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Alkali-Activated Concrete from Plasmarok®

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World Recycling Congress, Berlin 2016

27th July 2016

EPSRC Pioneering research and skills

UNIVERSITY OF BIRMINGHAM

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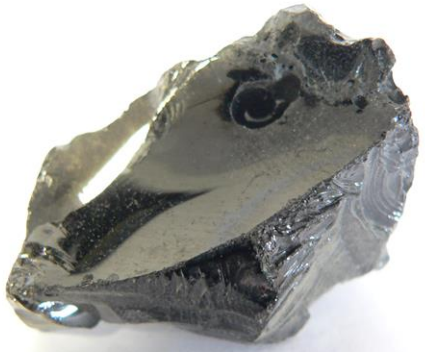
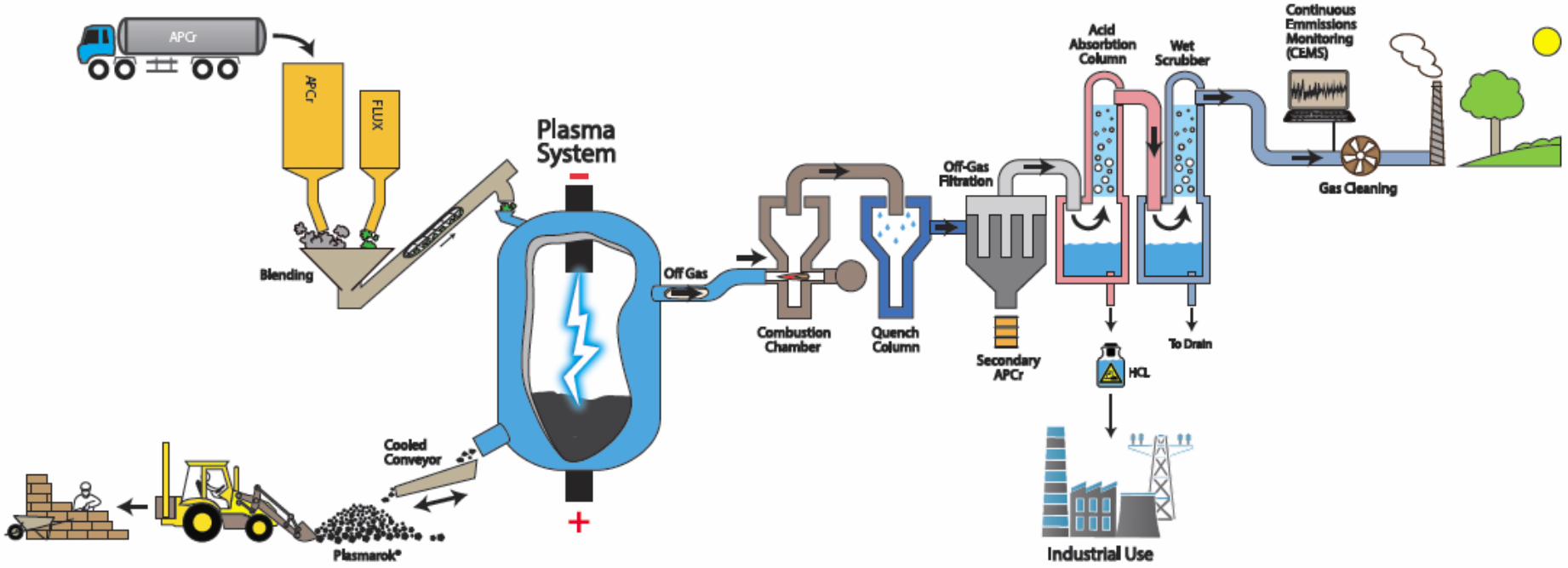
CENTRE FOR DOCTORAL TRAINING IN FORMULATION ENGINEERING

Air Pollution Control Residue (APCr)

- Mixture of fly ash, organic pollutants, carbon and alkaline salts produced during gaseous emissions cleaning from incineration activities.
- The UK is approaching the production of 500,000 tonnes of APCr per year.
- Thermal plasma can be used to transform the APCr into a non-hazardous material know as Plasmarok® via a vitrification process.
- Plasmarok® can be re-used as an aggregate in construction applications but Tetronics have currently been researching its application as a cement replacement.



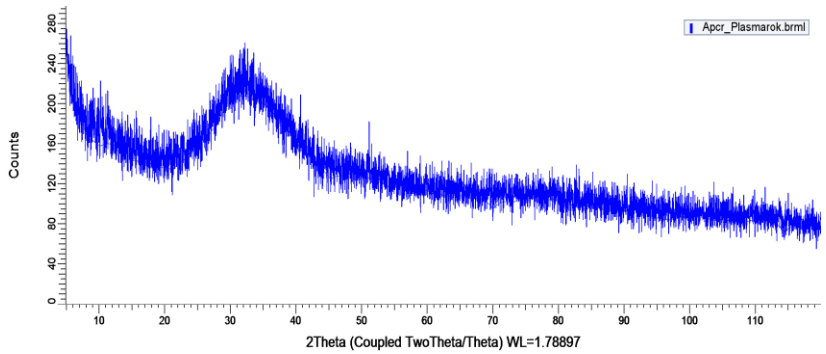
The Plasma Vitrification Process



Cement Replacements

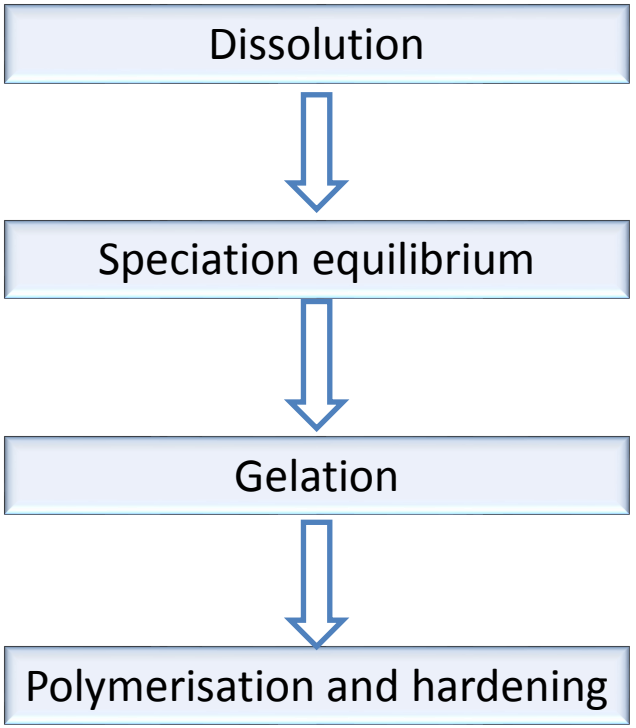
- Fly ashes, calcined clays, volcanic ashes and blast furnace slags are examples of successful commercial cement replacement materials.
- Materials with high SiO_2 and Al_2O_3 content, glassy phases and small particle sizes are good cement replacements.
- Alkali-activated concretes derived from Plasmarok can have very high compressive strengths (90 Mpa)
- Alkali-activated concretes require the material to be mixed with an alkaline solution such as NaOH to initiate their production.

Oxide	wt%
Al_2O_3	16
SiO_2	39
CaO	35
Fe_2O_3	4
MgO	1.3
TiO_2	1.3
P_2O_5	0.7
Na_2O	0.2



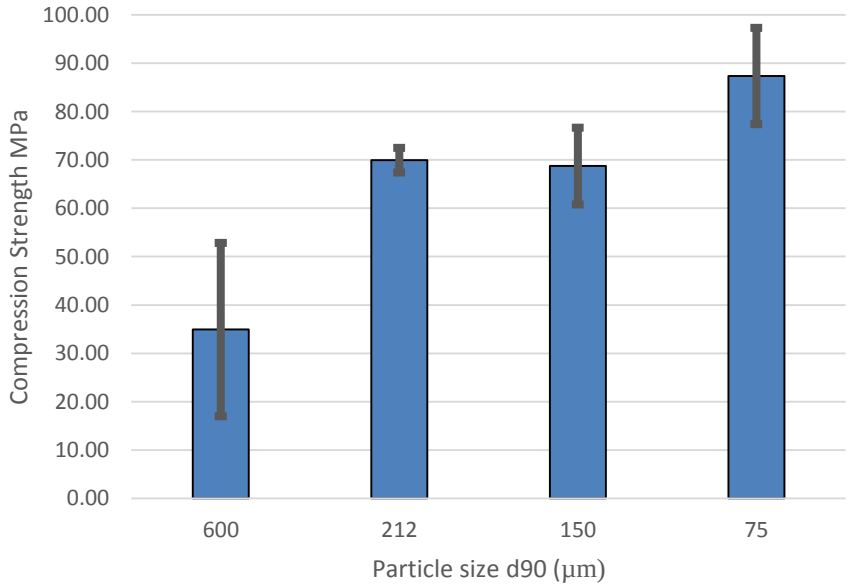
Factors effecting the material properties

- There a number of stages which occur as alkali-activated concretes are produced. These stages are affected by:
  - Particle size of the Plasmarok.
  - Chemical composition of the formulation.
  - Mix design.
  - Processing route.



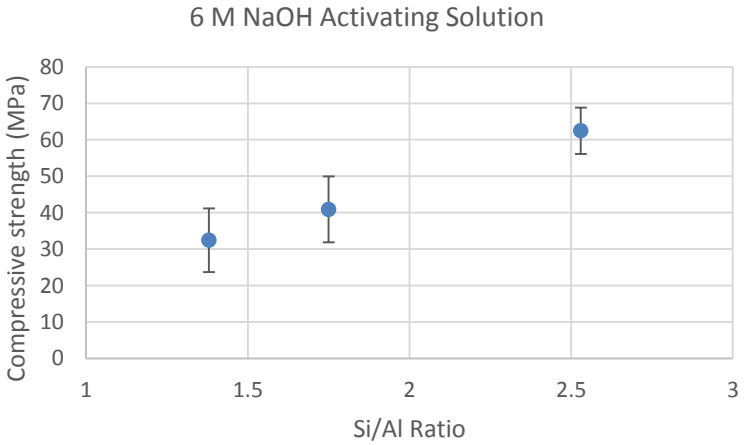
Particle size

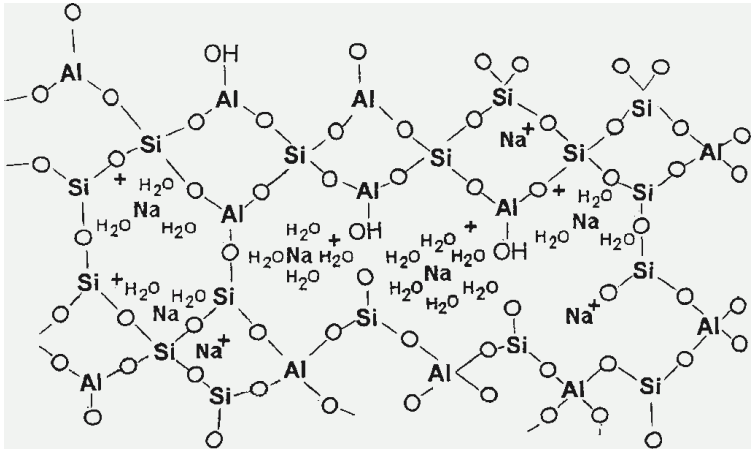
- The particle size distribution of the Plasmarok has a significant effect on the strength of the concrete.
- As the particle size is reduced the strength of the final alkali activated concrete is increased.
- Reducing the particle size increase the available surface area for the dissolution of the species from the Plasmarok into solution.
- As more species can dissolve into the solution, the stronger the material can become.



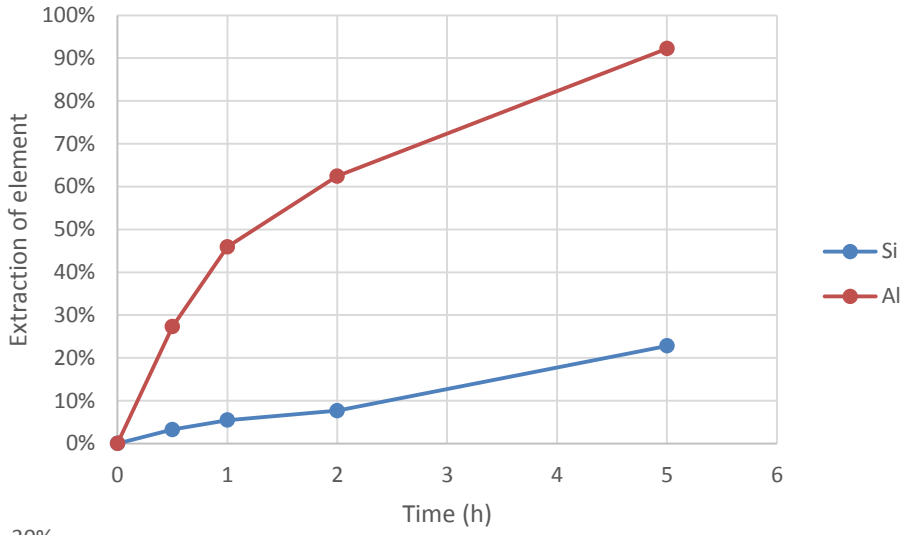
$SiO_2 – Al_2O_3$ Ratio

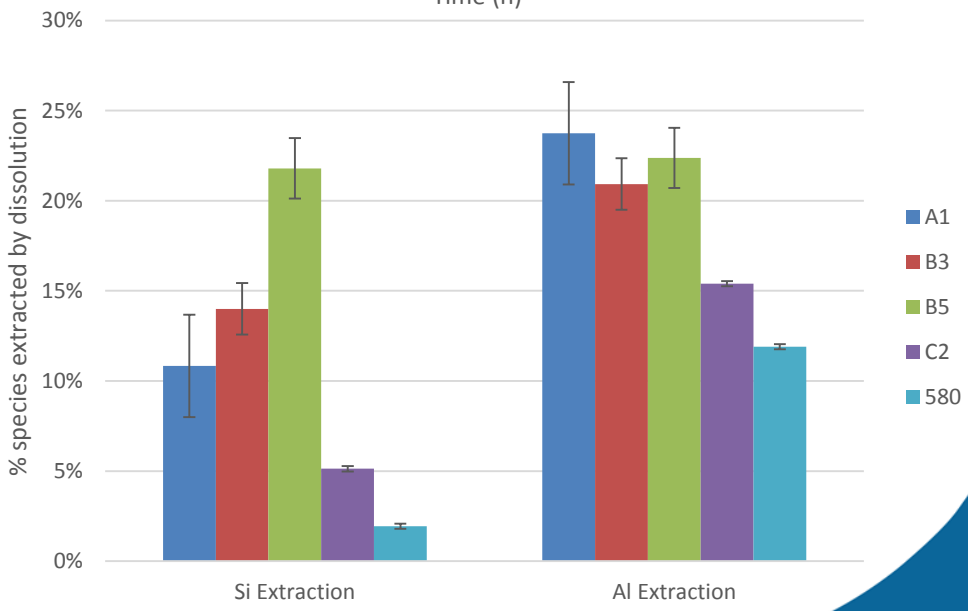
- Increasing the Si/Al ratio in the formulation can increase the compressive strength of the alkali-activated concrete.
- The species form alumino-silicate chains during polymerisation, but the Si-O bond is much stronger than the Al-O bond.
- The more Al in these chains the weaker they would be.
- Aluminium ions are more readily dissolved from the Plasmarok in alkaline environments than silicon ions.

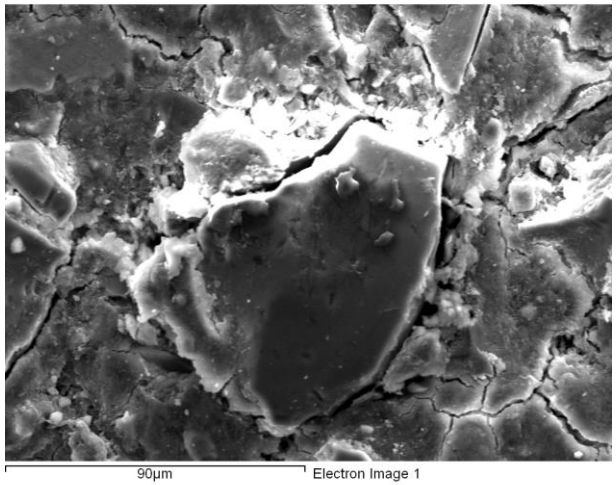


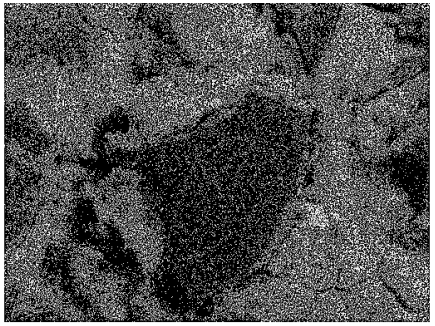


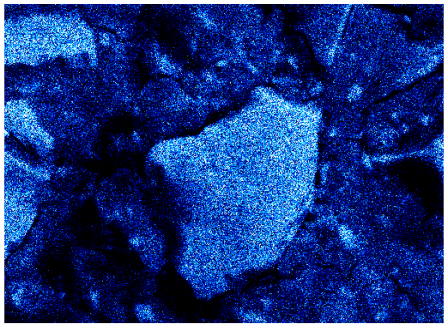
Oxide	A1	B3	B5	C2	580
SiO_2	34	35	30	40	42
Al_2O_3	17	22	25	16	10
CaO	36	36	36	36	40
Na_2O	5	0.3	1.2	0.7	0.2
Fe_2O_3	2.6	1.7	1.5	2.3	1.2
MgO	1.4	1.5	1.4	2.1	1.4
TiO_2	1.1	1.2	1.2	1.4	1.1

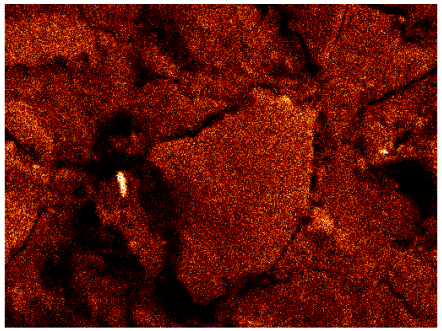


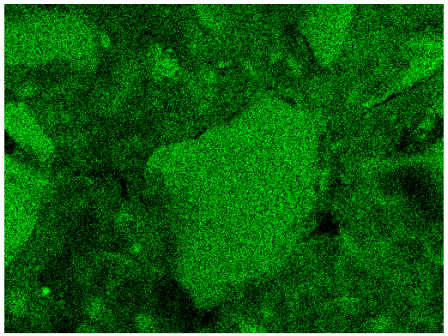





Na Ka1_2

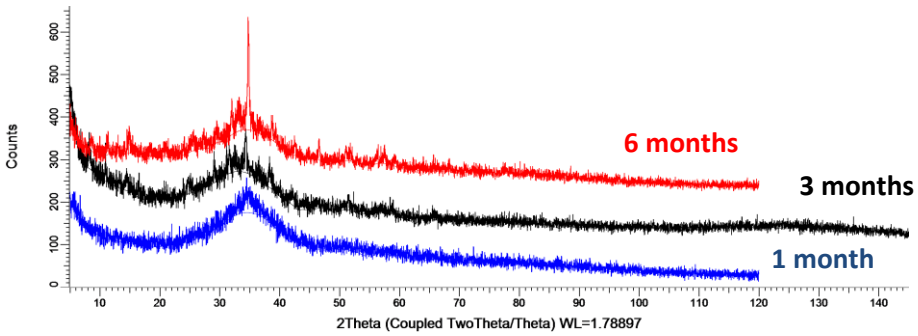

Al Ka1


Si Ka1


Ca Ka1

The binding phase is composed of sodium, aluminium, silicon and calcium oxides and so can be represented as a C-(N)-A-S-H binding phase.

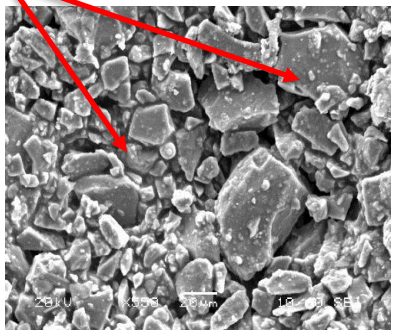
The binding phase is at first amorphous but gradually develops a semi-crystalline structure over time.

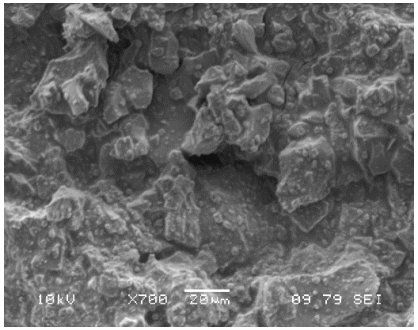


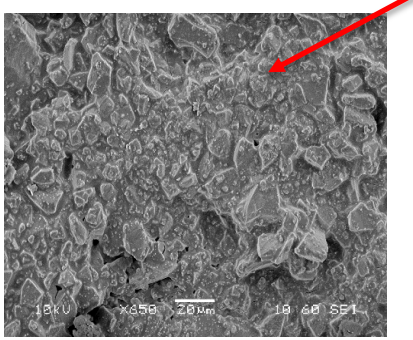
Increasing binding phase content

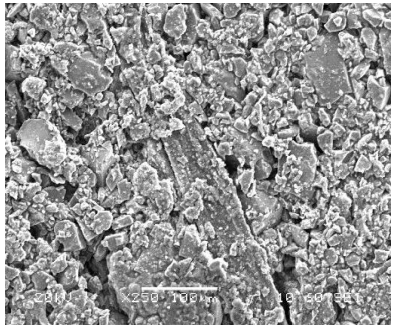
Unreacted particles

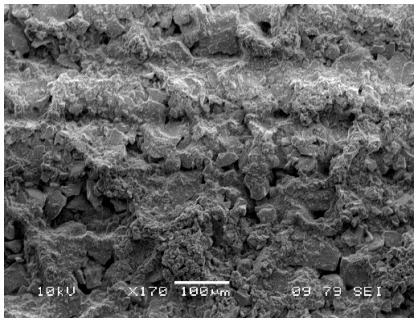
Binding phase

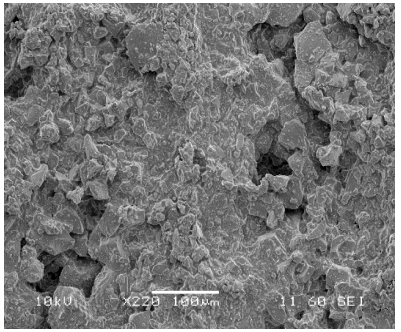












Solid : liquid ratio 10

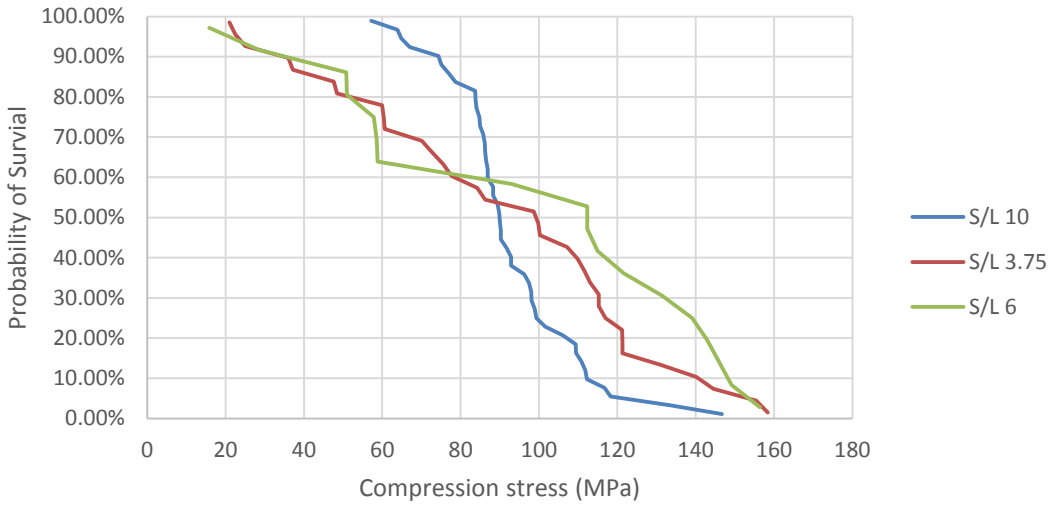
Solid : liquid ratio 6

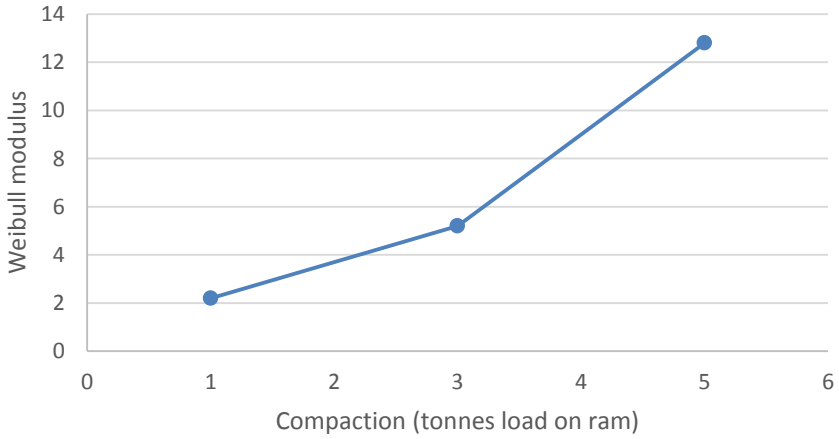
Solid : liquid ratio 3.75

Increasing characteristic strength

Process Route

- The strength of the material can be variable.
- Compaction of the mixture in the mould reduces the variability of the strength of the material.
- The compaction of the raw materials reduces residual stress in the final material derived from large pores.





Summary

- Hazardous wastes such as air pollution control residue can be transformed into a non-hazardous glass via plasma technology
- The non-hazardous glass can be recycled as a cement replacement and used to make high strength alkali-activated concretes.
- The properties of the alkali-activated concretes are dependant on a number of factors including intrinsic properties of the material and extrinsic influences such as the processing route or mix design.
- Understanding the influences of these factors helps us to be able to develop consistent materials which desirable properties.

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Acknowledgments and thanks:

Dr. David Deegan and Dr. Tim Johnson – Tetronics International

Professor Neil Rowson and Dr. Richard Greenwood – University of Birmingham

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