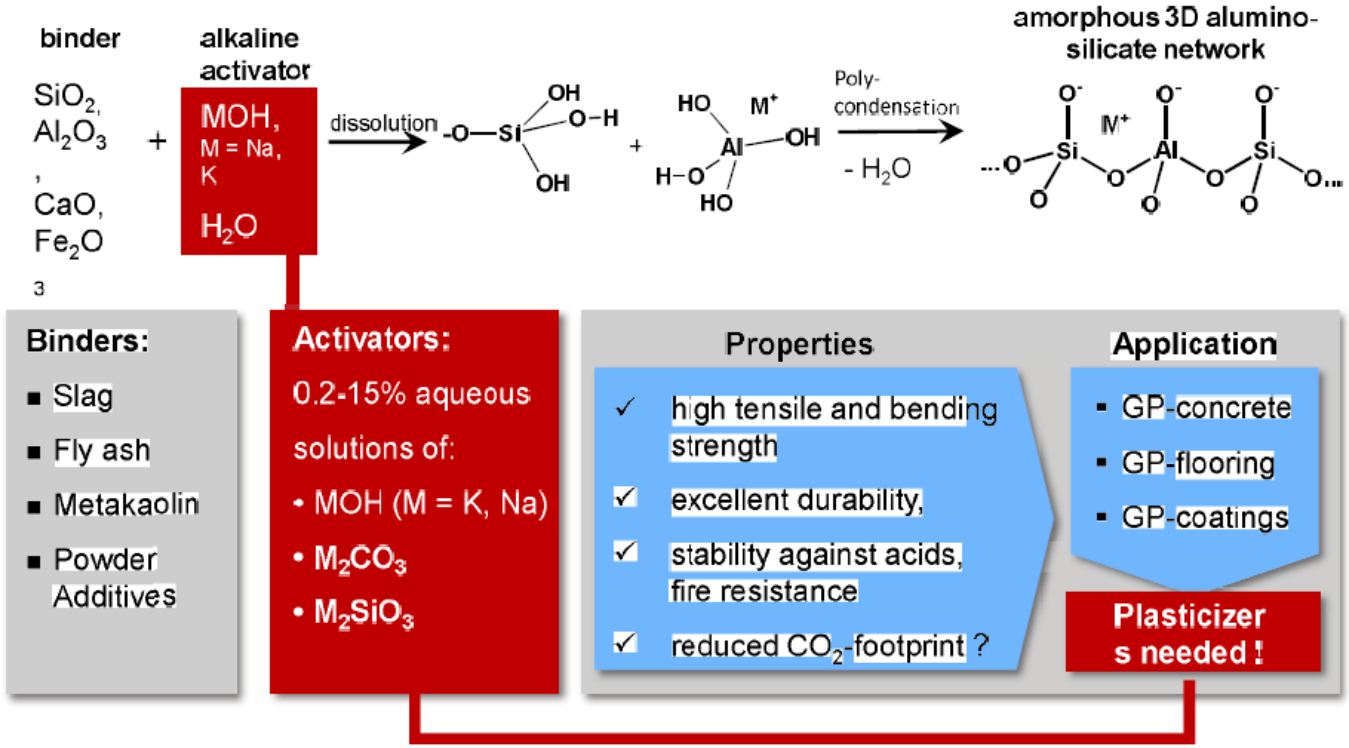
Geopolymer concrete

Miles Dacre - 12 July 2024

What is geopolymer concrete and why use it?

Geopolymer Basic Overview
Polycondensation vs hydration

Geopolymer: Polycondensation



OPC: Hydration

Tricalcium aluminate + gypsum + water → ettringite + heat

$C_3A + 3C\underline{S}H_2 + 26H \rightarrow C_6AS_3H_{32}$, $\Delta H = 207$ cal/g

Tricalcium silicate + water → calcium silicate hydrate + lime + heat

$2C_3S + 6H \rightarrow C_3S_2H_3 + 3CH$, $\Delta H = 120$ cal/g

Tricalcium aluminate + ettringite + water → monosulfate aluminate hydrate

$2C_3A + 3\,C_6A\underline{S}_3H_{32} + 22H \rightarrow 3C_4ASH_{18}$

What is geopolymer concrete?

It’s an alternative cementitious material to Ordinary Portland Cement (OPC) – OPC has been around for over 100 years and is a great, robust construction material.

Heard of SCMs – Supplementary Cementitious Materials – slag, fly ash & silica fume? When we add them to OPC based concretes as a partial cement replacement we rely on the alkalinity and heat that the OPC generates to activate.

In a geopolymer concrete all the OPC (GP cement) is removed and the activation of the slag and/or fly ash is achieved via an alkali-activator. They are starting to be referred to Alkali Activated Materials or Concrete.

Significance – it is all about carbon emissions

- To produce 1kg of cement clinker requires the release of ~1kg of carbon dioxide
- So OPC production contributes **~8% of the world’s total carbon emissions**
- Geopolymer concrete is one of the few ways that we can continue to use all the great structural properties of concrete and reduce emissions
- It's been known about and used for over 25 years – why aren’t we using it?

Challenges

There has been some drawbacks for Geopolymer

- Plasticising of geopolymer <10%
- Wet out times
- Finishability
- Workability
- Slump retention
- Set times
- Efflorescence
- Strength development
- Mix robustness
- Acceptance

Precast: Geopolymer

Customer Requirements

Fresh Properties	
Flow	500 – 650
T500	<5 s
Retention @ 10, 20 30 mins	Similar to control

Hardened Properties	
Compressive Strength @ 15 hours	> 30 MPa
30MPa Time	Similar to control
28 days	> 40MPa
Shrinkage	Same as control

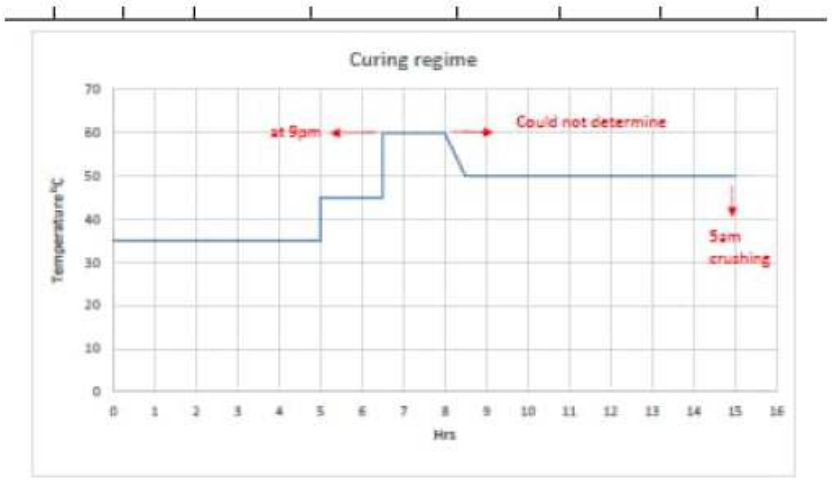
Ambiently cured and accelerated curing.

Precast: Early age strength is critical

Geopolymers systems have traditionally struggled with HES.

Accelerated Curing

Name	15 hours
Control 1 (0.35)	25
Geopolymer	24.5



Ambient Curing @ 23'c

Name @ 23'C	24 hours	28 hours	40 hours
Control 1 (0.35)	20	23.5	30.5
Geopolymer	18	22	27.5

Take away: Stripping strength achieved at same time as control mix

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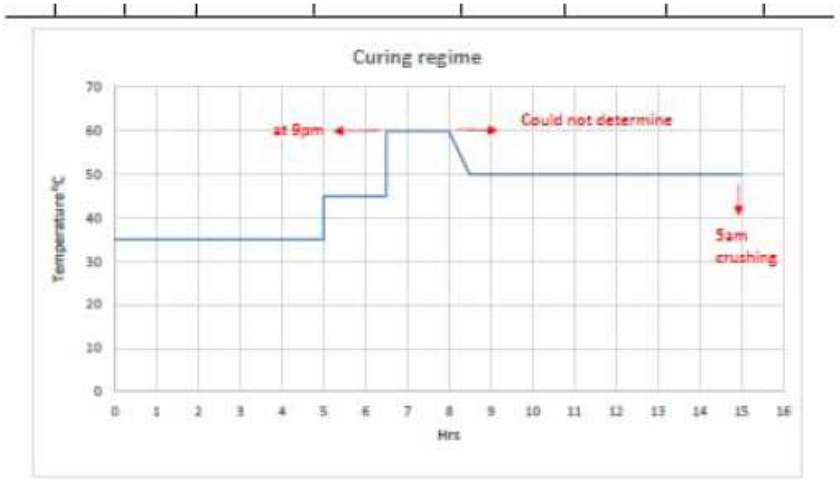

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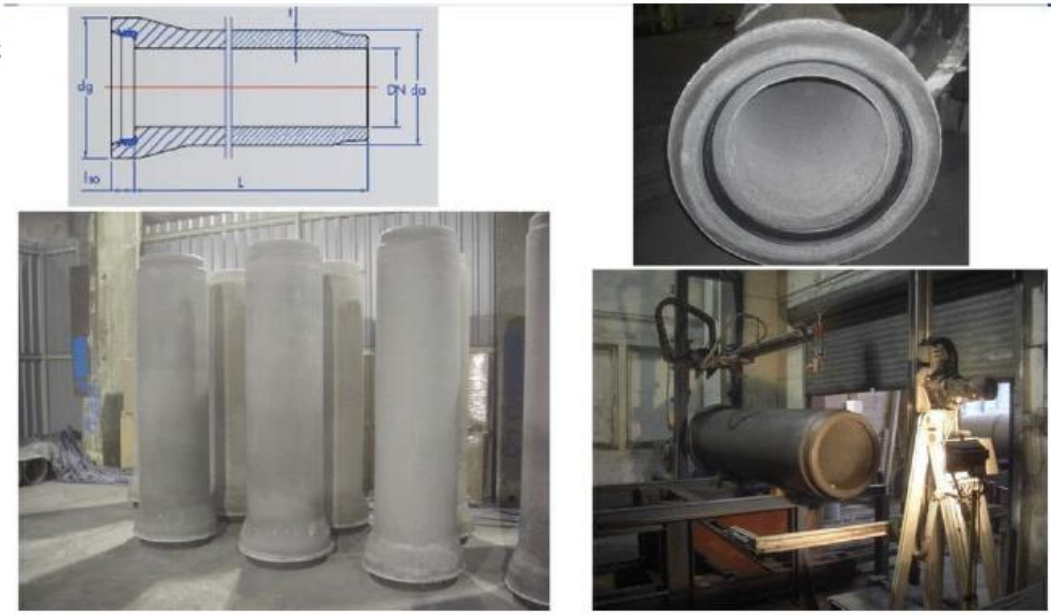
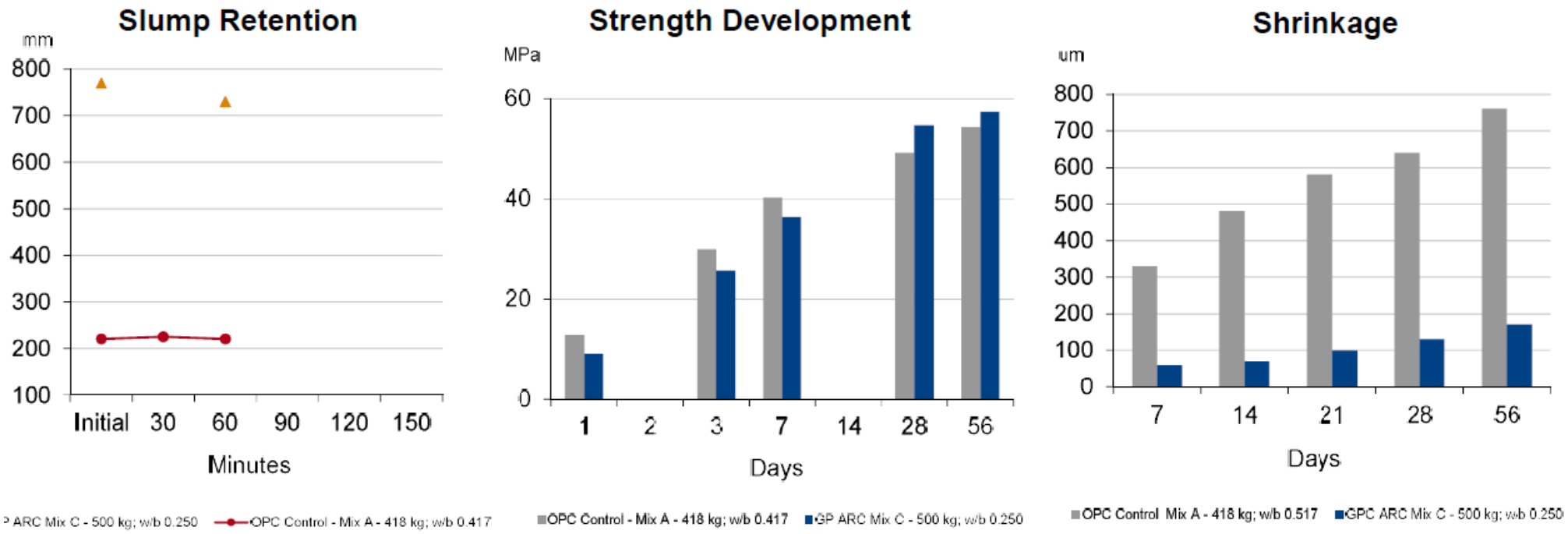
Precast: Potential applications

- Civil Precast Elements – Example Pits, barriers etc
- Railway sleepers
- Flat panel architectural precast panels
- Small elements – covers etc
- Drainage pipes



ARC Performance

High performing system with improved properties



Acid Resistant Geopolymer Concrete: Performance

- 28 days old mortar samples
- 2 hour impact
  + additional abrasion

Medium	GP weight loss, %
Water	~ 0.5
NaOH (pH 14)	~ 0.5
Lactic acid (pH 2)	~ 1.5

08.06.2015

- 28 days old mortar samples
- 12 weeks organic acid impact without abrasion
- previous results with other raw materials source

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- Concrete Testing – OPC Control vs CIP Binder; Sulfuric Acid; pH 0; Temp 22°C

Acid Resistant Geopolymer Concrete: Potential applications

- Septic Tanks
- Sewer Pipes
- TBM Segments
- Chemical Storage

Thank you.

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