Geopolymer Concrete and its Applications

1 May 2018

Austroads

Today's moderator

Eliz Esteban

Communications Officer

Austroads

P: +61 2 8265 3302

E: eesteban@austroads.com.au

About Austroads

The peak organisation of Australasian road transport and traffic agencies

- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Transport Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- Department of Infrastructure, Regional Development and Cities
- Australian Local Government Association
- New Zealand Transport Agency

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Austroads

- Austroads Board
  - Austroads National Office
    - Assets Program
      - Assets Task Force
      - Bridge Task Force
      - Pavements Task Force
      - Road Tunnels Task Force
      - Project Delivery Task Force
    - Network Program
      - Network Task Force
      - Freight Task Force
    - Safety Program
      - Road Safety Task Force
      - Road Design Task Force
      - Registration and Licensing Task Force
      - Austroads Safety Barrier Assessment Panel
    - Connected and Automated Vehicles
      - CAV Steering Committee
      - Industry Reference Group
    - NEVDIS
      - Vehicle governance
      - Licensing governance

Housekeeping

Presentation = 60 mins

Question time = 15 mins

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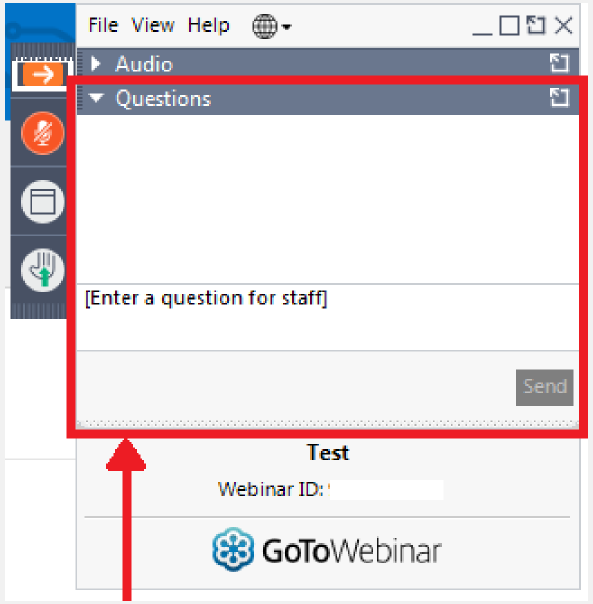

Please type your questions here

Let us know the slide number your question relates to

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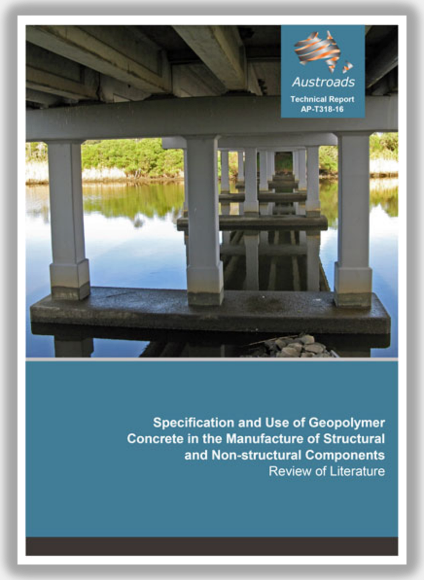
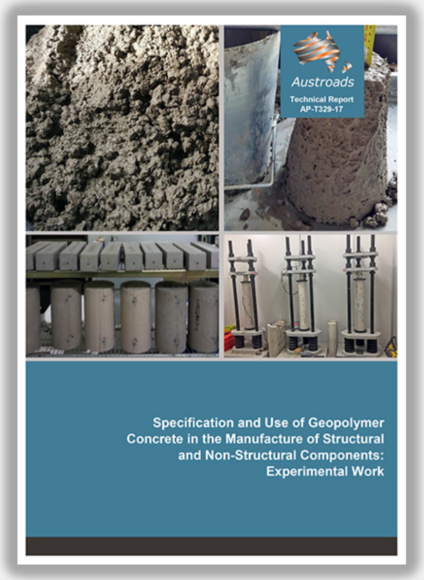


Austroads
Technical Report
AP-T318-16

Specification and Use of Geopolymer Concrete in the Manufacture of Structural and Non-structural Components
Review of Literature



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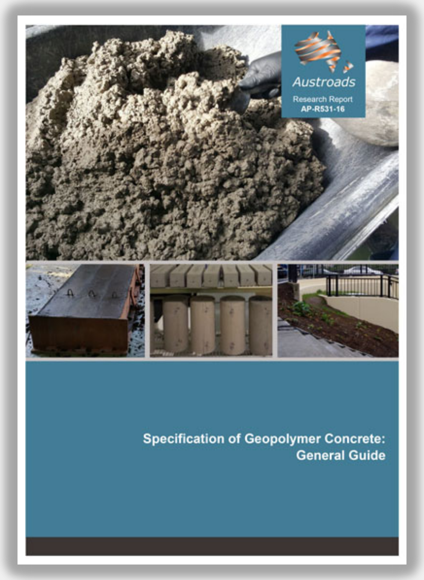
Technical Report
AP-T329-17

Specification and Use of Geopolymer Concrete in the Manufacture of Structural and Non-Structural Components: Experimental Work



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Research Report
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Specification of Geopolymer Concrete: General Guide

Download from Austroads Website:

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Today’s presenters

Dr Ahmad Shayan

Chief Technology Leader

Australian Road Research Board (ARRB)

P: +61 3 9881 1658

E: ahmad.shayan@arrb.com.au

Fred Andrews-Phaedonos

Principal Engineer

VicRoads

P: +61 3 9881 8939

E: fred.andrews-phaedonos@roads.vic.gov.au

Agenda

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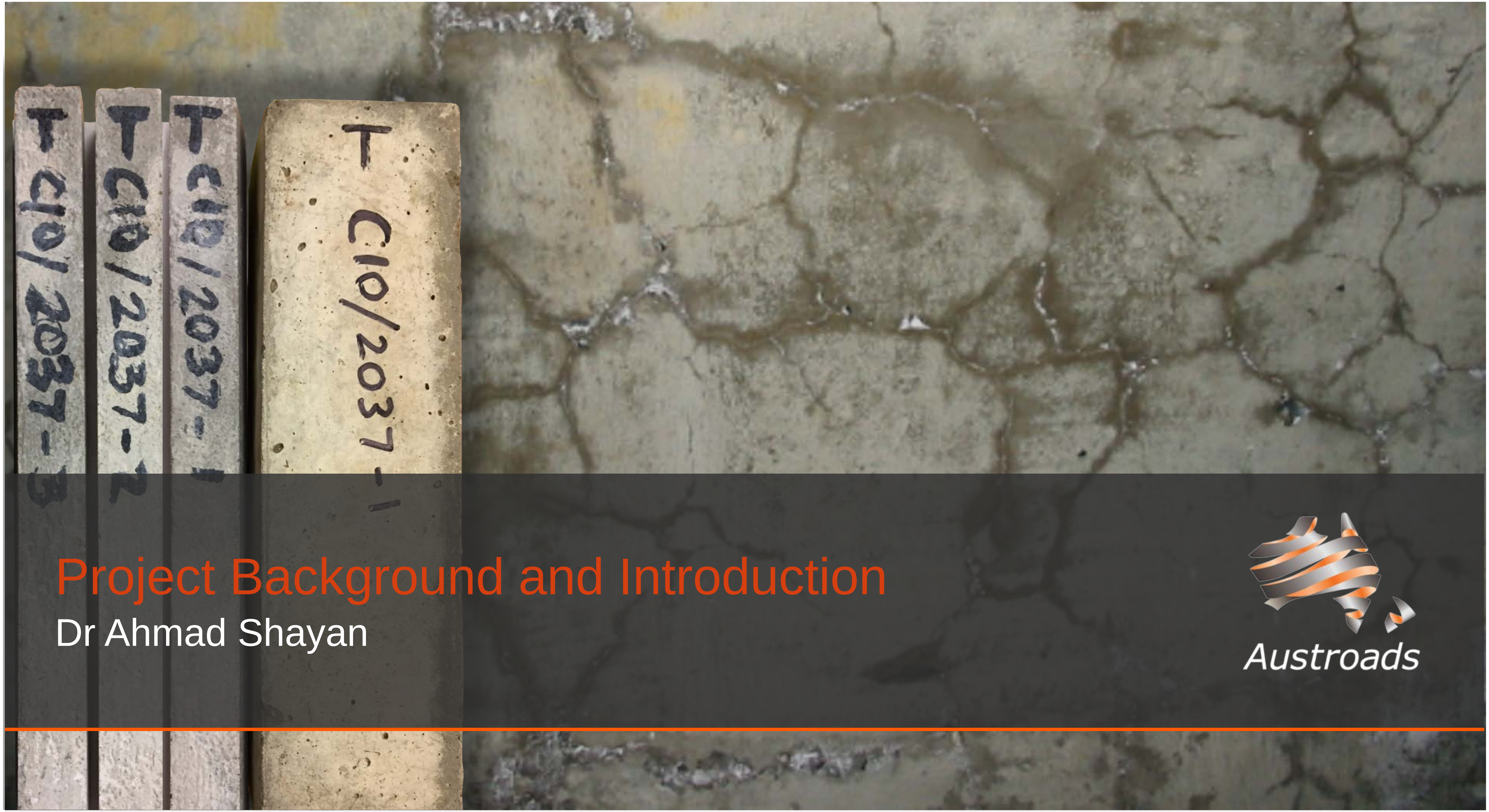
Topic	Presenter
Project Background and Introduction	Dr Ahmad Shayan
Literature Review	
Experimental Work	
Specification and Use of Geopolymer Concrete	Fred Andrews-Phaedonos
Field Application of Geopolymer Concrete: Case Studies	
Geopolymer Concrete Pipes	
Impediments to the Wider Use of Geopolymer Concrete	
Q&A	Both presenters



Project Background and Introduction

Dr Ahmad Shayan

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Introduction to team

Project Team

Austroads
Project Manager
Fred Andrews-Phaedonos

Project Leader
Dr Ahmad Shayan

Dr Aimin Xu - ARRB,
Chandani Tennakoon - (then) PhD Candidate, Swinburne University

Review Team

Austroads
Project Working Group

Stakeholders-
Road and Traffic Authorities

Austroads Bridge
Task Force

Austroads Board

The Project Team

Austroads

Austroads Bridge Task Force

Richard Underhill DIPL NT

Angela Ransom DTMR QLD

Parvez Shah RMS

Wije Ariyaratne RMS

Richard Yeo Austroads

Jo Hill Austroads

Neil Wong NTC

Karl Cloos TCCS ACT

Adam Lim MR WA

Phil Molloy DPTI SA

Andy Ng VicRoads

Anthony Rooke ARRB

John Reynolds NZTA

Barry Wright NZTA

Andrew Hargrave DSG Tas

Vincent Tang DSG Tas

Portland cement-based concrete (PCC)

- PCC = PC (binder) + aggregate + SCM (fly ash, slag, silica fume, meta-kaolinite etc.) + Water + Chemical Admixtures
- PC is an energy-intensive material
  - Limestone + clay + Heat (1300 °C)

    → Cement Clinker + CO_2 emission

(1 tonne of cement generates roughly 1 tonne of CO_2)

Geopolymer concrete (GC)

GC =

Aluminosilicate by-products (precursors) + Alkali Activator + Aggregate + Water

- No standard formulation for geopolymer binder

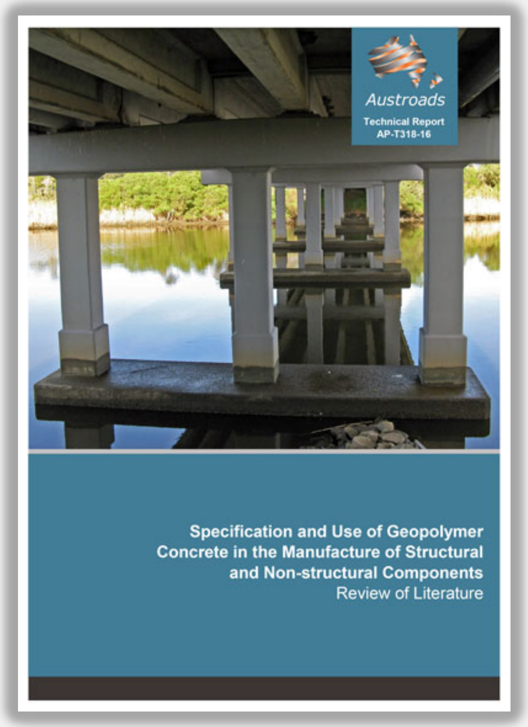
Process does not produce CO_2

- Use of waste or by-product materials (fly ash, slag (particularly BFS), silica fume, etc., do not require excavation of virgin materials
- Two environmental benefits

Background on project

- Road agencies keen to reduce their CO_2 emission footprint, in accord with global attempts to curb global warming
- Progress made by Industry in the development of GC as a construction materials
- Formulations were kept confidential to the industry (proprietary product)
- Austroads decided to generate transparent information

Austroads’ Geopolymer Concrete Project



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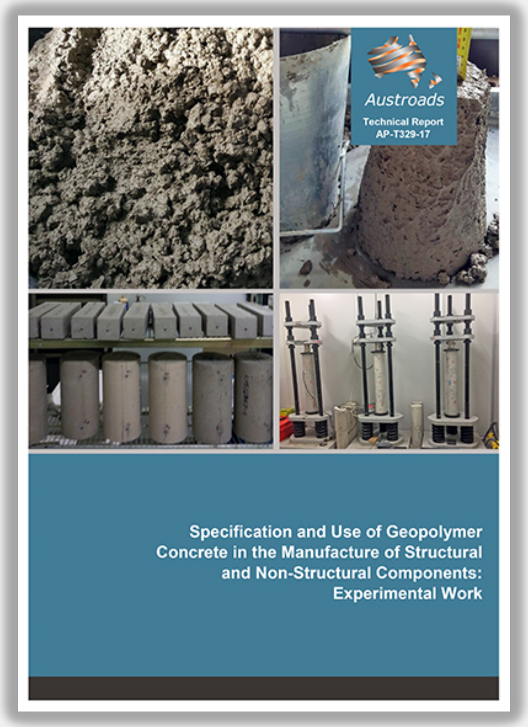
Specification and Use of Geopolymer Concrete in the Manufacture of Structural and Non-structural Components
Review of Literature

2012 – 2013: Literature review and gap analysis



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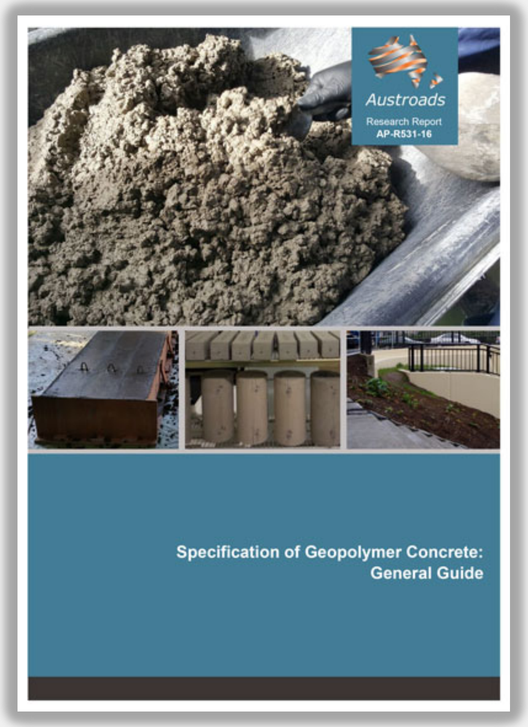
Specification and Use of Geopolymer Concrete in the Manufacture of Structural and Non-Structural Components:
Experimental Work

2013 – 2016: Experimental development of geopolymer concrete for field application



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Specification of Geopolymer Concrete:
General Guide

2016: Brief guide to geopolymer concrete and its specification

Literature Review

Dr Ahmad Shayan

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Literature Review: Important parameters

Influencing parameters in making geopolymer binder:

- Chemical composition and Mineralogy of precursor materials
- Amount, form (solid, liquid) and type of alkali-activator (NaOH/ KOH and Na/ K-silicate) [†], with optimum Na/Al ratio being around 1–1.5
- Si/Al ratio of precursor materials (optimum: 2.5 – 4) and amount of available calcium source, such as Portland cement, blast furnace slag and lime
- Ratio of water/total solids (Precursors + alkali salts)
- Ambient curing vs heat curing: effect on strength and drying shrinkage [≠]

Reaction products

- Low-calcium system (Low-Ca fly ash-based)
- High-calcium System (e.g. Slag-based)
- Low Ca geopolymer = mostly amorphous alkali-alumino-silicate gel (NASH, geopolymer gel) and nano-crystalline zeolite
- High Ca geopolymer products = CSH and Calcium alumino-silicate hydrate (CASH)
- Types of products influence the properties of the resulting geopolymers

Main gaps in published information

Is strength regression possible in the medium- to long-term?

Is geopolymer concrete susceptible to AAR?

Is alkalinity in the pore solution of geopolymer concrete adequate to resist reinforcement corrosion in the long-term?

Are PCC test methods, such as AAR, carbonation and rapid chloride penetration tests, applicable to geopolymer concrete?

Experimental Work

Dr Ahmad Shayan

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Experimental phase: Materials

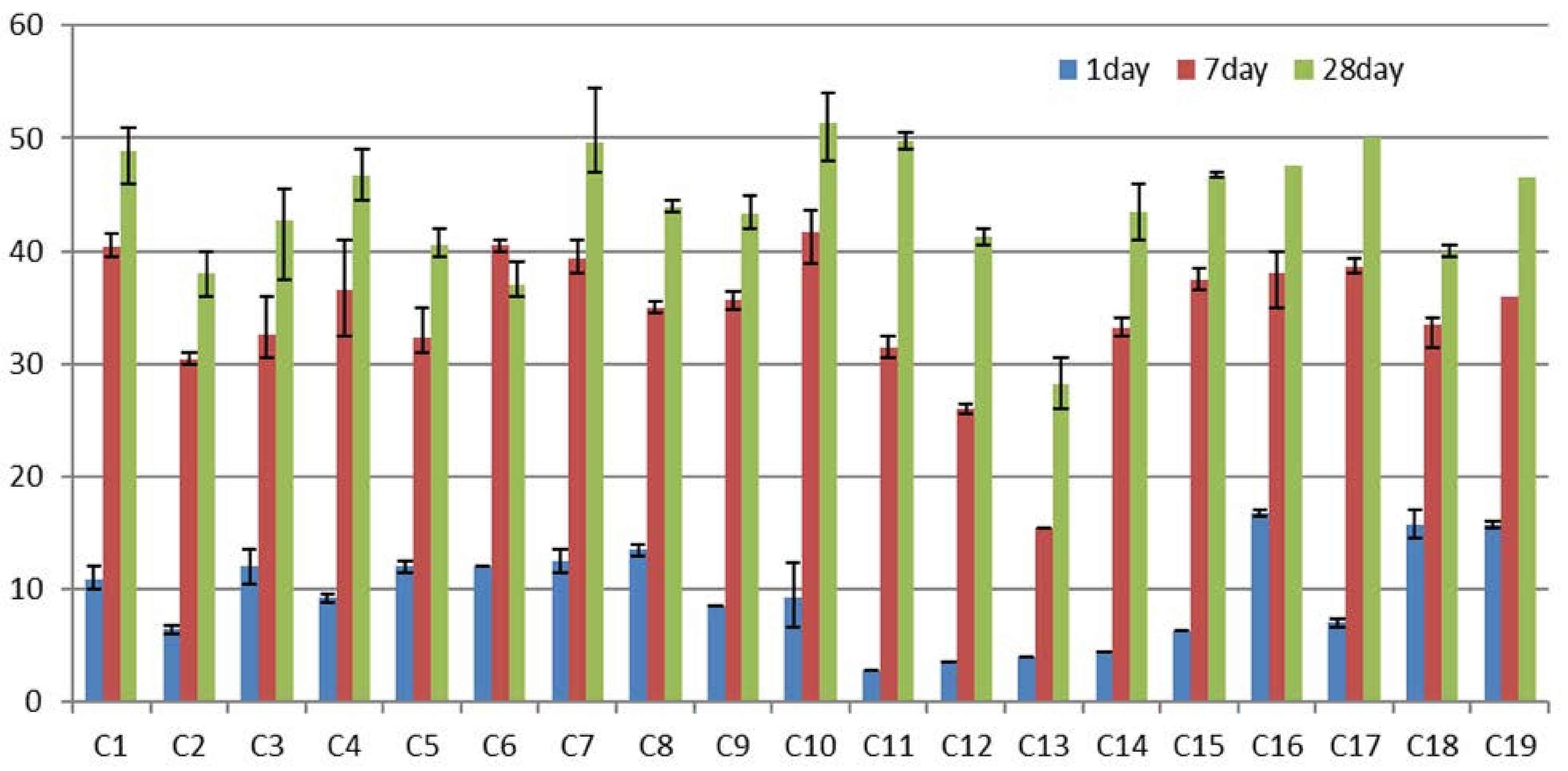
- Materials: commercially available aggregates, fly ash, slag, as well as liquid and anhydrous sodium metasilicate and sodium hydroxide
- Precursor formulations, using data from the literature:

	Range
Fly ash	0-100 %
Slag	100-0 %
Water/solid (geopolymer solid) ratios	0.38–0.40
Alkali-activator	Sodium silicate solution with silica modulus of 2, equivalent of 4–6% Na_2O by mass of precursor, also solid sodium metasilicate
Sodium- based activators	Mostly used (cheaper than Potassium based activators)

Assessment methods

- Binder formulations originally tested for rheological properties and strength development
- Effects of humidity, curing temperature and age on strength development originally tested on paste and mortar specimens
- Precursors and selected mixes characterised using XRD, NMR, SEM/EDX
- Formulations which resulted in satisfactory rheological behaviour and strength development were selected for testing as concrete

Geopolymer concretes and characterisation

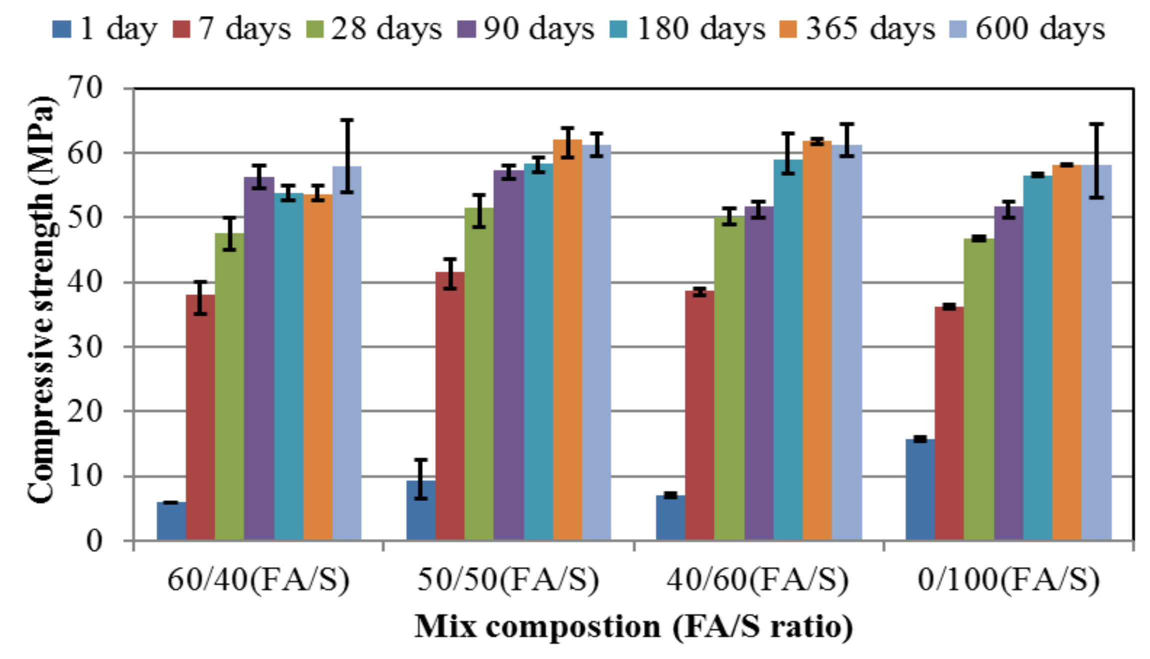


Concrete mixes selected for further testing

Mix proportion	Fly ash (kg/m³)	Slag (kg/m³)	Sodium meta-silicate pentahydrate content		Coarse aggregates and sand (kg/m³)			Extra added water (kg/m³)	Water/geo solids ratio
			(kg/m³)	(%)	14 mm	10 mm	Sand		
60% FA **40% slag**	240	160	61	13	630	450	680	156	0.39
50% FA **50% slag**	200	200	61	13	630	450	680	149	0.38
40% FA **60% slag**	160	240	61	13	630	450	680	149	0.38
100% slag	–	400	61	13	630	450	680	154	0.41

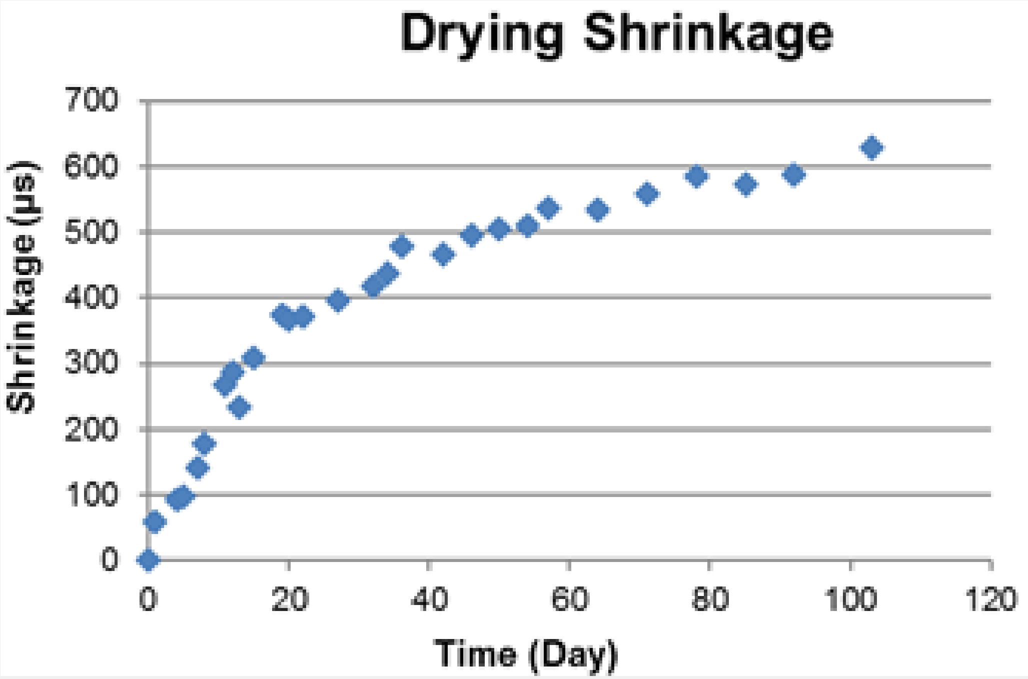
Long-term strength: Results

All mixes achieved higher than 45 MPa strength at age of 28 days of moist-curing and exceeded 50 MPa at 90 days



Typical example of drying shrinkage: Results

All selected mixes showed drying shrinkage values less than 700 µstrain at the age of 100 days, and comply with the requirements of AS3600 and AS5100 (<750 µstrain at 56 days)

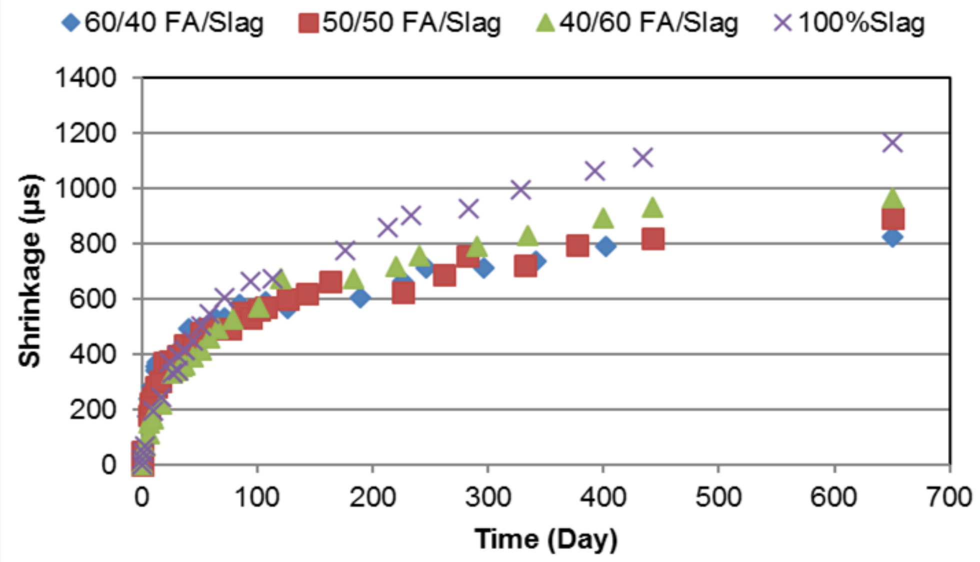


50/50 FA/Slag – anhydrous activator – 8% of total solids

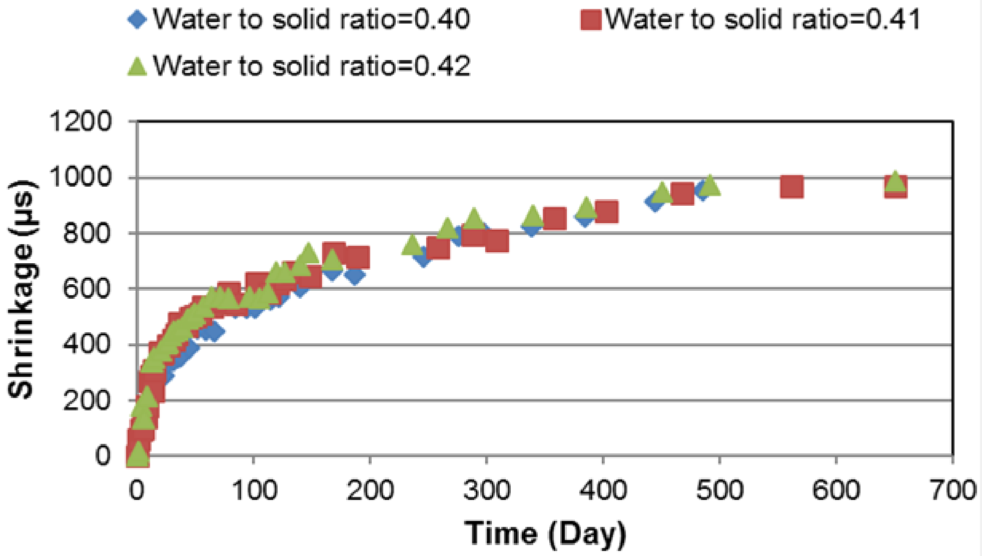
Long-term drying shrinkage

100% alkali-activated slag shows higher rate and magnitude of drying shrinkage than blends

Different Binders

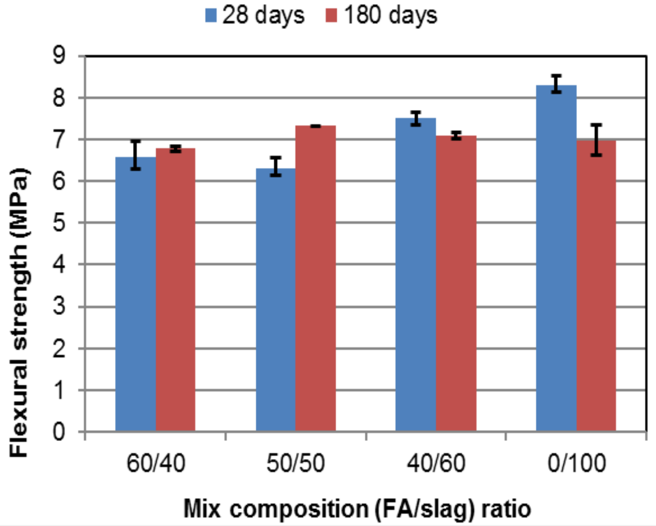


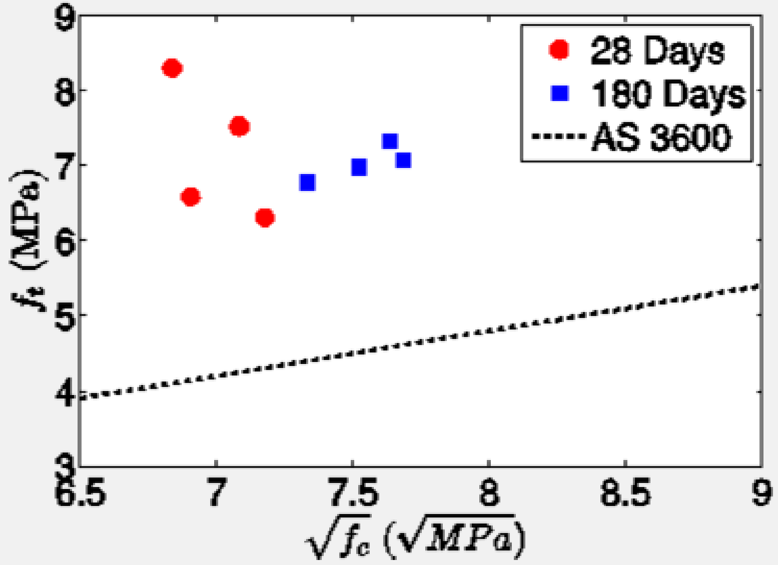
50/50 (FA/S) at different W/B Ratios



Flexural strength of 75 x 75 x 285mm concrete prisms

- Flexural strength higher than the AS3600 line for PCC
- Higher slag content caused reduced strength at 180 days than 28 days probably due to higher drying shrinkage
- The flexural strength is underestimated by AS3600

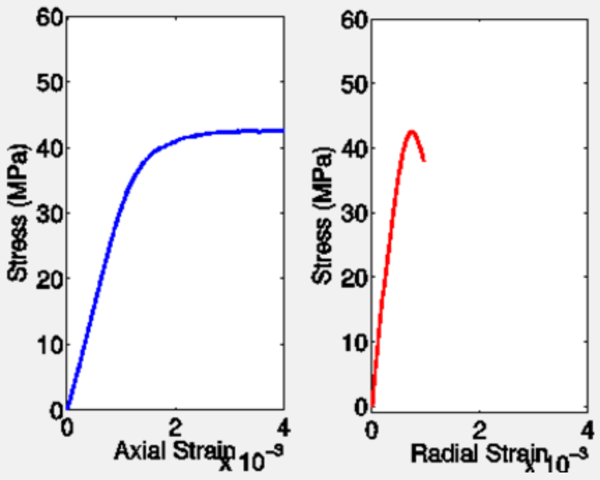




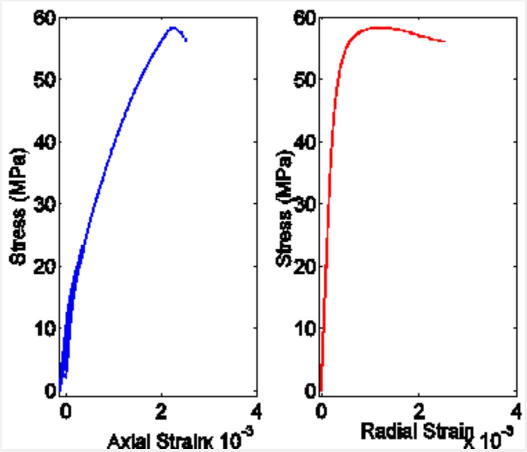
Examples of stress: Strain behaviour

- Strain at peak stress in the range 2.1–2.5 × 10^{-3} for blends, which is similar to that of PCC
- 100% S had lower load capacity
- GC failure occurred explosively (brittle failure) at peak stress rather than the gradual softening behaviour of normal strength PCC, i.e., GC behaves like high strength PCC
- Behaviour is influenced by nature of binder formed (Cross-linked geopolymer gel (brittle) vs layered CSH (ductile))

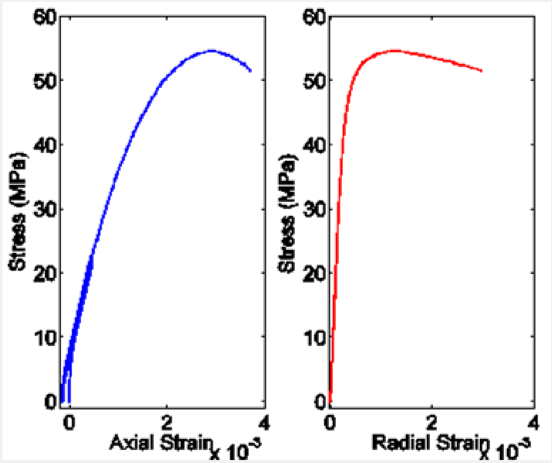
0/100 FA/slag



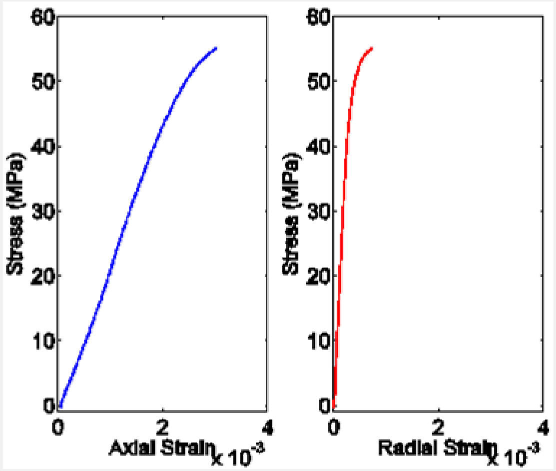
60/40 FA/slag



50/50 FA/slag

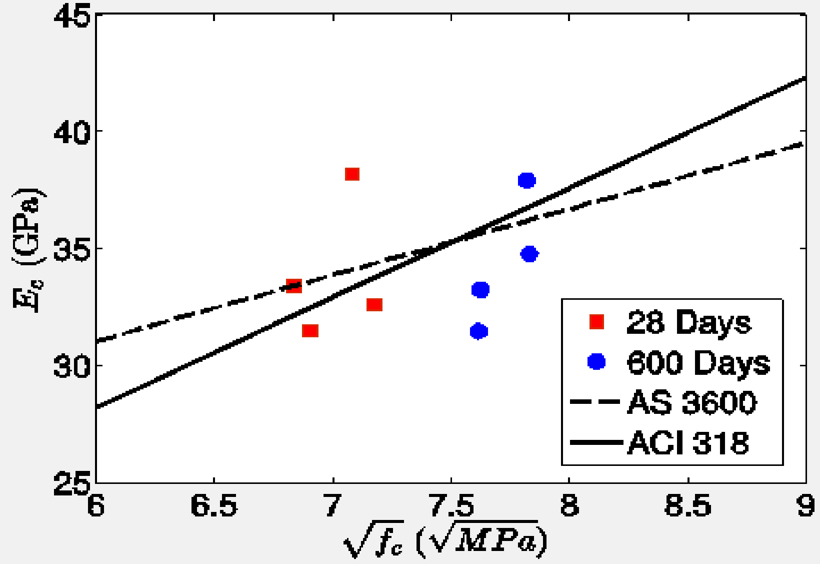


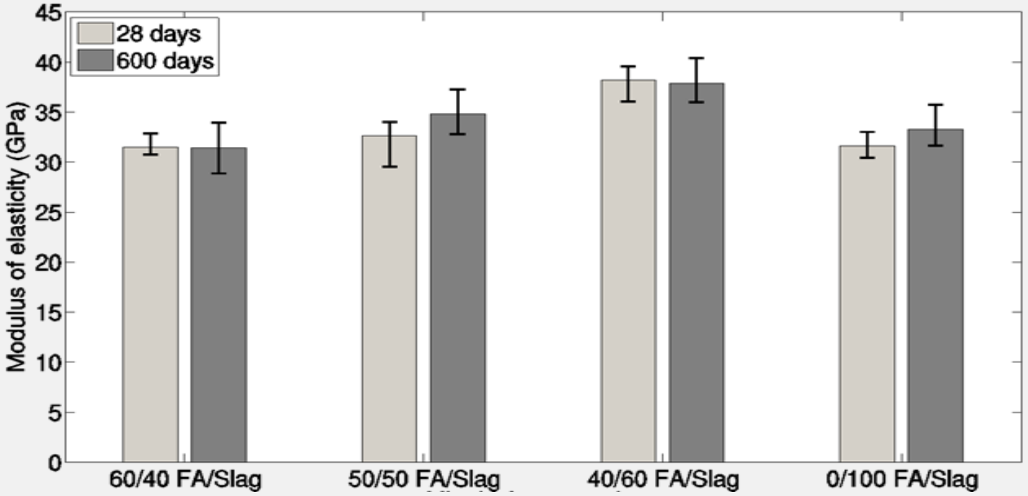
60/40 FA/slag

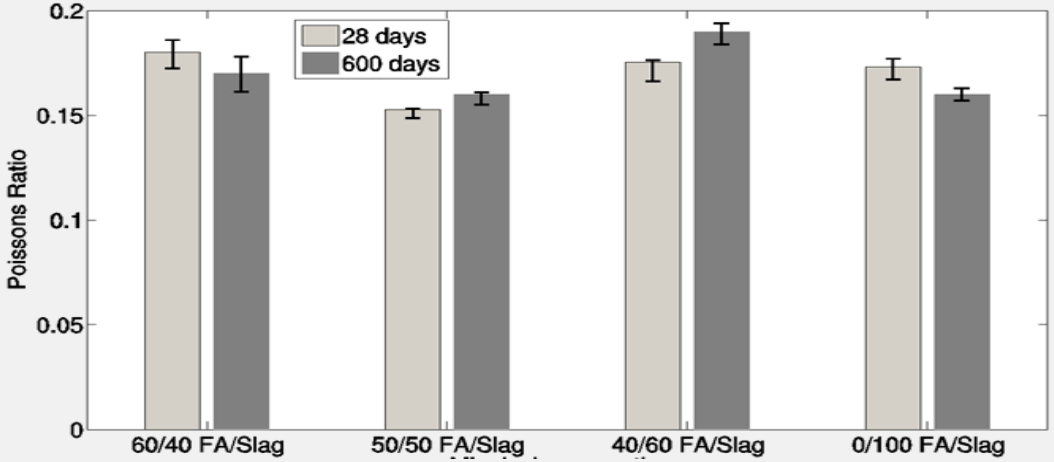


Elastic modulus test results and poison ratio AS 1012.17:1997

The elastic modulus would be largely overestimated by As 3600 and ACI 318







VPV values of various geopolymer concretes

Mix formulation	Section of cylinder	Apparent volume of permeable voids AVPV (%)	Average VPV of cylinder (%)	Density Surface dry saturated density, SSD (kg/m^3)
60/40 (FA/S)	Top	19.26	17.8	2411
60/40 (FA/S)	Middle	17.95		2444
60/40 (FA/S)	Bottom	16.19		2493
50/50(FA/S)	Top	17.55	17.1	2441
50/50(FA/S)	Middle	16.84		2456
50/50(FA/S)	Bottom	16.84		2459
40/60 (FA/S)	Top	18.31	17.7	2419
40/60 (FA/S)	Middle	17.87		2429
40/60 (FA/S)	Bottom	16.85		2458
100 Slag	Top	20.17	19.4	2427
100 Slag	Middle	19.67		2436
100 Slag	Bottom	18.50		2460

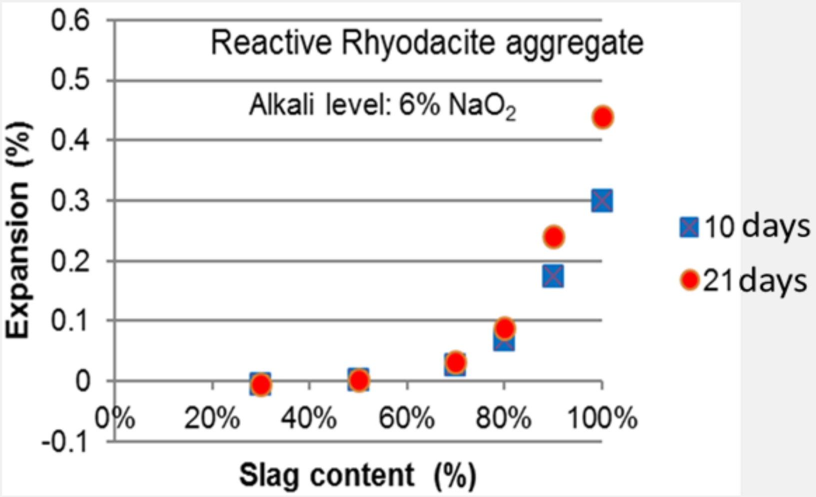
FA/S Geopolymers: (W/B = 0.38); VPV= ~17.5%. 100% S Geopolymer: (w/b = 0.40) VPV =19.4%. Water demand of Slag is higher

VPV

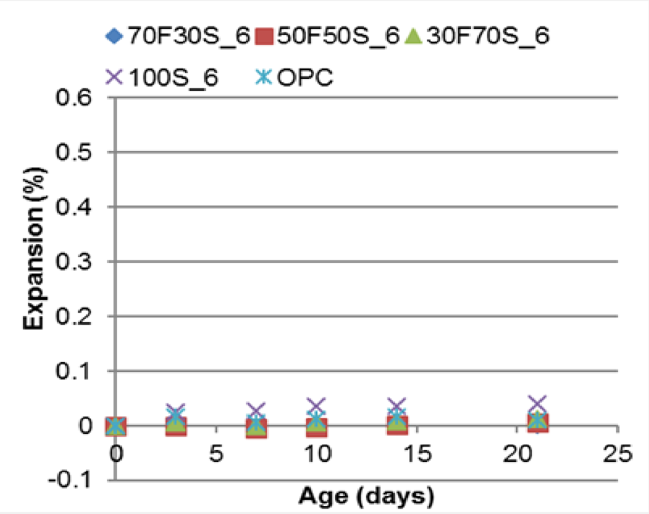
- VPV values of GCs are too high compared to PCC and well above the maximum values allowed by VicRoads Specification Section 610, of similar strength (14%).
- Does not necessarily reflect higher porosity, and could be due to the presence of hydrous alkali-silica gel in the geopolymer concrete, which can lose water on heating, appearing as if the VPV was high (Shayan, Xu and Andrews-Phaedonos 2013)

Alkali-Aggregate Reaction (AAR): AMBT Method

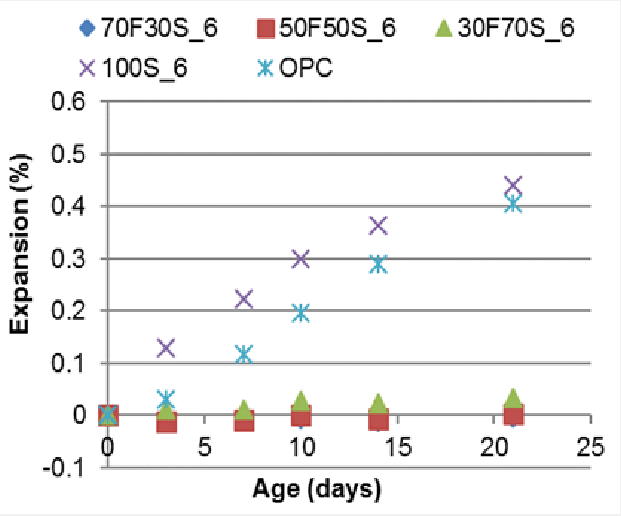
Geopolymers containing greater than 80% slag (less than 20% fly ash) caused expansion in the presence of reactive aggregate

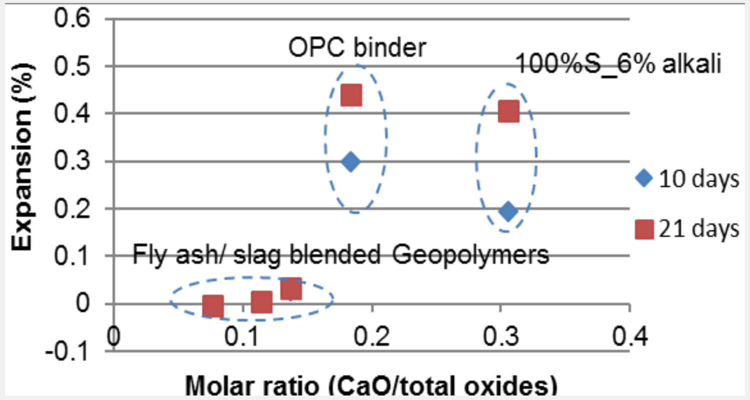


AMBT- Nonreactive aggregate



AMBT- Reactive aggregate

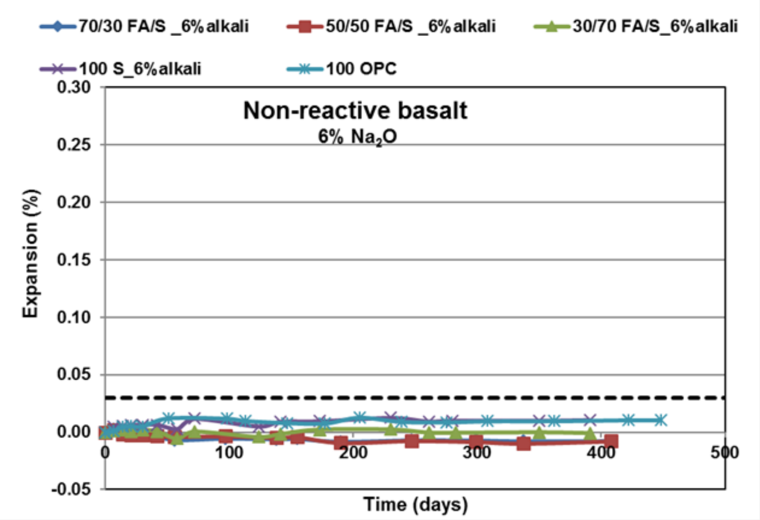




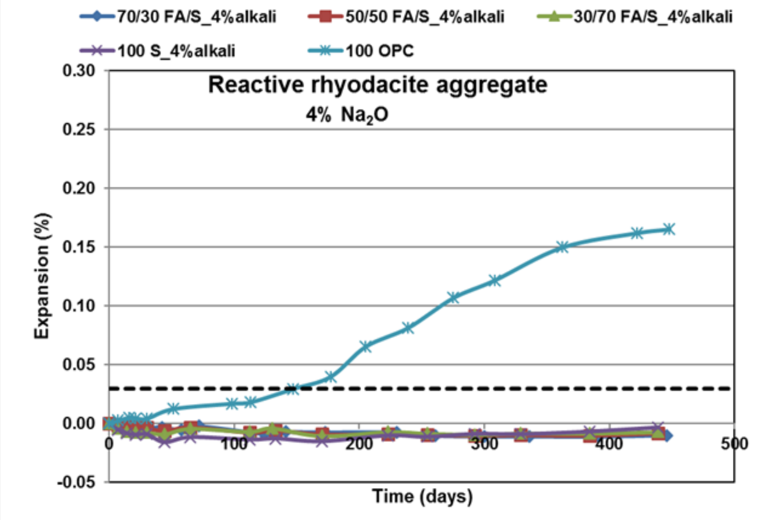
Alkali-Aggregate Reaction (AAR): CPT Method

Reactive aggregate caused expansion in the presence of Portland cement and only 100% slag–based geopolymer when alkali content was high (6%)

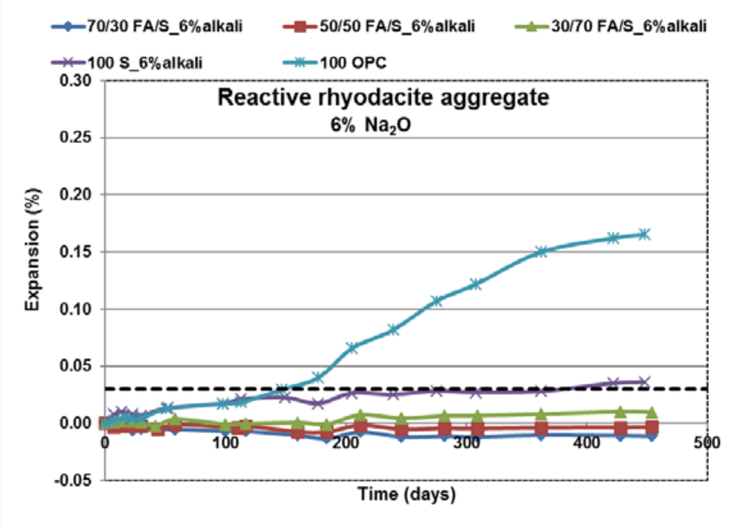
Non-reactive aggregate, high alkali



Reactive aggregate, low alkali

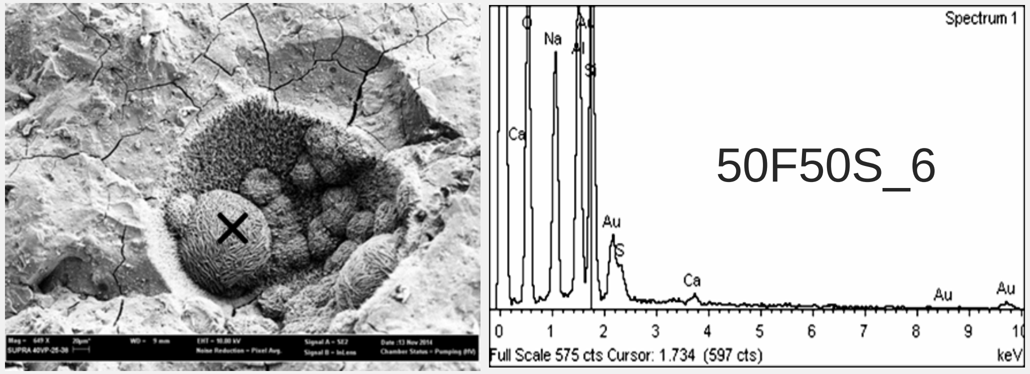


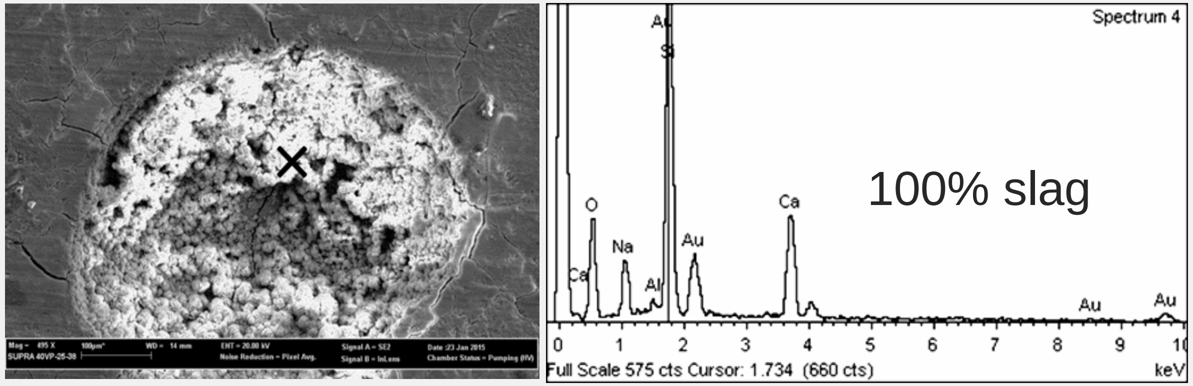
Reactive aggregate, high alkali

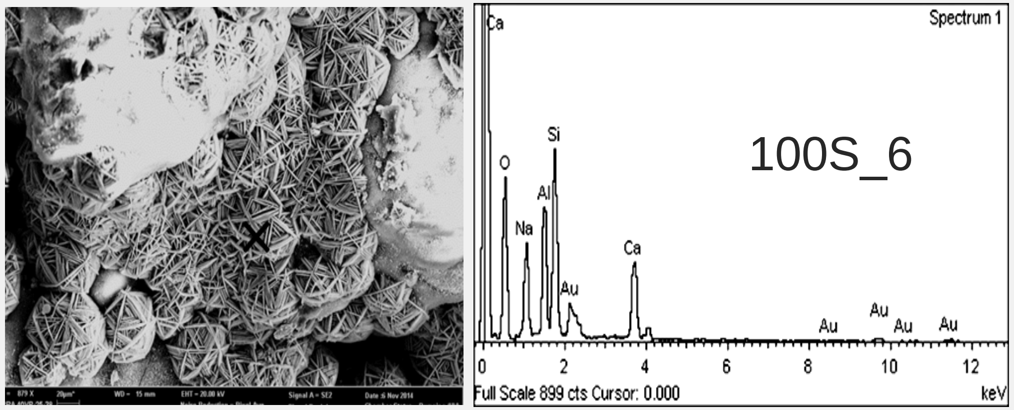


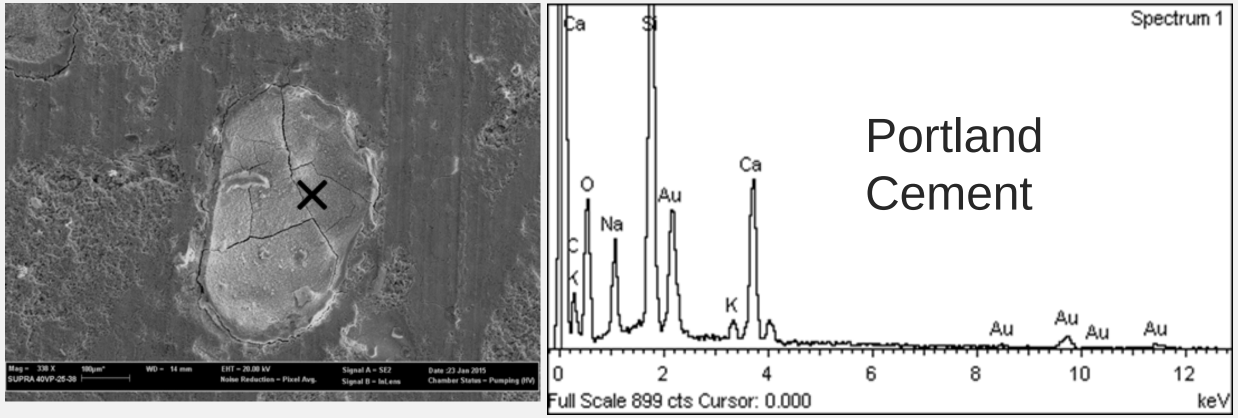
SEM observations on mortar bars

The products in geopolymers are very different from AAR products seen in 100% slag and PCC









Alkali available in various concrete prisms

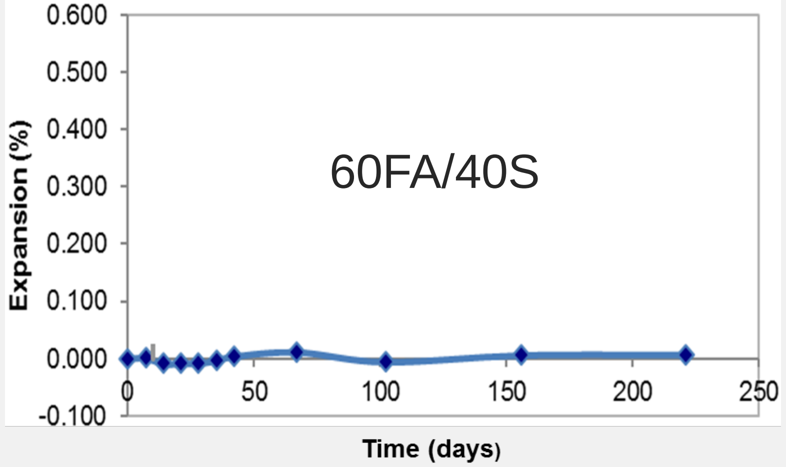
Binder type - (alkali content %)	**Initial**	**Recovered**
	Alkali per volume, (kg/m^3)	
OPC – (1.38 %)	5.63	3.11
100% slag – (6%)	31.58	22.90
100 % slag – (4%)	19.46	18.42
50/50 FA/slag – (6%)	31.58	19.88
50/50 FA/slag – (4%)	19.47	10.76

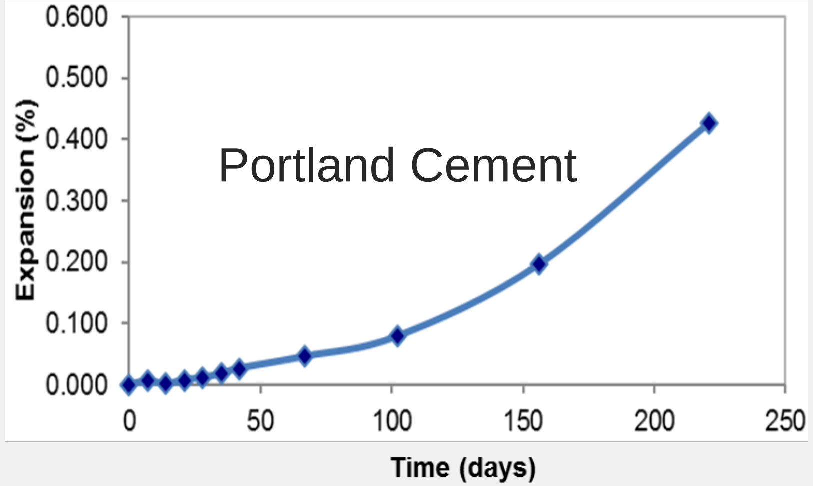
Geopolymer binders still contain large amounts of soluble alkali after the expansion tests

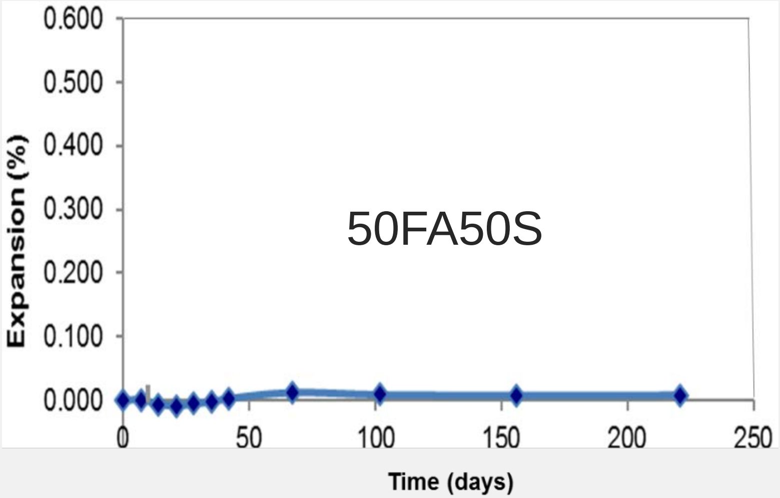
The high alkalinity would be important in protection of steel reinforcement against corrosion

Sulfate resistance of mortar bars

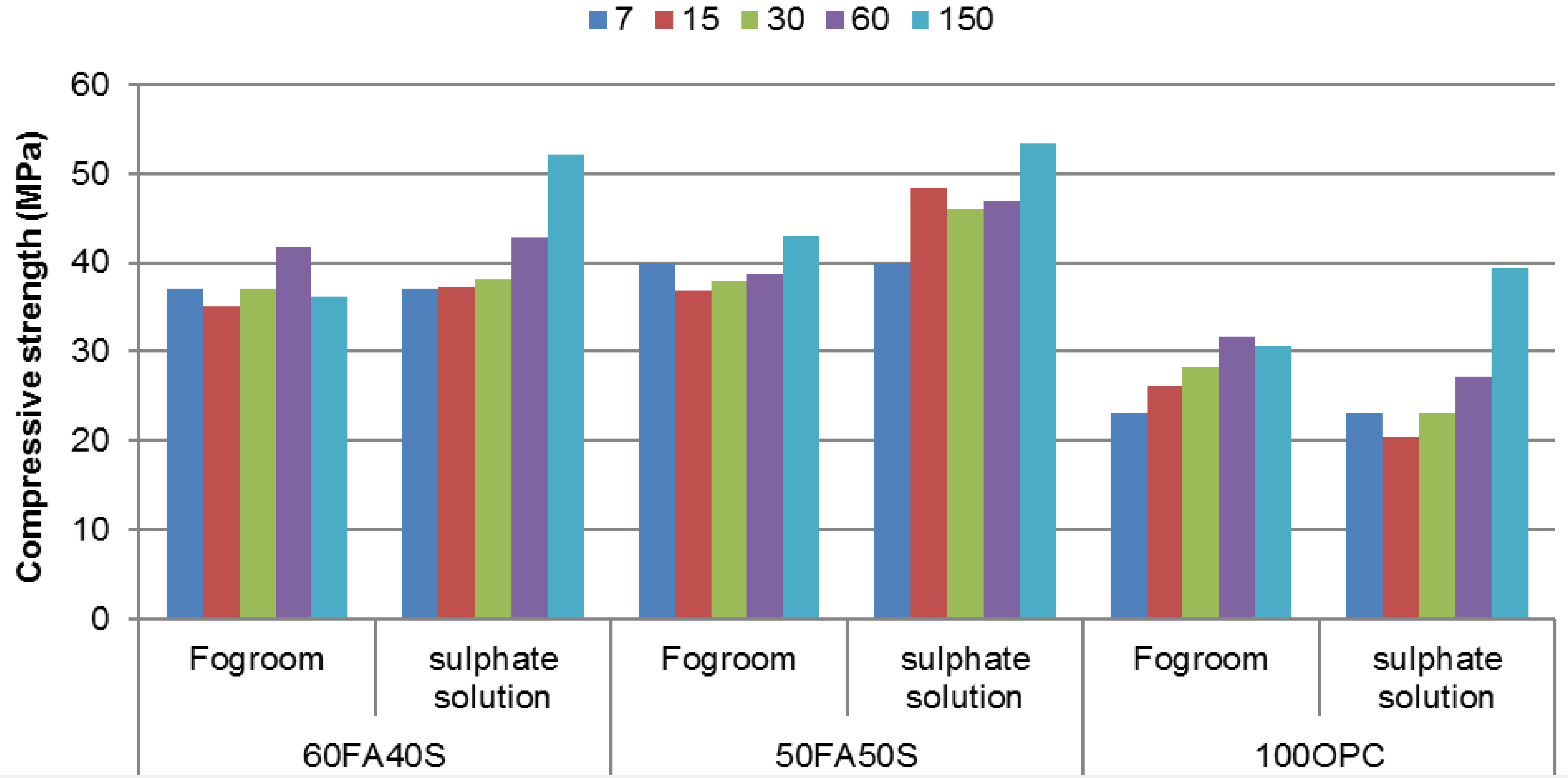
- Geopolymer mortars of W/B ratio of 0.40 are resistance to attack by 5% sodium sulfate solution and don’t undergo expansion
- PC mortars of the same W/B suffer significant expansion







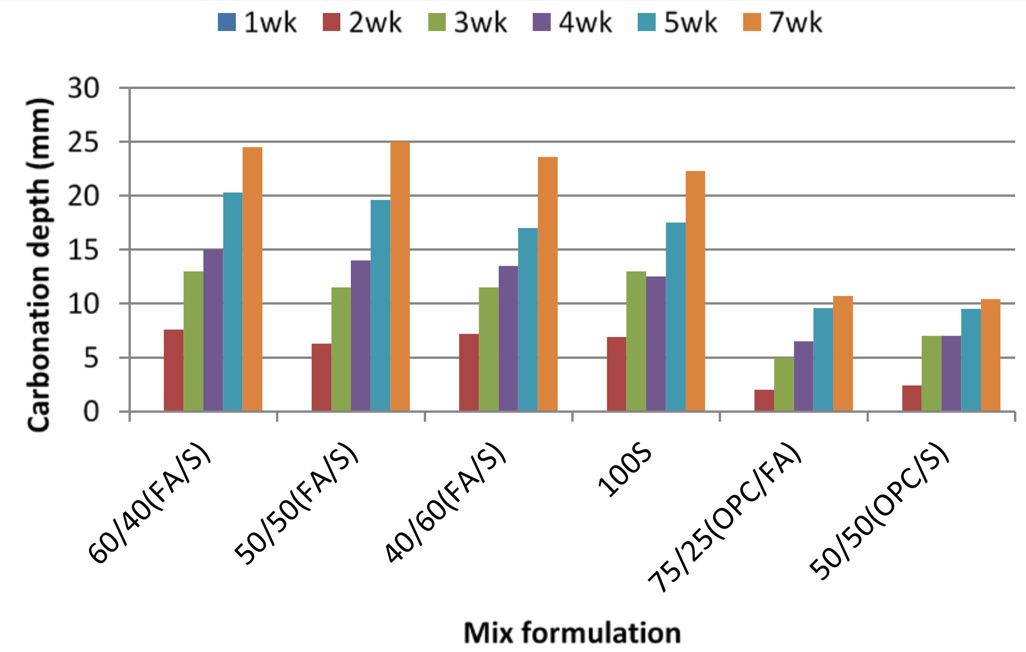
Effect of sulfate attack on mortar cube strength



Carbonation resistance (5% CO_2, 60% RH, 23 °C)

Geopolymers are less resistant to accelerated carbonation than binders containing Portland cement

Binder type	Binder content (kg/m³)	Added alkali content (Na_2O %)	Aggregate (kg/m³)			Water/solid ratio
			Sand	14 mm	10 mm	
60% FA 40% Slag	400	4	680	630	450	0.30
50% FA 50% Slag	400	4	680	630	450	0.30
40% FA 60% Slag	400	4	680	630	450	0.33
100% Slag	400	4	680	630	450	0.35
75% OPC 25% FA	400	0	680	630	450	0.40
50% OPC 50% Slag	400	0	680	630	450	0.42



Resistance to chloride penetration
ASTM C1202: 2012

Values of charge passed (Coulomb) at different ages for the various concretes (Rapid Chloride Penetration Test)

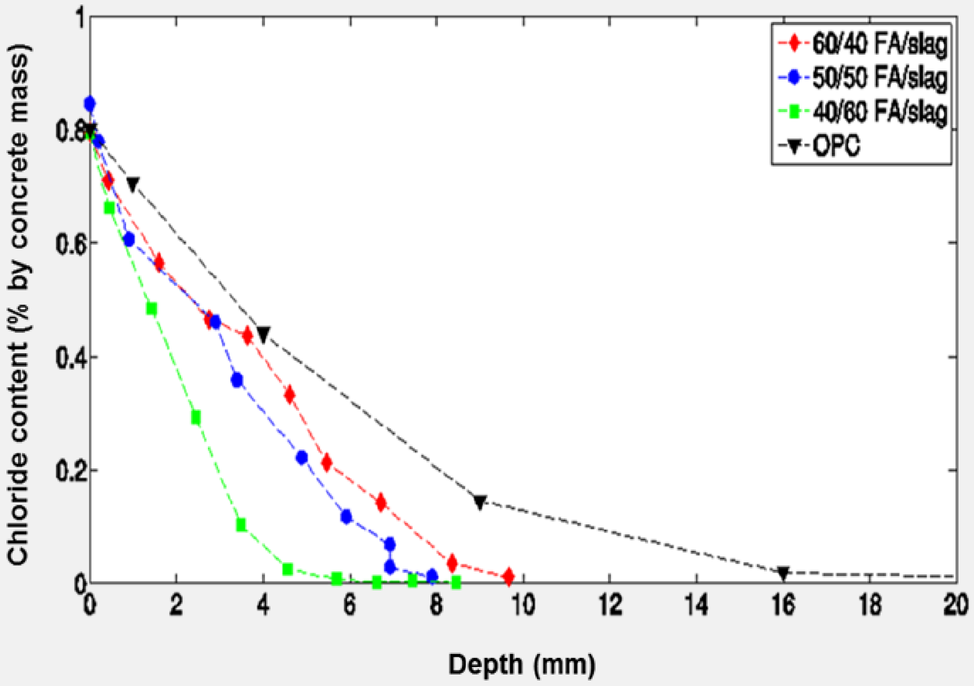
Binder type	28 days (C)	6 months (C)	500 days
60% FA 40% S	1020	370	333
50% FA 50% S	1712	464	312
40% FA 60% S	1348	468	308
100% S	1507	Not determined	
OPC	1920	1650	1570

2000–4000 Coulombs	Moderate permeability
1000–2000 Coulombs	Low permeability
Below 1000 Coulombs	Very low permeability

GC has lower chloride permeability than PCC of same quality

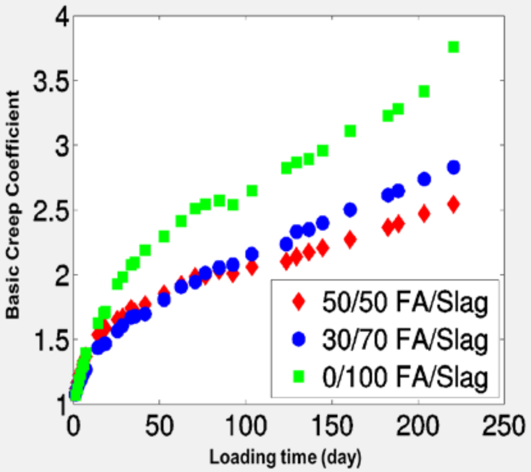
Chloride diffusion and diffusion parameters Nord Test NT Build 443: 1995

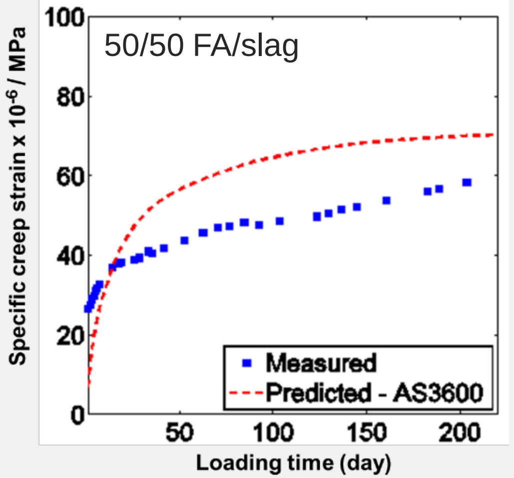
- GCs are more resistant to chloride diffusion than PCC
- Diffusion parameters are obtained by curve fitting

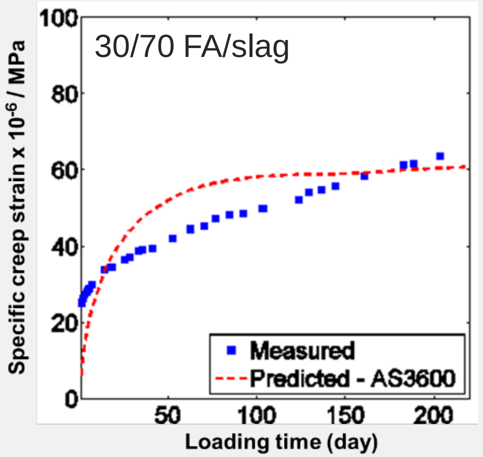


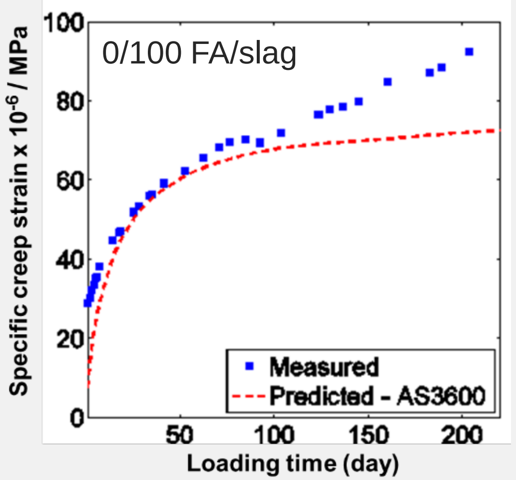
Geopolymer formulation	Surface Cl$^-$. % (C_s) (% wt. by concrete mass)	Apparent chloride diffusion coefficient (D_a) 10^{-12} m^2/s
60/40 FA/slag	0.80	5.17
50/50 FA/slag	0.89	2.38
40/60 FA/slag	0.81	1.01
OPC	0.80	6.70

Creep behaviour (50% RH, 23 °C)





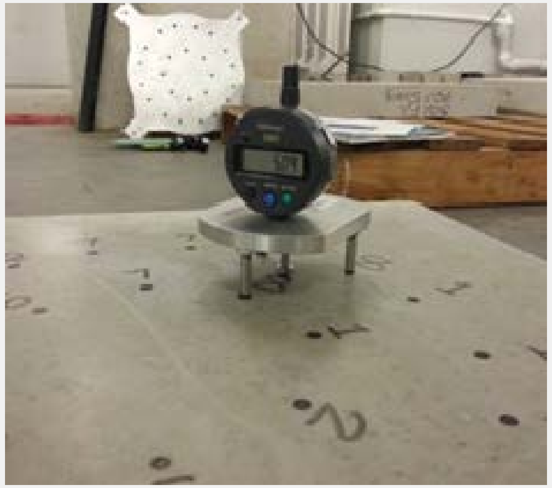




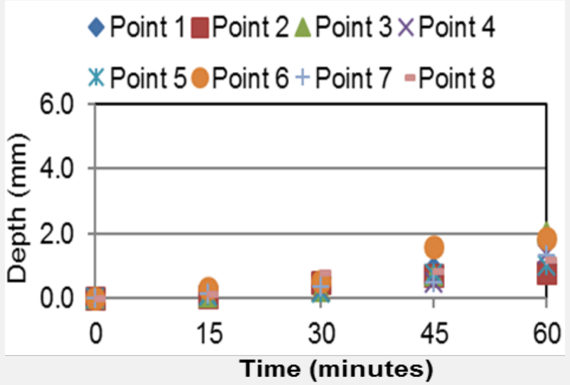
- Slag-rich geopolymers may undergo more deformation under loading
- Increasing trend of creep indicates more monitoring is needed

Binder	Load (MPa)
50/50FA/S	20
30/70FA/S	20
100% Slag	18

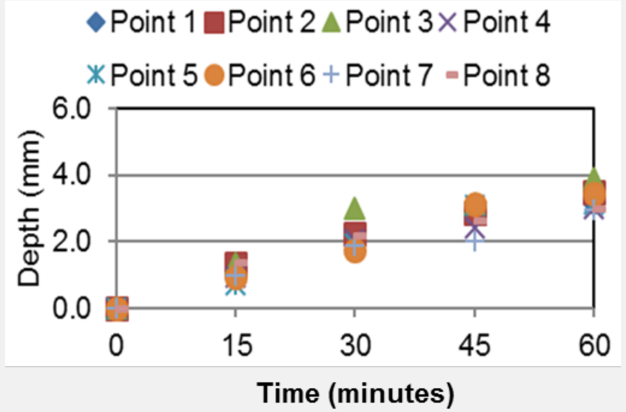
Abrasion resistance of PCC vs GC slabs EN13892-4: 2004 (Slabs cast upside down)



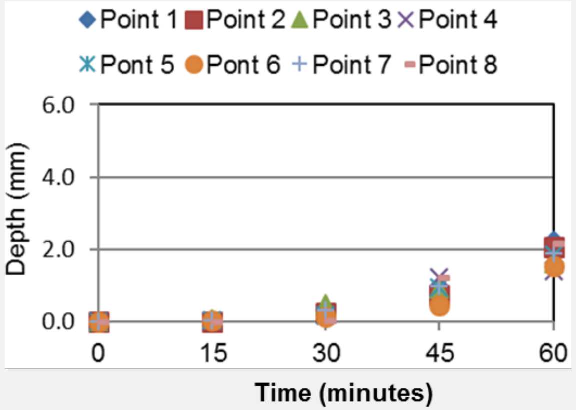
PCC Top



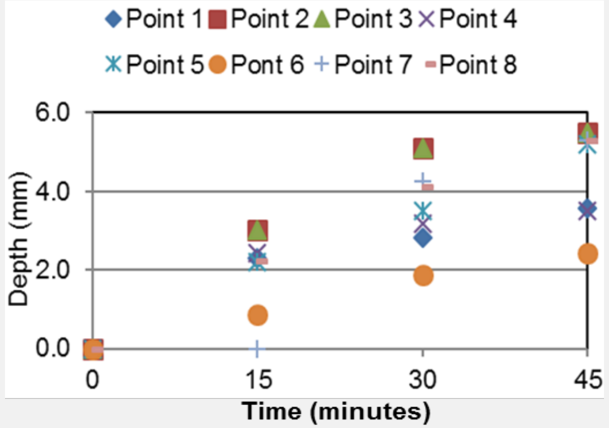
PCC Bottom



FA/S 50/50
GC Top



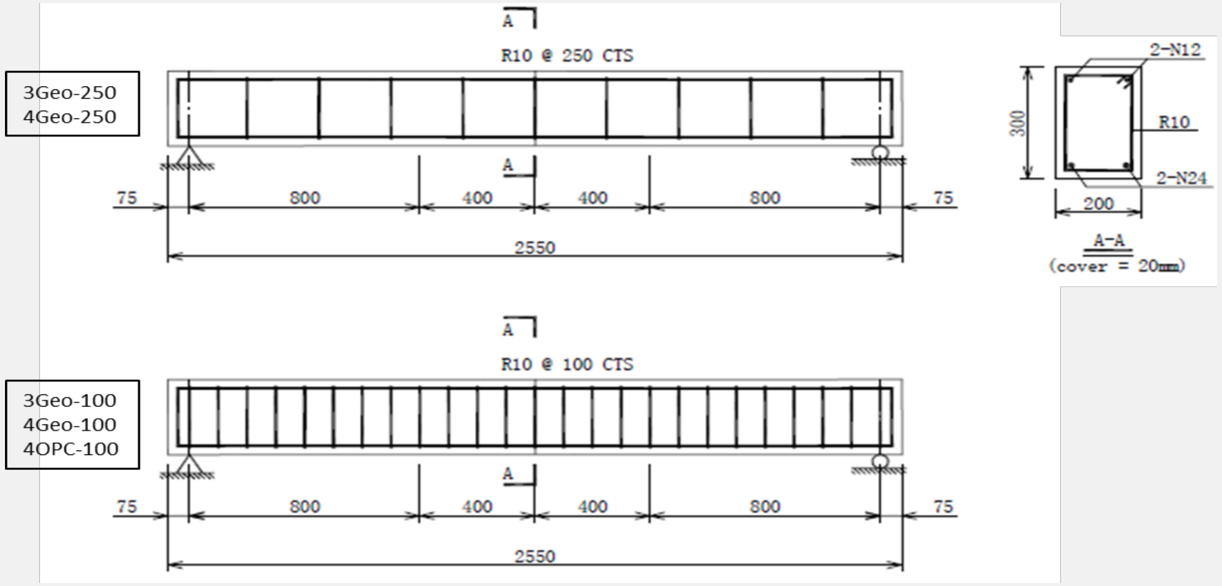
FA/S 50/50
GC Bottom



Ware resistance of GC is slightly less than that of PC, but it can be improved by increasing density/ decreasing porosity

Performance of large reinforced GC elements 200 x 300 x 2550 mm (cast in-situ)

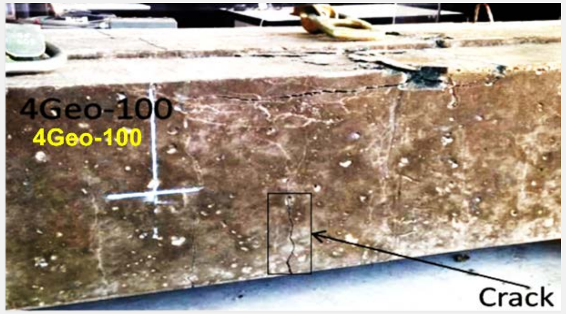
Concrete	Cement	Fly ash	Slag	Sodium meta-silicate	Coarse aggregate (14 mm)	Sand	Added Water	W/B Ratio
GC 50/50 FA/S	0	200	200	61.36 (Water 42.80)	1180	695 (Water 8.20)	170	0.47
PCC	400	0	0	0	1200	695 (Water 8.20)	179	0.448



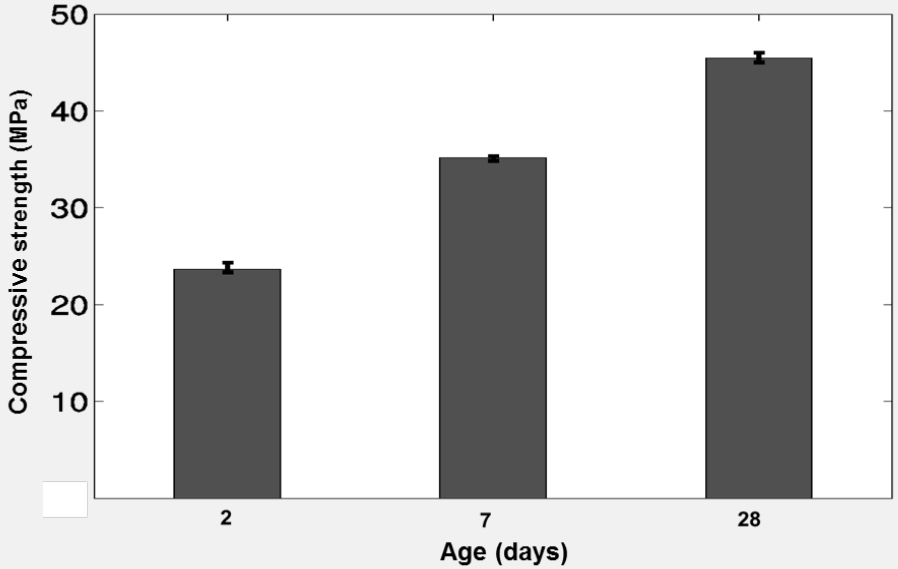
- Two types of beams with Reinforcement ratios: $\rho_{sv} = 0.31\%$ & $\rho_{sv} = 0.79\%$
- Two beams of each type tested by 3-point and 4-point loading tests
- Two modes of failure: 3-Point loading (shear failure) and 4-Point loading (bending failure)

Performance of large reinforced GC elements

Concrete type	28-day compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio	Flexural strength (MPa)
GC	45.5	22.5	0.15	3.70
PCC	50.0	34.5	0.20	4.24



Strength development of GC



- PCC: Wide cracks in a large area, large plastic hinge area
- GC: Narrow cracks in small area, small plastic hinge area
- Due to higher bond strength in GC

Conclusion: Experimental work

- Australian commercial fly ash and slag materials, which are suitable for use as supplementary cementitious materials, and solid sodium metasilicate activator (anhydrous and pentahydrate salts) can be used to manufacture GC
- 100% fly ash-based geopolymers:
  - Exhibited significantly delayed setting times and lower strength under in-situ field applications and ambient curing compared to geopolymers made from blends of fly ash and slag.
  - Required elevated curing temperatures (60 – 80 °C) and are more appropriate for pre-casting

Conclusion: Experimental work

- Strong and durable in-situ, structural grade geopolymer concretes were made from:
  - Blends of fly ash /slag in the range of 40–60% fly ash and 60–40% slag, particularly 50/50 and 40/60 fly ash/slag
  - Solid sodium silicate alkali activator (equivalent of 4 – 6% Na_2O by mass of precursor materials)
  - Water/Binder (total geopolymer solids) ratios of 0.38–0.42
- Water/ Binder has a significant effect on strength development of GC (same effect as in PCC)

Conclusion: Geopolymer concrete

Performance	Condition
Satisfactorily	under ambient casting conditions with respect to workability, drying shrinkage, strength development and other mechanical properties
Superior	compared to PCC with respect to drying shrinkage, sulfate resistance, chloride penetration, chloride diffusion and AAR (at least 20% fly ash needed for control of AAR)
Poorer	compared to PCC with respect to carbonation as tested under accelerated carbonation test, VPV and abrasion resistance

Conclusions: Load deflection tests

- For a given reinforcement configuration, the load-bearing capacity of PCC and GC are very similar
- For a given testing procedure (three-point or four-point loading) the stirrup spacing did not affect the total load capacity
- GC beams exhibited lower ductility than PCC beam, despite having similar load-deflection behaviours, which may arise from smaller plastic hinge regions of GC beam, which appears to result from stronger bond strength between geopolymer and steel, compared to that of PCC and steel
- Incorporation of stirrups in the bending zone of geopolymer beams improves ductility

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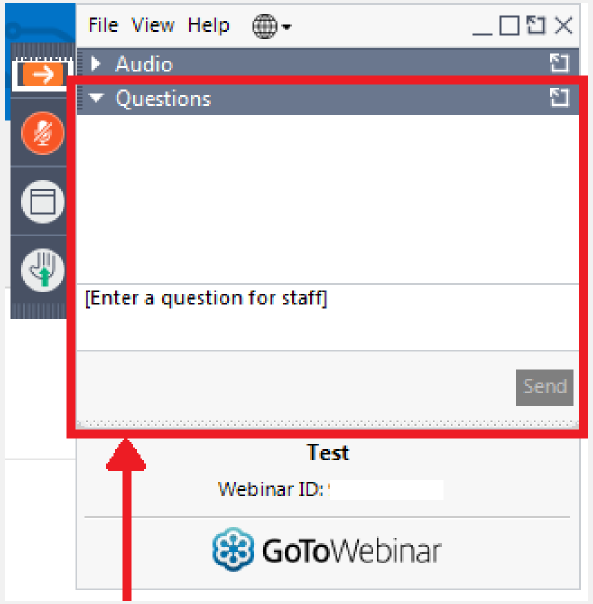

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Please type your questions here

Let us know the slide number your question relates to

Specification and Use of Geopolymer Concrete

Fred Andrews-Phaedonos

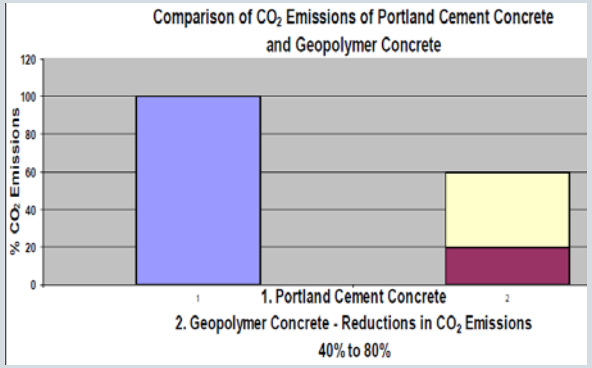
Austroads

Use of geopolymer concrete

	Recommendation to use geopolymer concrete
General Concrete Paving	YES
Commercial Construction Design Life 40 – 60 years	YES
RC Pipes	YES
Structural Concrete for major Infrastructure Design Life 100 years	Qualified YES. At this stage on a job by job basis, based on risk. • Must optimise mix design • Use compatible chemical admixtures • VPV to comply with Section 610

Note: Provided precursor materials such as slag, fly ash and silica fume comply with the relevant Australian standards AS 3582.1, 2 & 3

Conventional vs. geopolymer concrete

Conventional concrete	Geopolymer concrete
Characterised by the formation of • Calcium Silicate Hydrates (CHS) - (Calcium based system)   	• Consists of: − > 80% Fly Ash, GGBF Slag, Silica Fume or metakaolin − up to 20% alkaline components (alkaline activator) − sand, stone (up to 75% to 80% of total mass), water and admixtures • Characterised by an amorphous (non-crystalline) microstructure of an Aluminium-silicon based system • Geopolymerisation Process − Alkaline solution dissolves out Al and Si molecules − Si-O-Si-O cross-link & harden to Geopolymer concrete

Typical geopolymer mix design

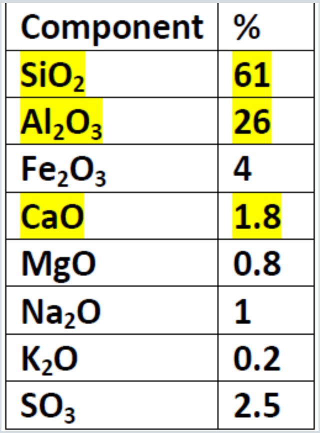
Materials		Mass (kg/m³)
		Precast/Cast-in-situ/Pipes
Cementitious Binder		VR330/32-VR470/55 - Equiv
Coarse Aggregates (60%)	20 mm	Similar to Conventional
	14 mm	Similar to Conventional
Fine Sand (40%)		Similar to Conventional
Fly Ash		% Could be low to large
GGBF Slag (%)		% Could be medium to large
Mineral Additives (GP Cement) (x %)		**Nil (in some systems small amount)**
Sodium Silicate solution ($SiO_2/Na_2O=2$)		OHS issues in practice
Sodium Hydroxide Solution		OHS issues in practice
Solid Sodium Silicate (y %)		Some, more effective, OHS o.k
Water reducer Superplasticiser?		**Nil**
Air Entrainer		Some (in some systems small amount)
Water		Much higher than conventional
Water/Binder Ratio		Relatively High
Slump		50 – 180 mm

Fly ash-based geopolymers vs.
Slag plus fly-ash based geopolymers

Fly ash-based

Characterised by delayed setting times and lower strength, under ambient conditions:

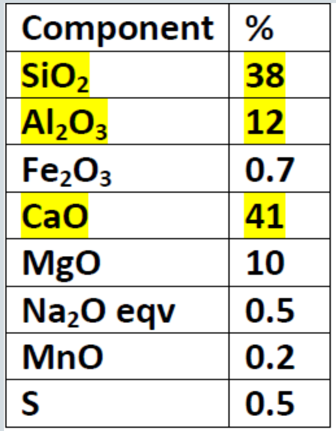
- elevated curing temperatures are required for plain fly ash based geopolymers
- more suitable for manufacture of precast elements



Component	%
SiO_2	61
Al_2O_3	26
Fe_2O_3	4
CaO	1.8
MgO	0.8
Na_2O	1
K_2O	0.2
SO_3	2.5

Slag plus fly-ash based

- Higher source of calcium
- Improved performance under ambient field conditions



Component	%
SiO_2	38
Al_2O_3	12
Fe_2O_3	0.7
CaO	41
MgO	10
Na_2O eqv	0.5
MnO	0.2
S	0.5

Ratio of Si/Al influences the physical properties of geopolymer concrete. Optimum around Si/Al ratio of 2 – 3 to 1.

Use of SCMs - Lower carbon footprint and more durable concrete bridges

- Sustainable ‘Green’ VicRoads Concrete > 20 years
- Reduction of CO_2 by ~15% - 30% per cubic metre
- Both structural (Section 610) and general purpose concrete construction

Fly Ash

GGBF Slag

Silica Fume

Geopolymer concrete and VicRoads

See Specifications, Section 703 – General concrete paving

- Introduced as equivalent product to Portland cement concrete in 2010
- Strength grade same as normal concrete of 20 MPa, 25 MPa and 32 MPa.
- Construction requirements of placing, compaction, finishing, curing and sampling and testing of geopolymer concrete **same as** conventional concrete.
- Due to greater susceptibility to unsatisfactory practices, manufacture and delivery practices for geopolymer concrete are more in line with Section 610.

Five standard VicRoads specifications

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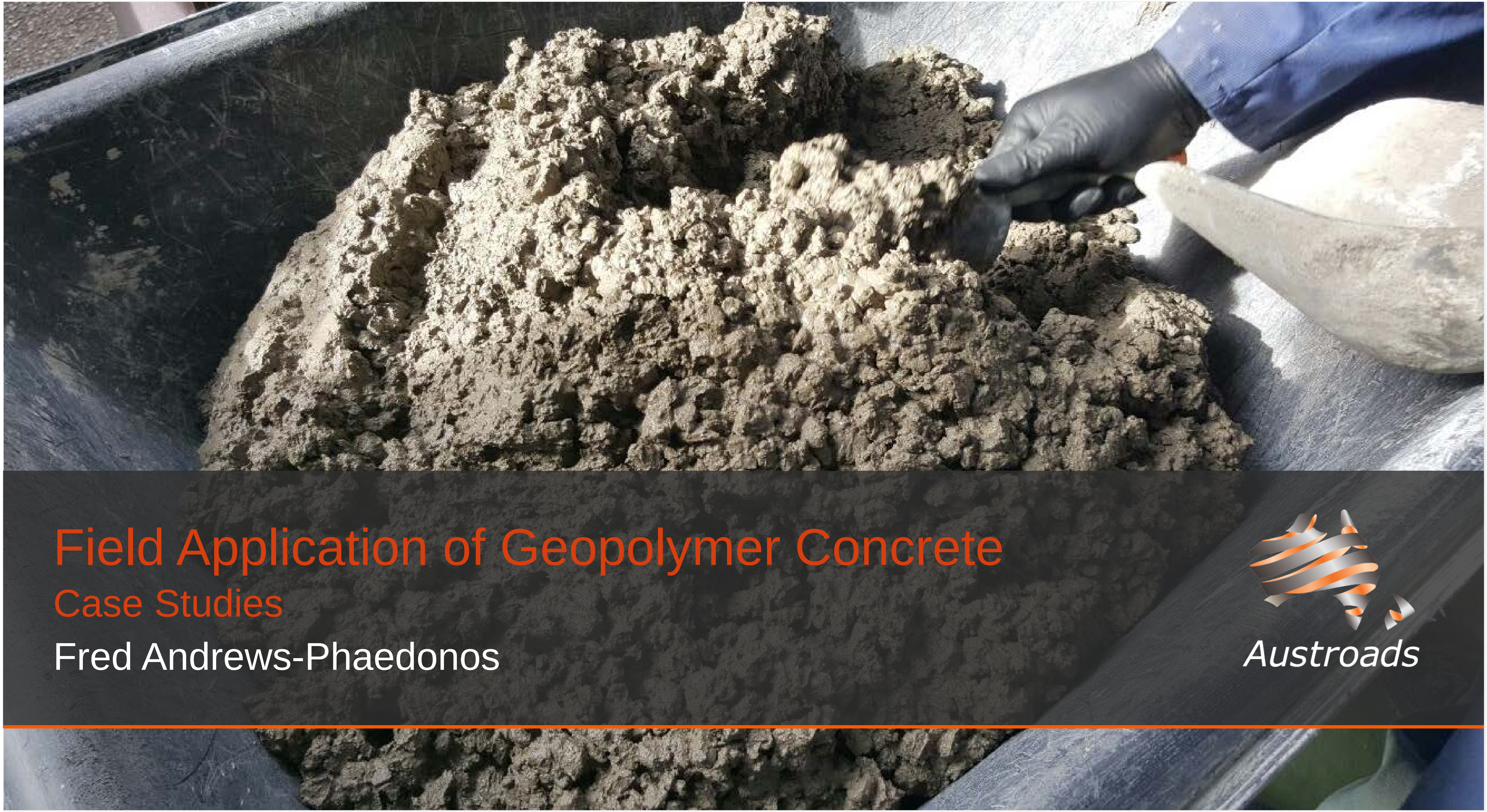
Amended to include geopolymer concrete

Section		Year
703	General Concrete Paving, geopolymer concrete defined	2010
701	Underground stormwater drains, Reinforced Concrete Pipes	2013
705	Drainage Pits, precast and in-situ drainage pits	2013
711	Wire Rope Safety Barrier - anchor blocks, post footings, maintenance strips and other associated concrete works	2013
708	Guard Fence	2013



Field Application of Geopolymer Concrete

Case Studies

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Geopolymer concrete footway panels

Salmon Street Bridge over West Gate Freeway

180 precast footway units concrete grade VR470/55 to Section 610 manufactured/installed - 2009

Retaining walls

Bridge over Yarra River

Monitoring junction boxes, reference electrodes, electro potentials - since 2009

Bicycles and footpaths
No-fines geopolymer concrete

Significant lengths of footpath and bicycle path using 25 MPa geopolymer concrete per Section 703 – since 2009

Geopolymer concrete wall
M80 Western Ring Road

- First major in-situ construction on a major infrastructure project in Australia – in mid 2012
- Near vertical 450 metre long *“chevron”* or zig-zag landscape retaining wall designed to double up as raised planter beds

Precast footway deck planks
Longford Bridge

- Trial synthetic fibre reinforced geopolymer concrete (FRGC) precast footway deck planks – 2014
- Manufactured and installed on pedestrian bridge as part of long term monitoring of in-situ performance
- Dry delivered 250km from Melbourne – water, fibres, activator added on site

Geopolymer Concrete Pipes

Fred Andrews-Phaedonos

Austroads

Geopolymer concrete pipes
Proof and Ultimate Load

Pipe Type	First crack kN/m	Proof Load kN/m	AS/NZS 4058 Min. Proof Requirement kN/m	Ultimate Load kN/m	AS/NZS 4058 Minimum Ultimate Requirement kN/m
Geopolymer Pipes	65	85	30 - 50	125	45 - 80
Conventional Pipes	55	80		120	

Geopolymer concrete pipes
Average absorption and VPV values

See AS/NZS4058 and Section 610/AS 1012.21)

Pipe Type	Average Absorption %	AS/NZS4058 Max Allowable %	VPV %	Maximum VPV Values at 28 days, (%) for core, Section 610
Geopolymer	5.5 – 5.8	6	15.0 – 15.5 rounded down	15
Conventional	5.0 – 5.5	6	11.5 – 12.5 rounded down	15

Water absorption samples

VPV testing

Geopolymer concrete pipes - on site and installation
Princess Highway Duplication - Winchelsea, Victoria

Geopolymer concrete pipes - stored on site

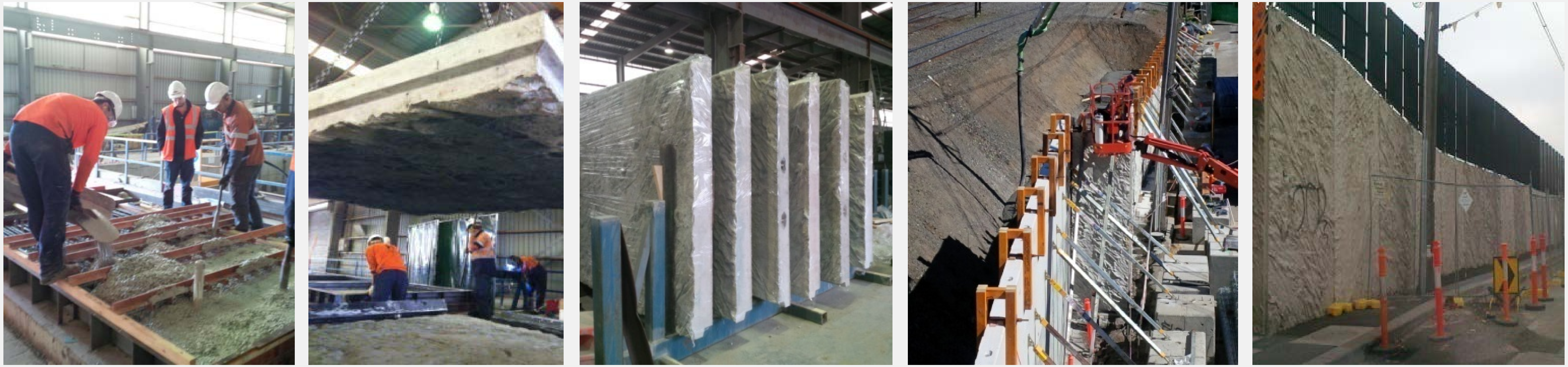
Drainage works in Harley Street, Bendigo Victoria

Following VicRoads acceptance of geopolymer concrete pipes - early 2013 per Section 701

Structural concrete walls

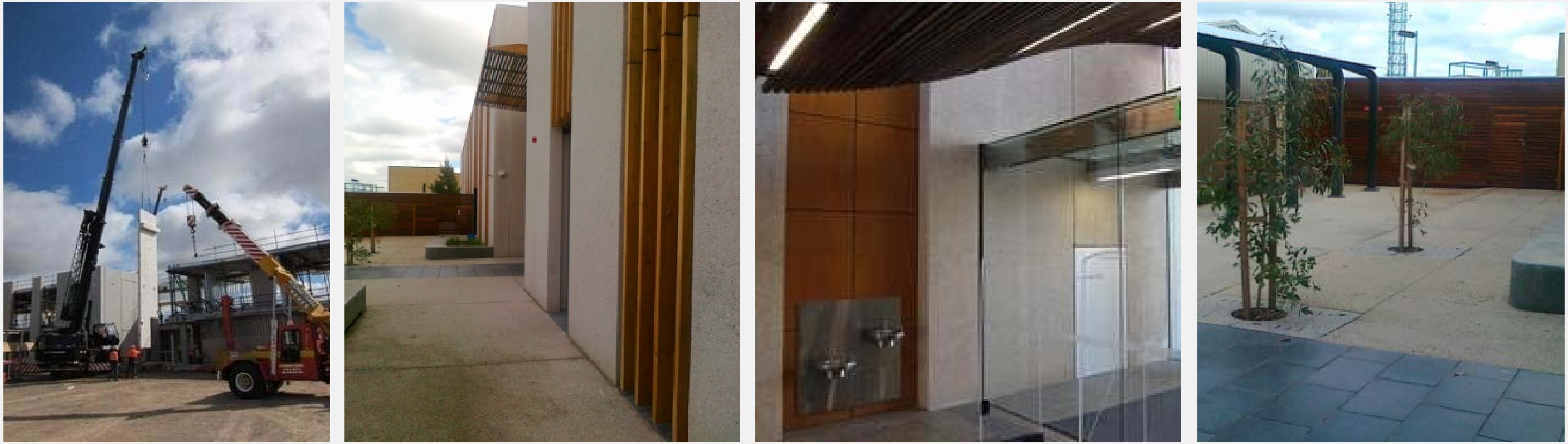
Dudley St Railway Bridge

Reinforced soil and post and panel walls based on equivalence to concrete grade VR400/40, part of Regional Rail Link works



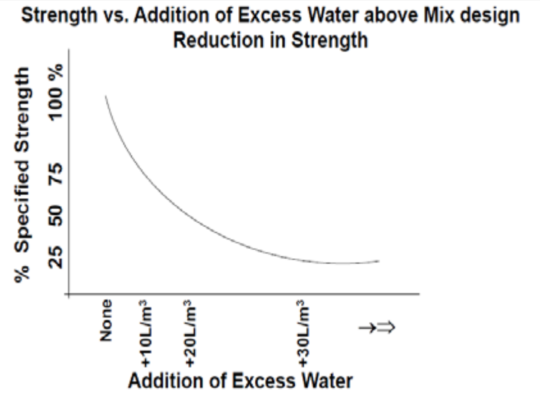
Other applications

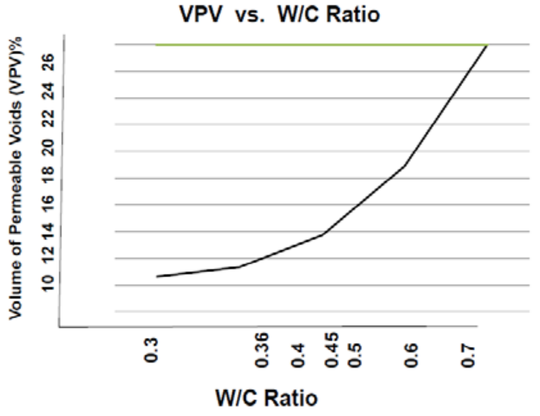
- Slabs and footings in housing and commercial construction
- Library building which utilised precast panels



Excess water addictions and its effects

Geopolymer concrete is less forgiving and more susceptible to excess water additions





Impediments to the Wider Use of Geopolymer Concrete

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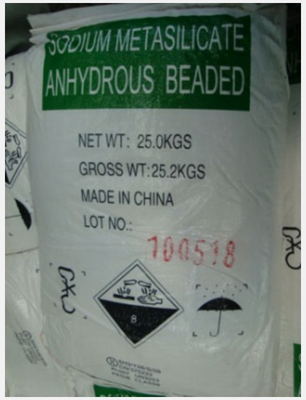
Impediments

- Require to significantly improve mix designs – need to think of permeability as well as strength, not just strength!
- Suitable chemical admixture will refine the mix and reduce amount of alkali activator required to achieve required strength and permeability → Change cohesion and setting time characteristics



Less of this!
Alkali Activator

and more of this
Compatible Admixtures

Impediments

- Resistance to release Intellectual Property
- Commercialisation still in infancy
- Lack of interest in technology by cement/concrete companies
- More experience required to optimise geopolymer mixes on commercial basis
- VicRoads Specifications in place but there is Lack of an Australian Standard

Questions?

Dr Ahmad Shayan

Chief Technology Leader

Australian Road Research Board (ARRB)

P: +61 3 9881 1658

E: ahmad.shayan@arrb.com.au

Fred Andrews-Phaedonos

Principal Engineer

VicRoads

P: +61 3 9881 8939

E: fred.andrews-phaedonos@roads.vic.gov.au

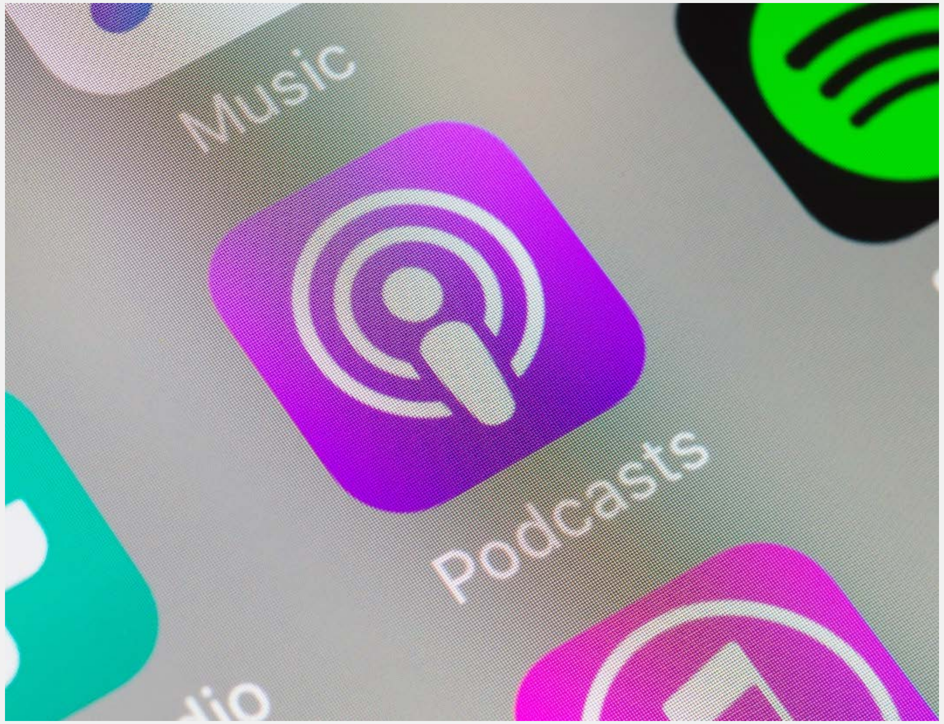
Upcoming Austroads webinar

Austroads

Topic	Date
Towards Safe System Infrastructure	10 May
Best Practice in Road Safety Infrastructure Programs	15 May
Updated Pedestrian Facility Selection Tool	29 May

Register at www.austroads.com.au/event

Webinars now available as podcasts



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