Outcome of the National Asset Centre of Excellence (NACoE) Insitu Slaking of Quicklime Trials

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Australian Pavement Recycling and Stabilisation Conference

Sustainable Pavements for Future Generations

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Recap

(Since 2019 AustStab Annual General Meeting)

NACOE trial Mackay Ring Road 2018

Intention of field trials to explore innovative methods of slaking quicklime

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Why do we need this?

- Quicklime is cheaper than hydrated lime:
  - 76% of quicklime is required compared to hydrated lime
  - hydrated lime is essentially carting 24% water to a project.

NACoE trial Mackay Ring Road 2018

Chemical Reactions

- Burning
  - $CaCO_3$ + heat (>1000°C) -> $CaO + CO_2$
- Slaking
  - $CaO + H_2O$ -> $Ca(OH)_2$ + heat
- Pozzolanic reaction
  - $Ca^{++} + OH^{-}$ + soluble clay silica -> Calcium Silicate Hydrate (CSH)
  - $CA^{++} + OH^{-}$ + soluble clay alumina -> Calcium Aluminate Hydrate (CAH)

Cunningham Highway Freestone Creek Lime Stabilised Core

Project Aim

To assess and evaluate the alternative method of slaking quicklime by insitu wet mixing, rather than the conventional method of quicklime surface slaking prior to incorporation.

Flinders Highway trial 2023

Benefits

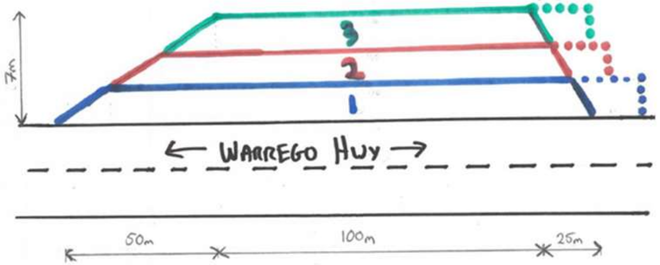
Flinders Highway trial 2023

Challenges finding insitu slaking trial location

- ✗ Truck stop 1: Within 10 metres of Gas pipeline.
- ✗ Truck stop 2: Endangered grass species.
- ✗ Truck stop 3: No black soil.

Truck stop 2 (18B 66.1km) and 5 (18C 26.0km)

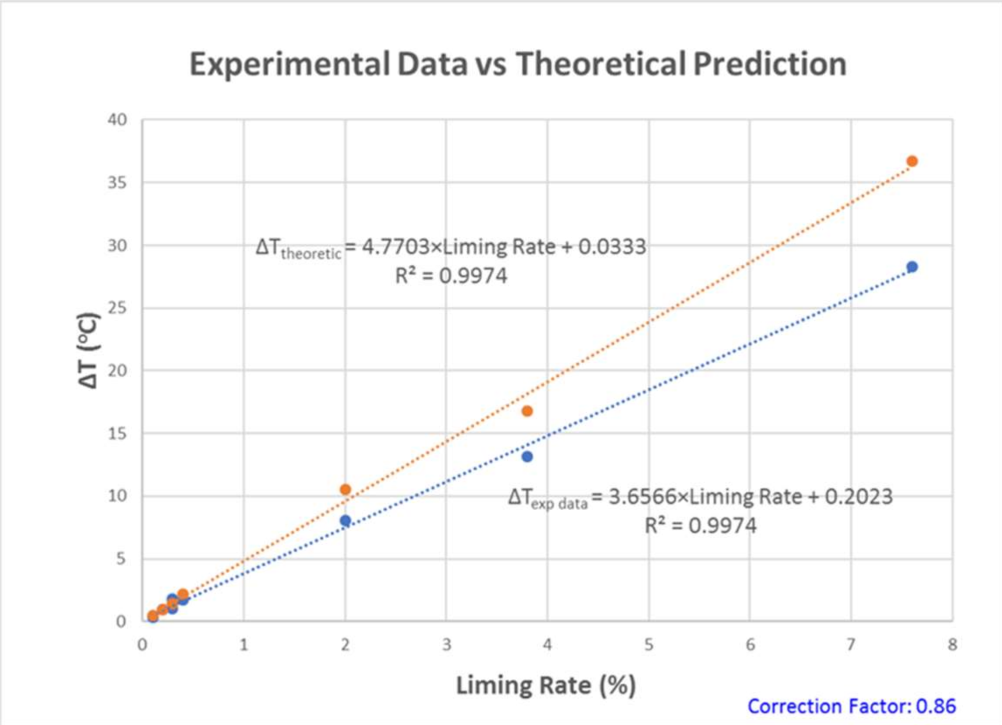
- Lot 1:
  - Hydrated lime as per MRTS07A
- Lot 2:
  - Quicklime as per MRTS07A
- Lot 3 (option 3A or 3B):
  - Quicklime trial - refer to trial brief.



Laboratory phase 2019 to 2022

TMR Lab, Bulwer Island 2019

Linear relationship between change in temperature vs lime rate (%) (2019)



Q = mcΔT

Q_CaO

- The energy released from the quicklime can be calculated.

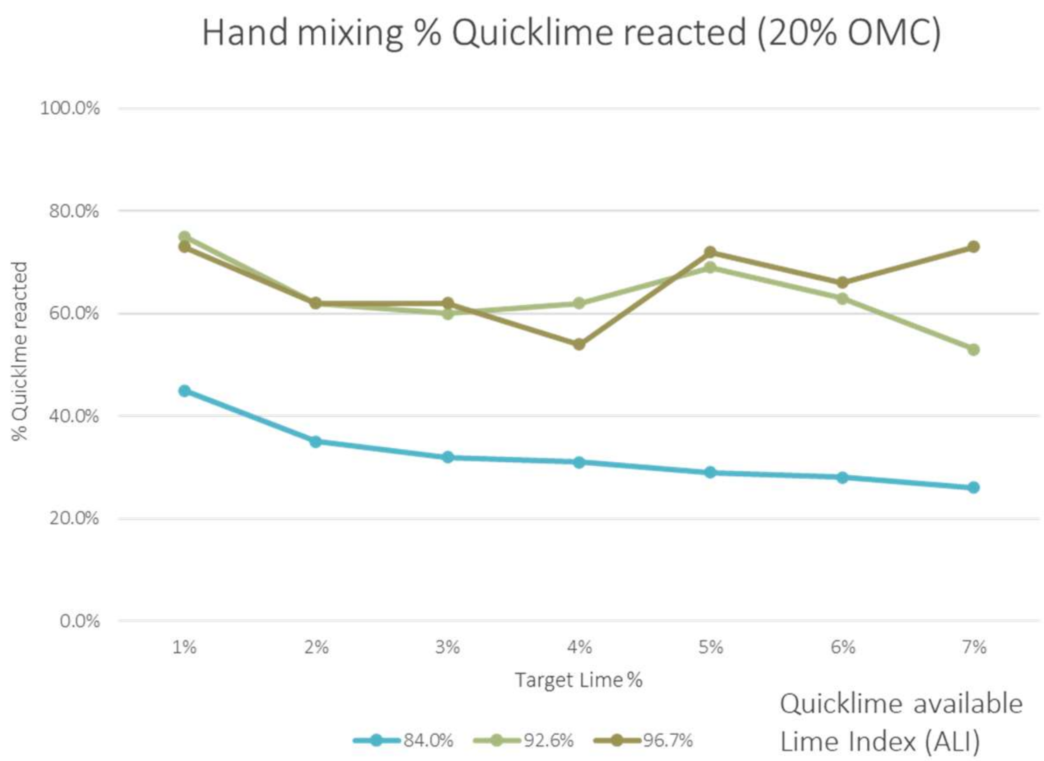
ΔT=Q/mc

- Change in temperature can be determined from the mass of soil and water using specific heat capacity.
- Ratio of theoretical temperature vs actual temperature = % lime reacted.

$Q_{CaO} = Q_S + Q_W$

- Ratio of energy released from the quicklime vs energy absorbed by the system = % lime reacted.

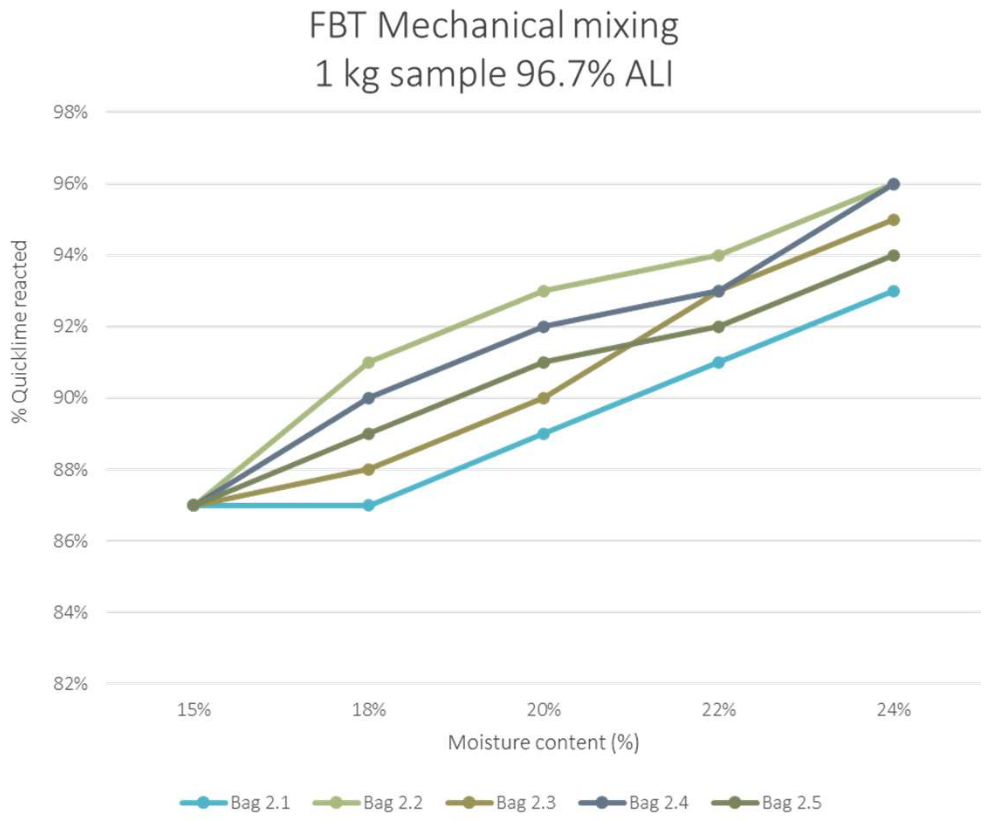
Comparison of three different lime source (2021)



Hand mixing:

- Results did not achieve the expected 86%.
- Results varied from 53% - 83% reacted lime.
- Lime with a slower slaking rate (*AS4489.3.1*) calculated less than 45% of reacted lime in the sample.

Repeatability of the draft Q259A method



Mechanical mixing

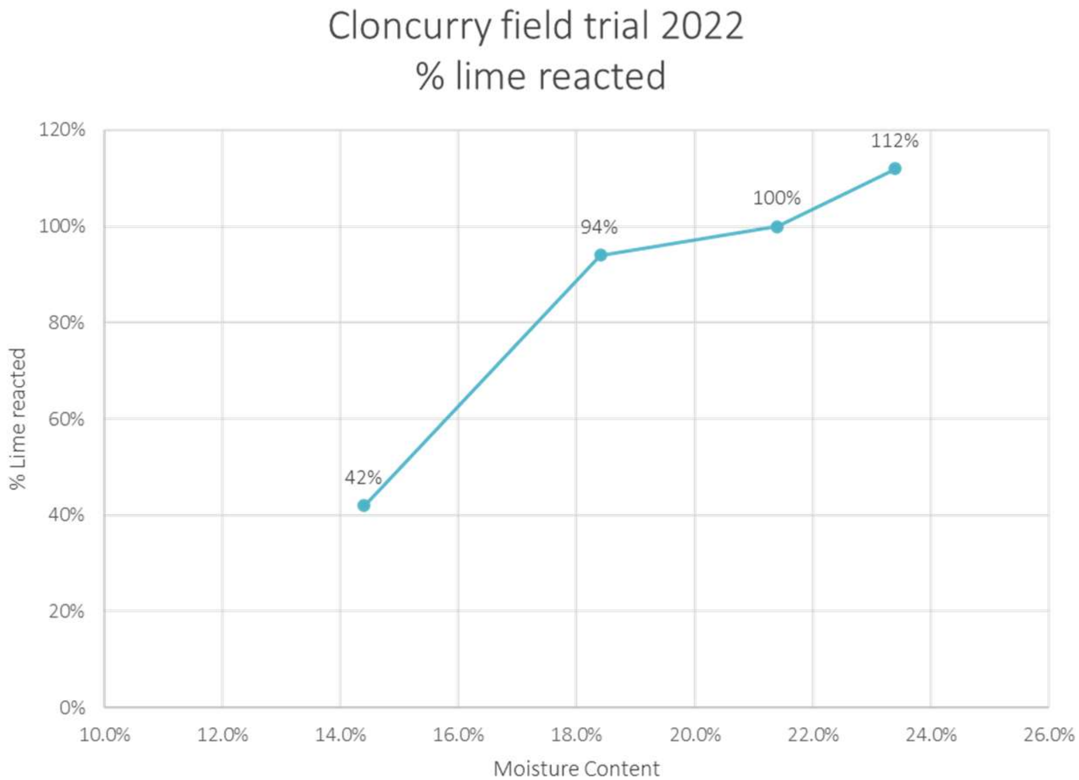
Using a lime with a fast slaking rate and 96.7% available Lime Index (ALI):

- results confirmed a linear relationship with each 2% addition of water
- results were repeatable between 93% - 96% reacted lime for five samples.

Flinders Highway trial 2022

Test Method field trial stage June 2022

Cloncurry truck stop field trial 2022



Flinders Highway trial 2022

Cloncurry truck stop field trial 2022

Flinders Highway trial 2022

Cloncurry truck stop field trial 2022

Flinders Highway trial 2022

Flinders Highway trial 2023

Field trial
June 2023

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Trial Sections

Control *MRTS07A* (50m)

Day 1

- spread 7.5kg/m2 and surface slaked
- incorporation mix.

Day 2

- spread 7.5kg/m2 and surface slaked
- incorporation mix.

- final wet mix.

AustStab (50m)

Day 1

- spread 7.5kg/m2 and insitu slaking incorporation mix

- spread 7.5kg/m2 and insitu slaking incorporation mix

- final wet mix.

NACOE Trial (100m)

Day 1

- spread 7.5kg/m2 and insitu slaking incorporation mix

- spread 7.5kg/m2 and insitu slaking incorporation mix.

Day 2

- final wet mix.

Control Section

Flinders Highway trial 2023

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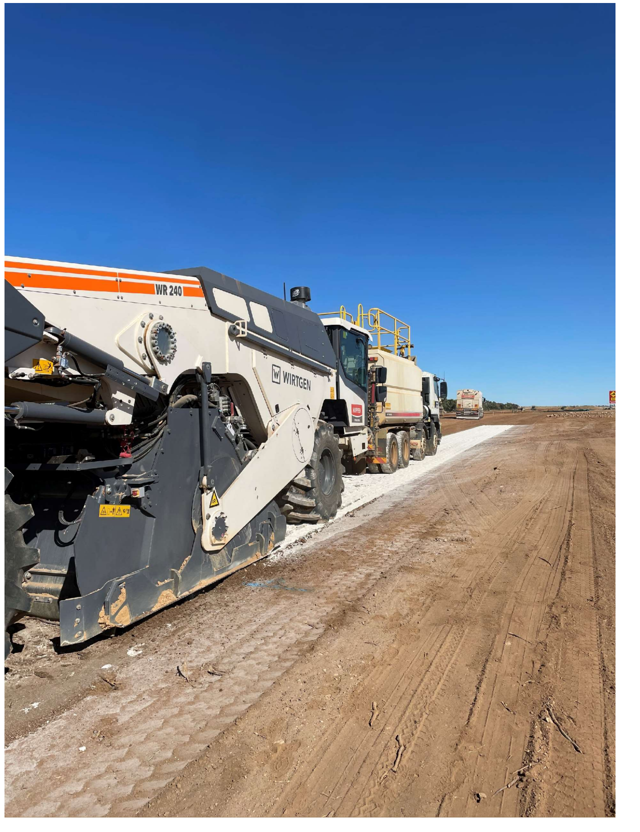

Flinders Highway trial 2023

NACoE Section

Flinders Highway trial 2023

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Insitu lime slaking - Draft Q259A method

Initial temperature

Sample taken directly behind the stabiliser

Temperature rise is measured onsite

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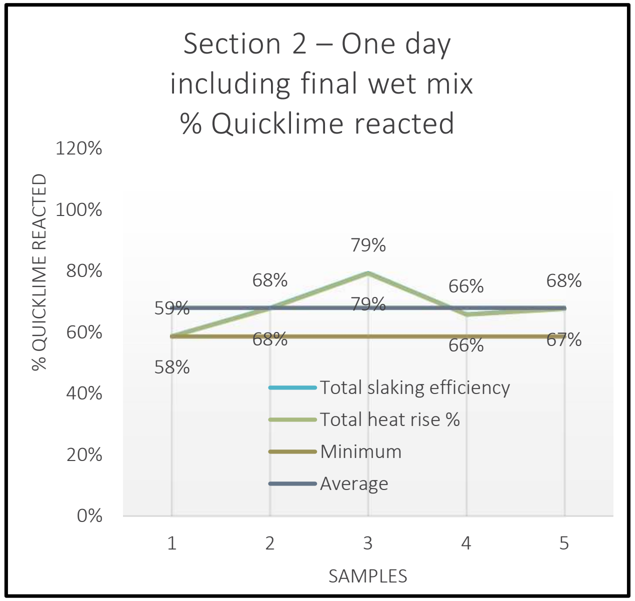
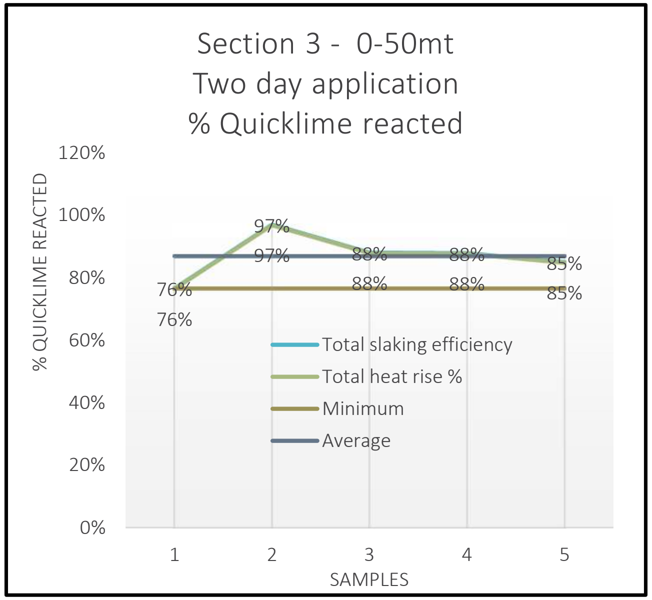
One day application vs Two day application

Insitu Moisture Content 11.4%



Insitu Moisture Content 15.8%



Insitu Moisture Content 15.8%

- One day procedure 58% - 79% reacted
- Two day procedure 76% - 97% reacted (0-50m)
- Two day procedure 69% - 99% reacted (50-100m)

Sample 1 was sampled within the first 5-10m of lot.

Calculation Spreadsheets

Pre-Field testing results		
Maximum Dry Density of soil	(t/m³)	1.69
Available lime index	(%)	92.2
Insitu Moisture Content	(%)	12.5
Target Optimum Moisture Content	(%)	16.0
Lime spread rate / water spread rate		
Lime ID		
	(kg/m3)	(%) and (time)
Target Quicklime (kg/m³)	15.0	3.55
Drop 1 Quicklime (kg/m³)	7.4	1:10:00 PM
Drop 2 Quicklime (kg/m³)	7.4	2:24:00 PM
Total Quicklime (kg/m3)	14.8	3.50

- Red text cells are automatically calculated

Data entry onsite includes:

- Pre-Field testing results
- Lime spread rate
- Sample identification details
- % Moisture added to site
- Depth of lot
- Mass of sub-sample
- Initial soil and water temperature
- Final slaked soil temperature

Field slaked soil testing						
Bulk sample ID		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Bulk sample location		Insitu	Insitu	Insitu	Insitu	Insitu
Temperature probe		CB027.11	DL1	DL2	DL3	CB27.10
% of target Quicklime added	%	100%	100%	100%	100%	100%
% Water added to soil (Total)	%	3.0	3.0	3.0	3.0	3.0
Moisture content of soil (insitu + water added)	%	15.5	15.5	15.5	15.5	15.5
Depth of site stabilisation	m	0.250	0.250	0.250	0.250	0.250
Depth of sample portion	m	0.200	0.200	0.200	0.200	0.200
% lime based on depth of sample portion	%	4.379	4.379	4.379	4.379	4.379
		EQUATIONS BACK CALCULATED FOR MASS OF QUICKLIME AND				
Mass of test portion (soil and lime)	kg	2.4	2.4	2.4	2.4	2.4
Mass of Quicklime in test portion (calculated)	kg	0.101	0.101	0.101	0.101	0.101
Mass of hygroscopic water in test portion (calculated)	kg	0.248	0.248	0.248	0.248	0.248
Mass of water added on site in test portion (calculated)	kg	0.067	0.067	0.067	0.067	0.067
Total mass of water in test portion	kg	0.315	0.315	0.315	0.315	0.315
Total Moisture content of test portion	%	15.1%	15.1%	15.1%	15.1%	15.1%
Dry mass of soil in test portion	kg	1.984	1.984	1.984	1.984	1.984
Dry mass of soil (calculated)	kg	1.984	1.984	1.984	1.984	1.984
Dry mass of soil and lime (calculated)	kg	2.085	2.085	2.085	2.085	2.085
Mass of slaked soil	kg	2.400	2.400	2.400	2.400	2.400
Initial soil temperature	°C	21.7	21.7	21.7	21.7	21.7
Initial water temperature	°C	16.8	16.8	16.8	16.8	16.8
Final soil temperature	°C	47.0	52.8	48.5	49.1	49.7
Time to max heat rise	Minutes	16	15	17	12	13
Change in sample temperature from slaking	°C	25.43	31.23	26.93	27.53	28.13
Theoretical Heat Rise						
Energy released by Quicklime (theoretical)	kJ/mole	105.440	105.440	105.440	105.440	105.440
Energy absorbed by water	kJ/mole	33.464	41.096	35.438	36.227	37.017
Energy absorbed by soil	kJ/mole	42.306	51.953	44.801	45.799	46.797
Energy absorbed total	kJ/mole	75.770	93.049	80.239	82.026	83.814
Energy absorbed total / Energy released by Quicklime (theoretical)	%	72%	88%	76%	78%	79%
Theoretical heat rise	°C	35.47	35.47	35.47	35.47	35.47
Change in temperature of soil / Change in temperature theoretical	%	72%	88%	76%	78%	79%
Residual Energy of Quicklime	kJ	29.67	12.39	25.20	23.41	21.63
Residual Quicklime	kg	0.026	0.011	0.022	0.021	0.019
Residual Quicklime	g	26.12	10.91	22.19	20.61	19.04
Residual Quicklime / Mass of Quicklime in test portion (calculated)	%	26%	11%	22%	20%	19%
Moles CaO in test portion	moles	1.6553	1.6553	1.6553	1.6553	1.6553
Energy released by Quicklime (theoretical)	kJ	105.440	105.440	105.440	105.440	105.440
Theoretical water required to complete reaction	kg	0.030	0.030	0.030	0.030	0.030
Results						
Slaking efficiency (Value from row 83)		72%	88%	76%	78%	79%
Average Slaking efficiency (reacted)		78.7%				
% Measured heat rise (value from row 85)		72%	88%	76%	78%	79%
Minimum % measured heat rise		71.7%				

Summary Spreadsheet

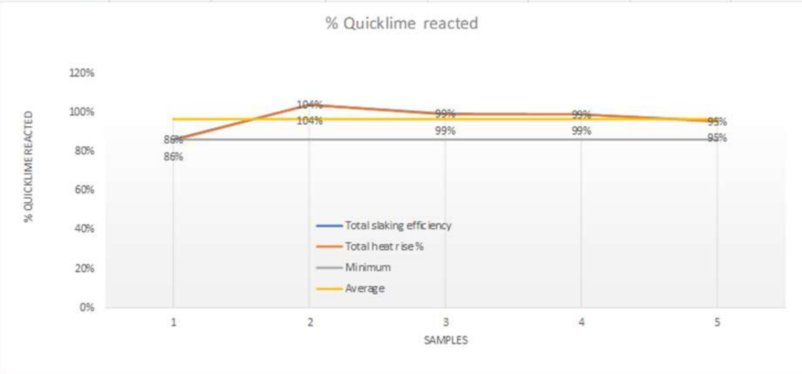
Q259: Slaking of Quicklime worksheet (draft V1.4)

Worksheet for Residual Quicklime - Summary

Sample details

Test Method	**Q259: Slaking of Quicklime (draft)**			Tested by	**RD, SV**
Sample ID	**Section - Q259 trial - 2 days**			Date tested:	**22/06/2023**
Client sample ID	**Cloncurry - Julia Creek**			Target Quicklime (%)	**3.00**
Material type	**Black soil**	ALI (%)	92.2	Quicklime / ALI (%)	**3.25**
Location	**0-50mt - Chainage (50mt) 71.790**			Energy released for Quicklime Reacted (Av)	**96%**
	days	hours		Heat rise for Quicklime Reacted (Min)	**86%**
Time for curing before final wet pass (slaking)	**day/s**	**17.0 hour/s**		Result for Quicklime Reacted	**SLAKED**

Average	Minimum		CB027.11	DL1	DL2	DL3	CB027.10
96%	86%	Total slaking efficiency	86%	104%	99%	99%	95%
		Total heat rise %	86%	104%	99%	99%	95%



RD, SV, DV, KL
21/06/2023
3.00
3.25
85%
72%
ADD MORE WATER

Considerations for test method *Q259A*

- Slow reacting lime does not reach the same heat rise as fast reacting:
  - slaking rate needs to be considered
  - more research required into a correlation factor.
- Agreed % for slaked lime yet to be determined:
  - currently set to more than 90% average and 80% minimum.
- Soil Temperature – initial and final temperature is critical
  - 2°C missed temperature rise equals 6-7% slaking.

Flinders Highway trial 2023

Observations and recommendations

- Trapped heat appeared to cause cracking in both June 2022 and June 2023 trials.
- Final wet mix on separate day releases heat.

Seeking trial in high lime percentage stabilisation project.

Acknowledgements

- NACoE Project P107: Undertaken by ARRB and TMR through the National Asset Centre of Excellence (NACoE) Program.
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