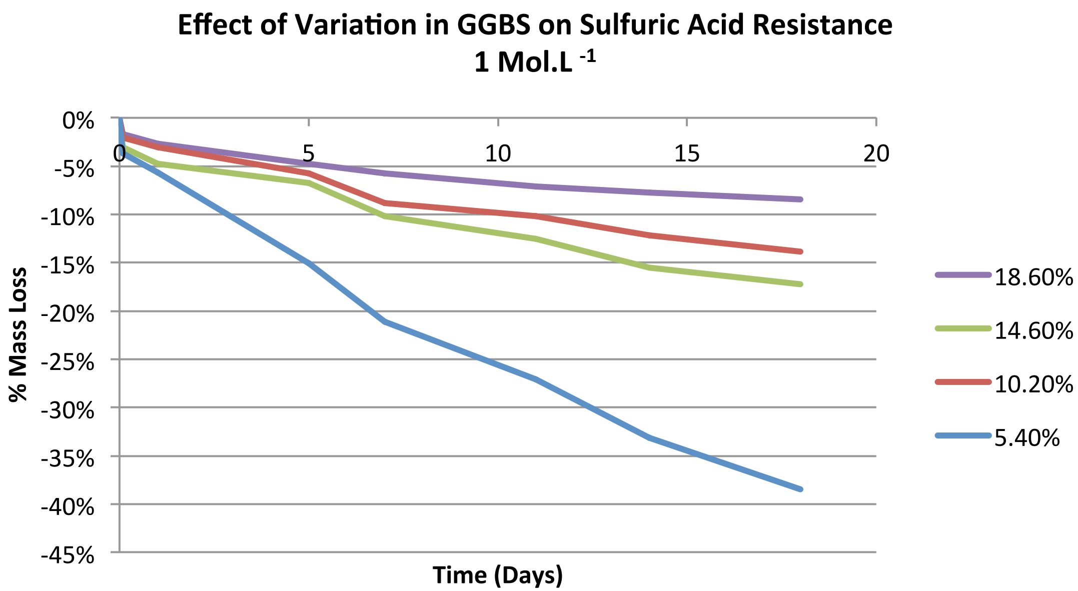
Acid / Sulfate Resistance

Further testing began to reveal a trend:



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Third Party Accreditation

Physical Testing

Flexural Strengths	-	Tensile Strengths
Modulus of Elasticity	-	Vapour Permeability
Water Absorption	-	Initial Surface Absorption (ISAT)
Freeze Thaw	-	Capillary Water Absorption
Slip Resistance	-	Abrasion Resistance
Pull-off Tests	-	Effect of Water/Cement Ratio

Chemical Testing of Hardened Cement/Concrete

Acid Resistance	-	Sulphate Resistance
Chloride Diffusion	-	Protection to Steel Reinforcement
Alkali Aggregate Reaction	-	Chloride Ion Penetration
Leaching / Efflorescence	-	Coefficient of Thermal Expansion
Microstructure Observation		

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Environmental Impact

CO_2 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

- OPC – 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

- GPC – 1.23 tonnes raw m[illegible] 1 tonne product
  - 0.77 ton[illegible]gical precursor
  - 0.46 t[illegible]or alkali-silicate component

Worst Case Scenario

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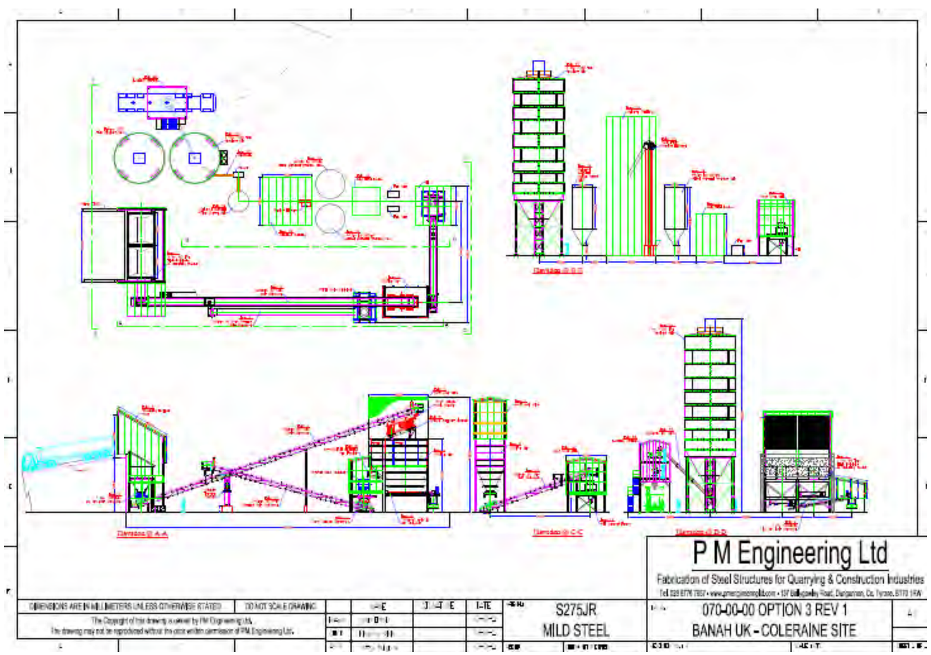
Production Plant



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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