

Use of General Purpose Limestone (GL) Cements in Pavement Stabilisation

Matthew Bond, Senior Technology Leader

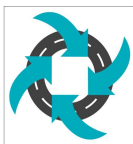
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Agenda

- Overview of CO₂ emissions of Portlandic Cements
- Emissions reduction potential of limestone ~ clinker replacement (GL cements)
 - International acceptance of limestone cements
 - Carbon reduction estimates
- Laboratory assessment of GL cement in road-base stabilisation, including as fly-ash blended cement
 - Stabilising agent content to 7 + 28 day UCS
 - Working times
 - Capillary rise



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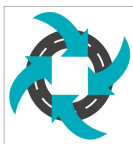
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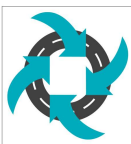


Carbon emissions of Portlandic cements

- Portland cement clinker production requires heating of limestone with other minerals (approximately 1,400 °C)
- Majority of emissions are due to calcination of limestone



- Partially replacing clinker with limestone avoids both heating + calcination emissions
- AS 3972.1 sets maximum limit of 7.5% limestone replacement for General Purpose cement
- 8% - 20% is accepted for General Purpose Limestone (GL) cement



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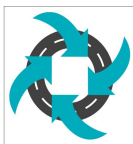


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Carbon emissions of General Purpose cements

- Australian GP cements: 920 ~ 1040 kg.CO₂e / tonne of GHG emissions
- Clinker: 940 ~ 980 kg.CO₂e / tonne
- Crushed limestone: 2.3 kg.CO₂e / tonne

Values from AusLCI database (ALCAS 2023)



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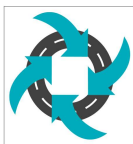


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Calculated emissions – GL Cement

Modelling Scope 1 emissions (AusLCI Database values)

Constituent material	Type GL20	Type GL15	Type GL (13%)	Type GL10	Type GP (reference case)
Clinker	72.5%	77.5%	79.6%	82.5%	85.0%
Gypsum	3.5%	3.5%	3.5%	3.5%	3.5%
Limestone	20%	15%	12.9%	10%	7.5%
Other minerals	4.0%	4.0%	4.0%	4.0%	4.0%



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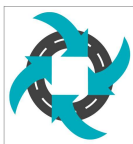
Emissions Reductions – GL cement

Imported clinkers

Modelled scenario	Type GL20	Type GL15	Type GL (trialled)	Type GL10	Type GP
Embodied emissions of stabilising agent (kg.CO ₂ e/tonne)	914	963	983	1,012	1,036
Reduction from reference case (kg.CO ₂ e/tonne)	122 (11.8%)	73 (7.1%)	53 (5.1%)	24 (2.4%)	0 (0.0%)

Australian clinkers

Modelled scenario	Type GL20	Type GL15	Type GL (trialled)	Type GL10	Type GP
Embodied emissions for stabilising agent using (kg.CO ₂ e/tonne)	800	847	867	894	918
Reduction from reference case (kg.CO ₂ e/tonne)	117 (12.8%)	71 (7.7%)	51 (5.5%)	24 (2.6%)	0 (0.0%)



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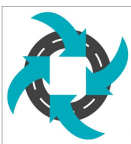
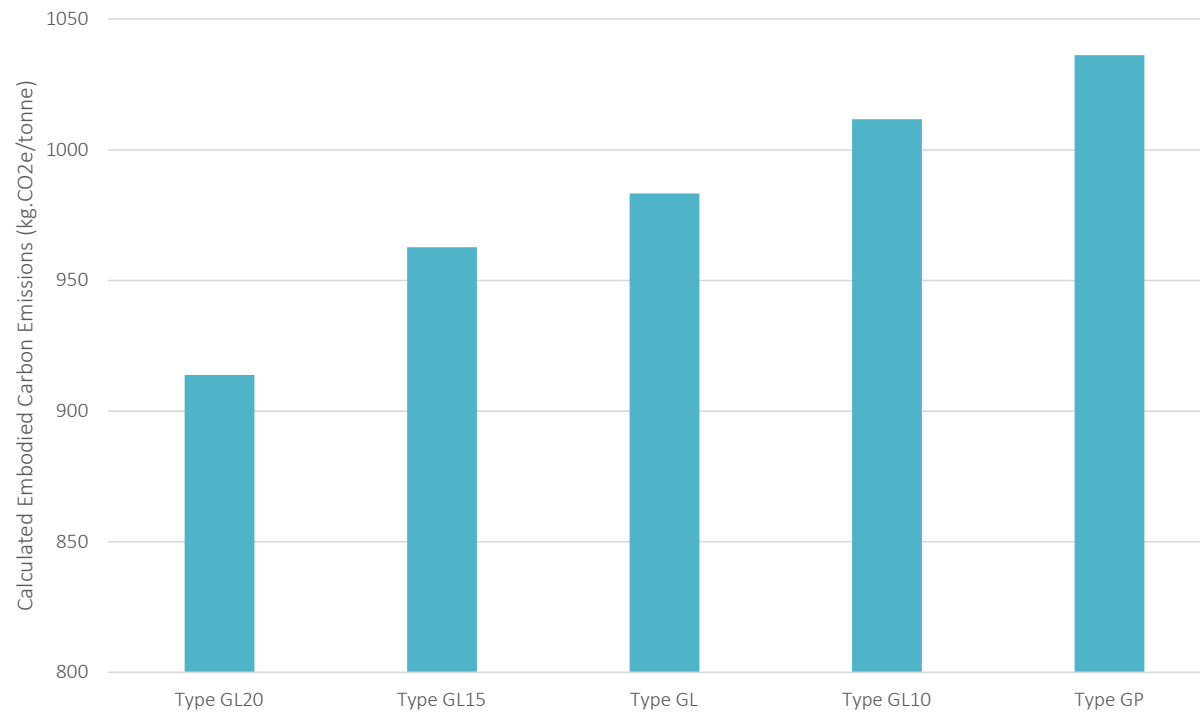
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Calculated emissions – GL cement



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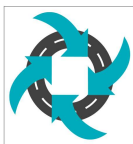
Laboratory evaluation

- Laboratory Mix Designs to TMR Technical Note 204

Stabilising agents tested

GP	GL	GB	GBL
100% GP cement	100% GL cement	75% GP cement 25% Fly ash	75% GL cement 25% Fly ash

- Moisture density relationships
- 7 and 28 day Unconfined Compressive Strength (UCS) – at multiple stabilisation agent contents
- Working times
- Capillary rise



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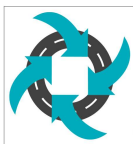
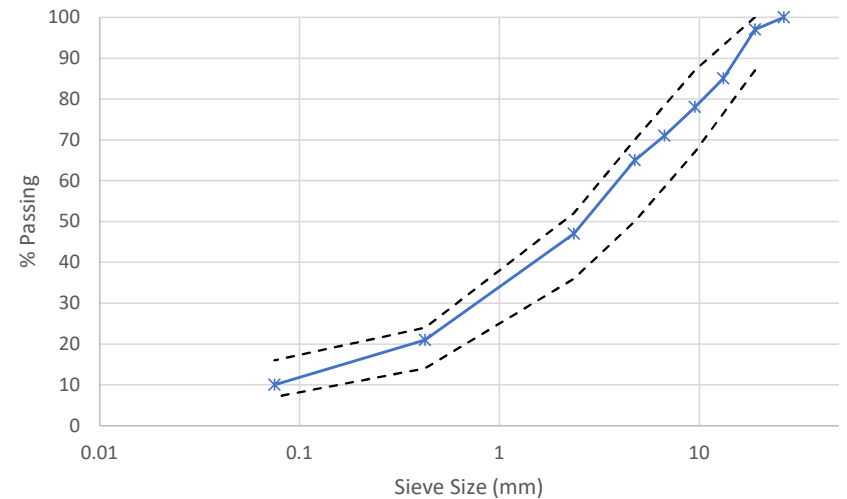
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Laboratory evaluation

Host unbound granular material

Test	Properties/Results	MRTS05 limits (< 70% recycled)
Geological type	Metagraywacke	–
Material classification	MRTS05 Type 2.1	–
Linear shrinkage (Q106) %	1.8%	1.0–3.5
Liquid limit (Q104A) %	19.2%	25 max
Plastic limit (Q105)	14.0%	–
Plasticity index (Q105)	5.2%	–
Weighted plasticity index (Q105)	107%	–
Weighted linear shrinkage (Q106)	37%	85 max

Particle Size Distribution



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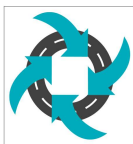


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Results – Moisture density relationship

(1.0% stabilising agent)

Stabiliser type	Type GP	Type GL	GB	GB _L
OMC (%)	7.5	7.5	7.0	7.5
MDD (t/m ³)	2.22	2.23	2.23	2.23



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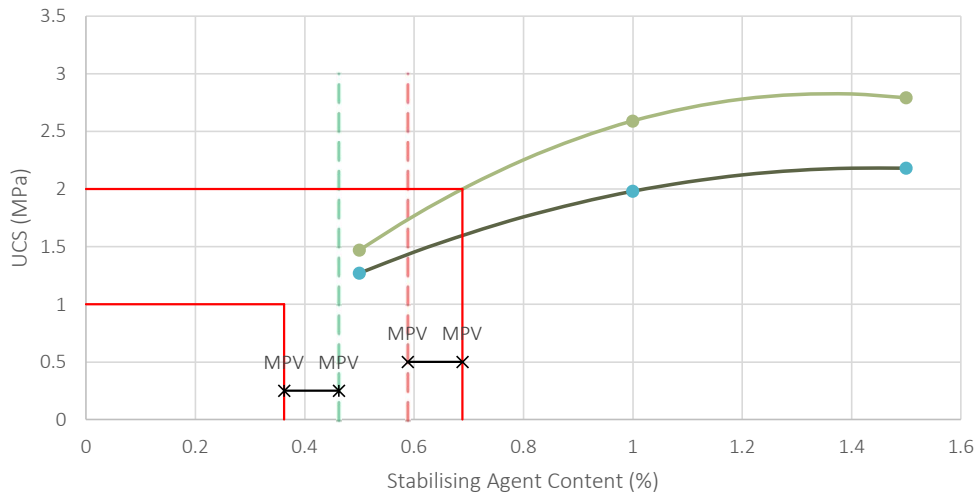


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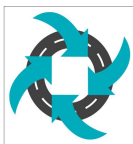
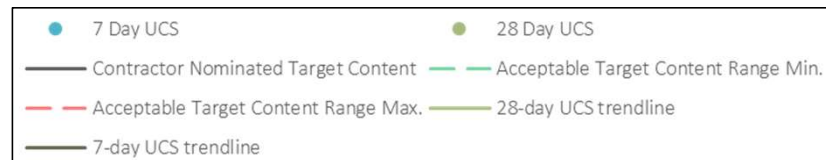
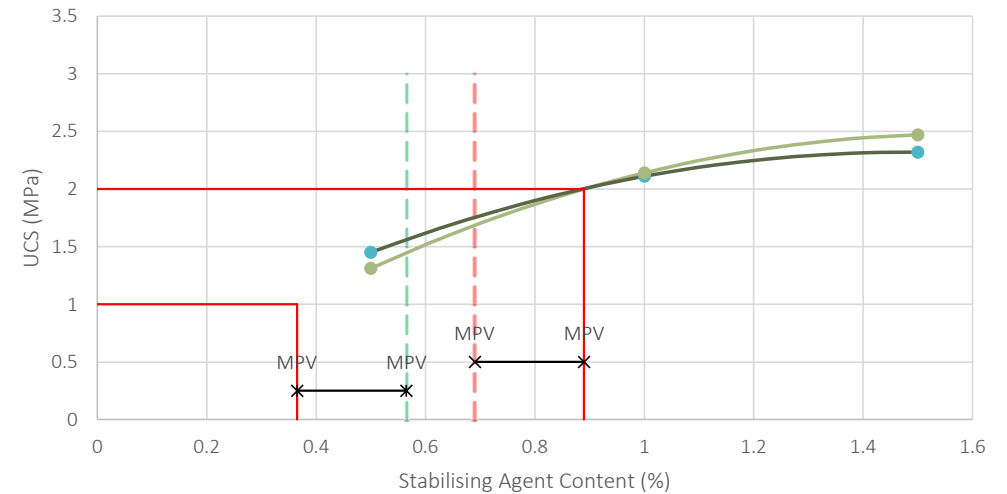
UCS and target stabilising agent contents

Straight cement (GP and GL)

Target Content of Stabilising Agent – GP



Target Content of Stabilising Agent – GL



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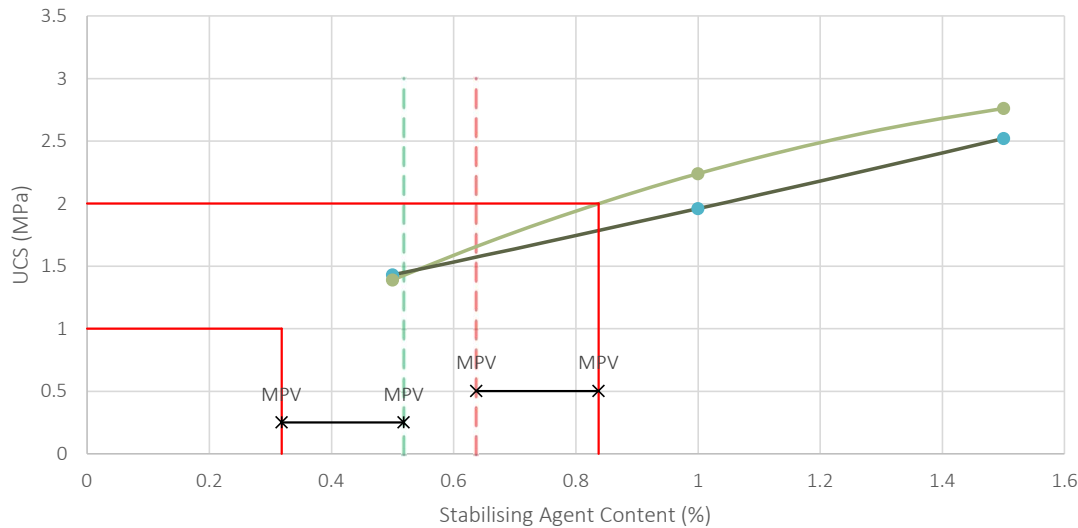


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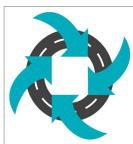
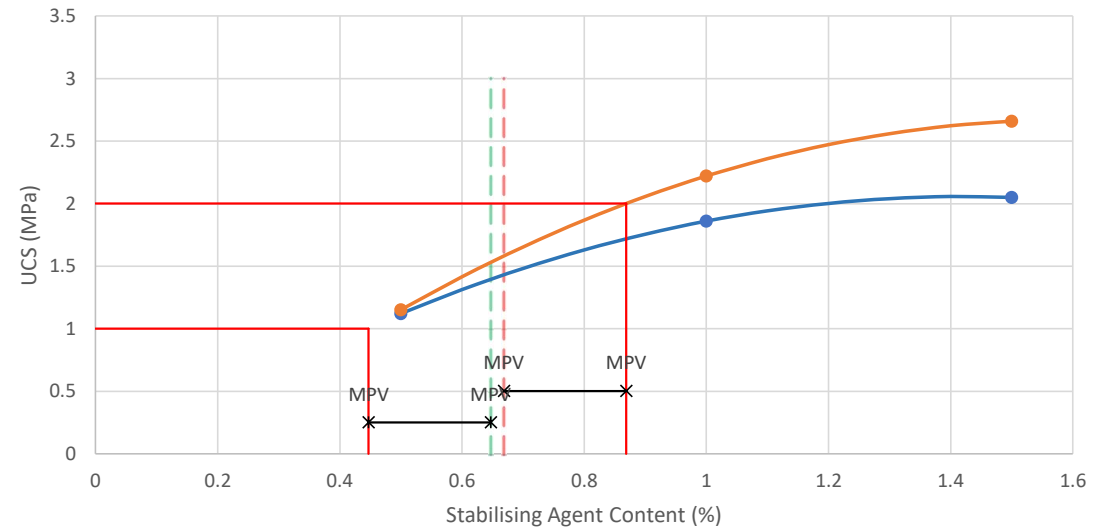
UCS and target stabilising agent contents

25% fly ash blended cements (GB and GB_L)

Target Content of Stabilising Agent – GB



Target Content of Stabilising Agent: GB_L



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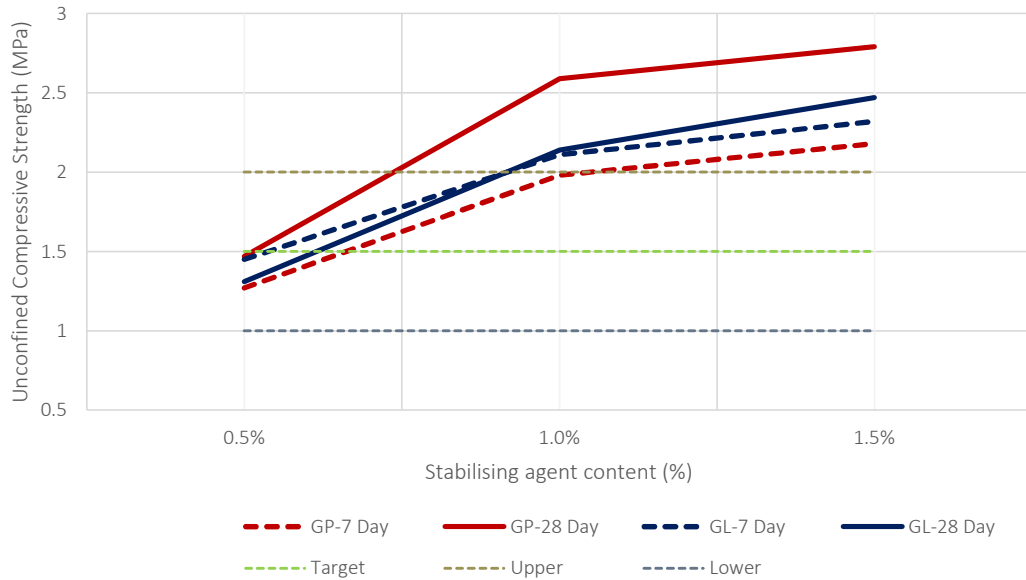
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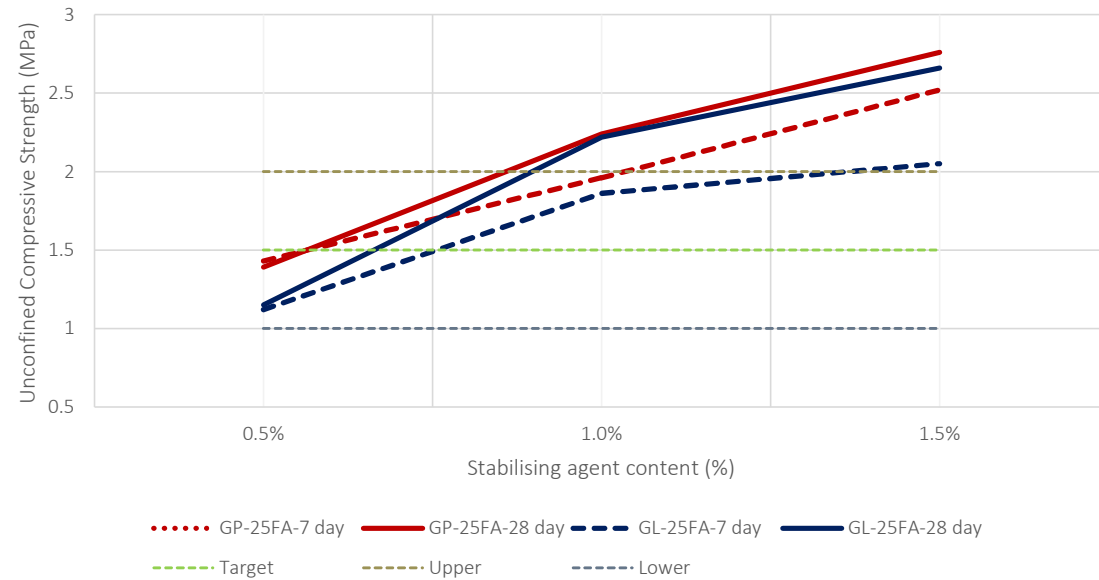
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UCS at var. stabilising agent contents

7 and 28 day strengths (straight cements)



7 and 28 day strengths (blended cements)



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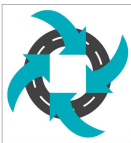


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Target stabilising agent contents

Target stabilising agent contents

Stabilising agent	Nominated MPV	Lower stabilising agent content limit	Upper stabilising agent content limit	Target stabilising agent content nominated for further trials
GP	0.10%	0.46%	0.59%	0.60%
GL	0.20%	0.56%	0.69%	0.60%
GB	0.20%	0.52%	0.64%	0.60%
GB _L	0.20%	0.55%	0.75%	0.60%



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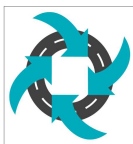
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UCS working times

Stabiliser type	Type GP	Type GL	Type GB	Type GB ₁
Stabiliser dose (wt.%)	0.60%	0.60%	0.60%	0.60%
Reference achieved dry density (ADD _R) (t/m ³)	2.22	2.23	2.23	2.23
Calculated ADD working time (WT ADD)	Not obtainable	5.5	5	Not obtainable
Reference UCS (UCS _R) (MPa)	1.2	1.2	1.5	1.1
Working time UCS (UCS _{TL}) (MPa)	1	1	1.2	0.9
UCS working time	5	4.5	2.5	3.5
Allowable working time	5	4.5	2.5	3.5



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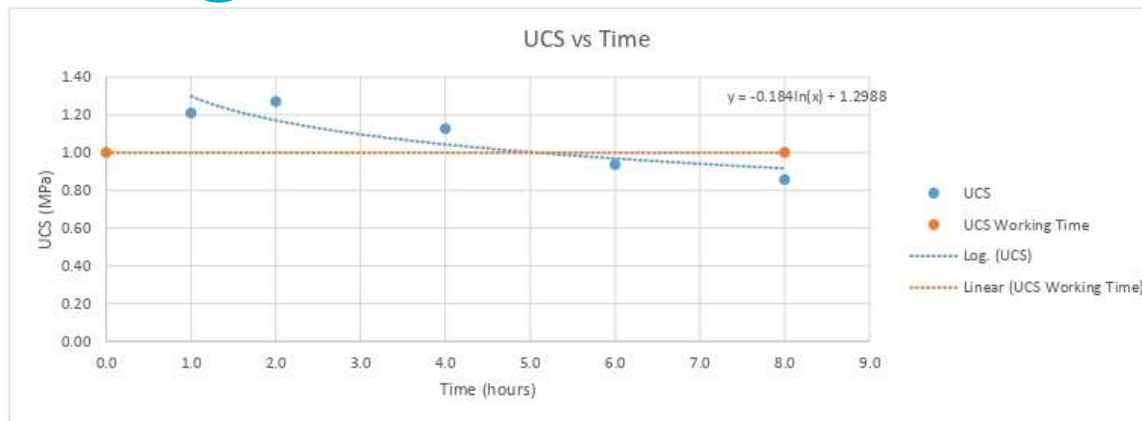
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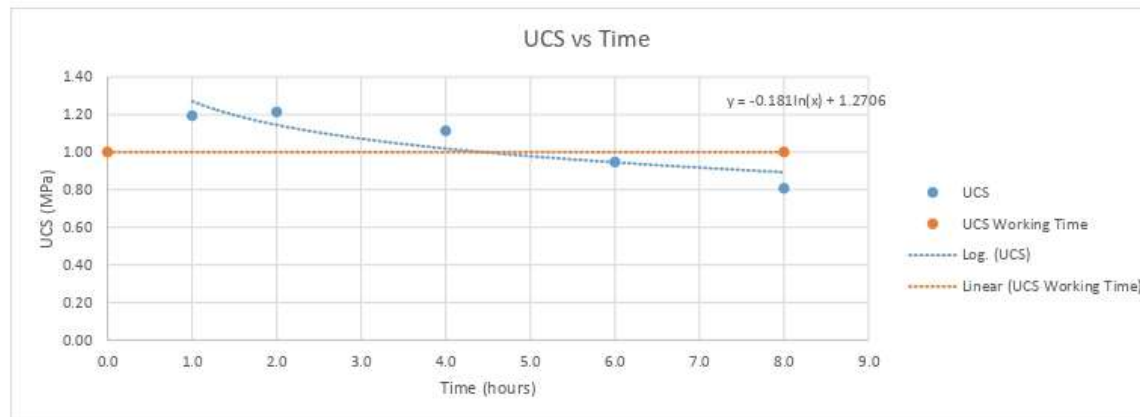
UCS working times

Type GP



Working Time UCS
1.0 MPa
Calculated UCS Working Time
5.0 hours

Type GL



Working Time UCS
1.0 MPa
Calculated UCS Working Time
4.5 hours



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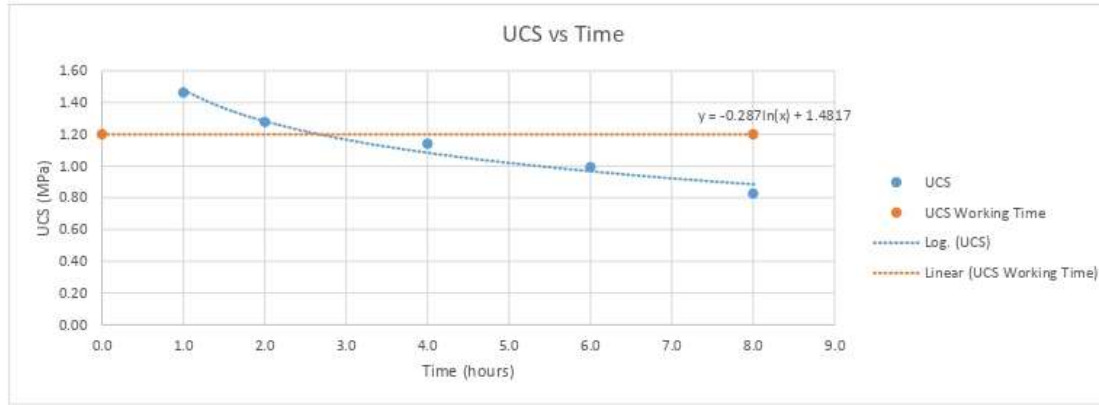
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UCS working times

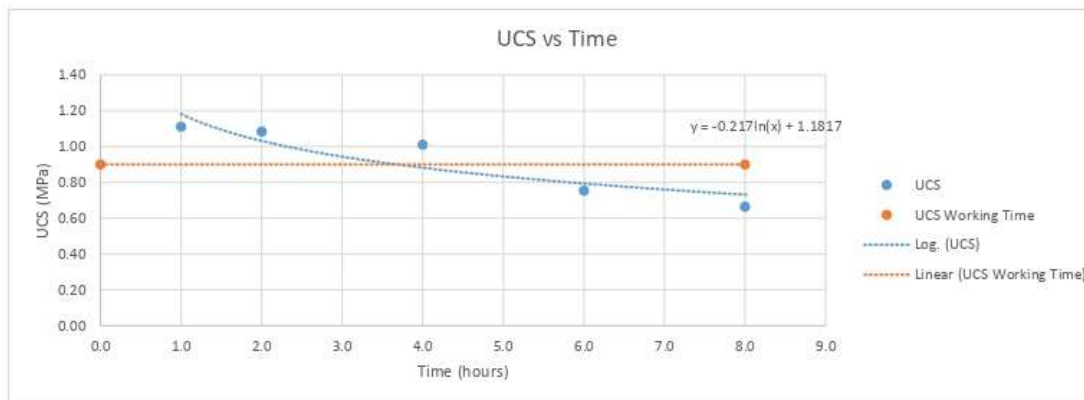
Type GB



Working Time UCS
1.2 MPa

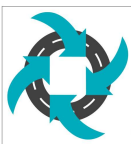
Calculated UCS Working Time
2.5 hours

Type GB_L



Working Time UCS
0.9 MPa

Calculated UCS Working Time
3.5 hours



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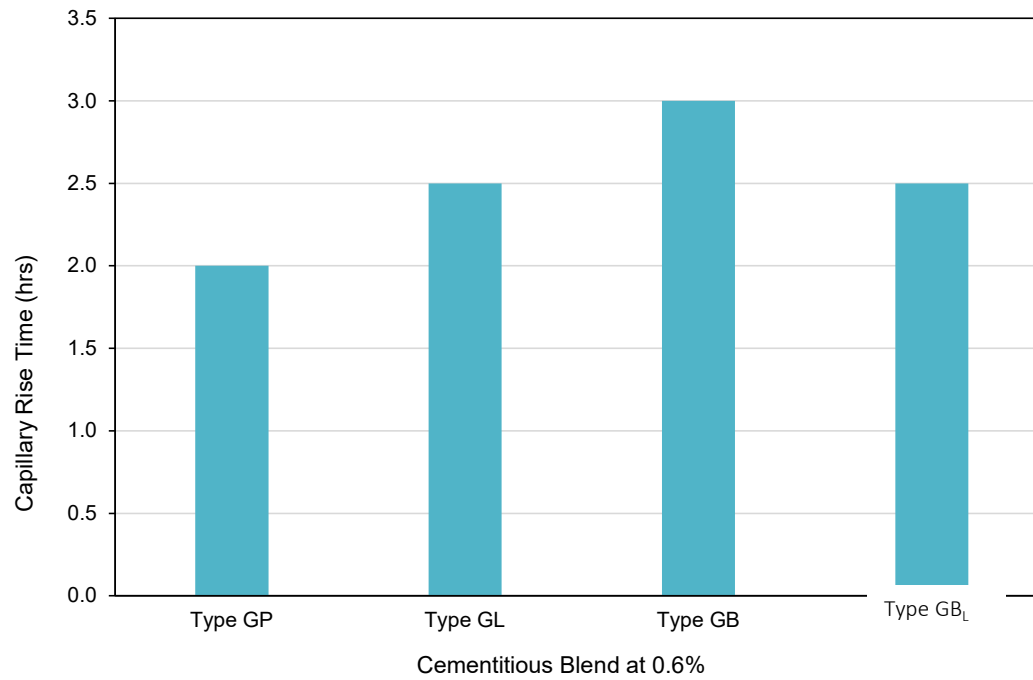
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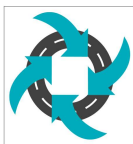


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Capillary rise



Specimen heights - 115mm
Achieved 100% capillary rise



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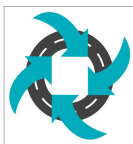
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Summary

- Limestone cement is increasing in international adoption
- Limestone cement estimated to offer a carbon emissions reduction of 5% ~ 10% compared to General Purpose cement
- In stabilised granular material trial conducted:
 - A potential reduction in 7-28 day strength growth was noted in a straight GL, compared to a straight GP (in a single trial). This was not reflected when blended with 25% fly ash.
 - The achieved working times, target cement contents, capillary rise and moisture density ratios of both GP and GL cements appeared comparable, including when blended with 25% fly ash.



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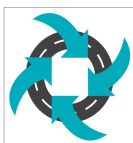
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