Category 2: Industry Excellence in Consulting, Research or Education

Development of a New Mix Design Procedure for Basegrade Stabilisation

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2021 AustStab Awards of Excellence

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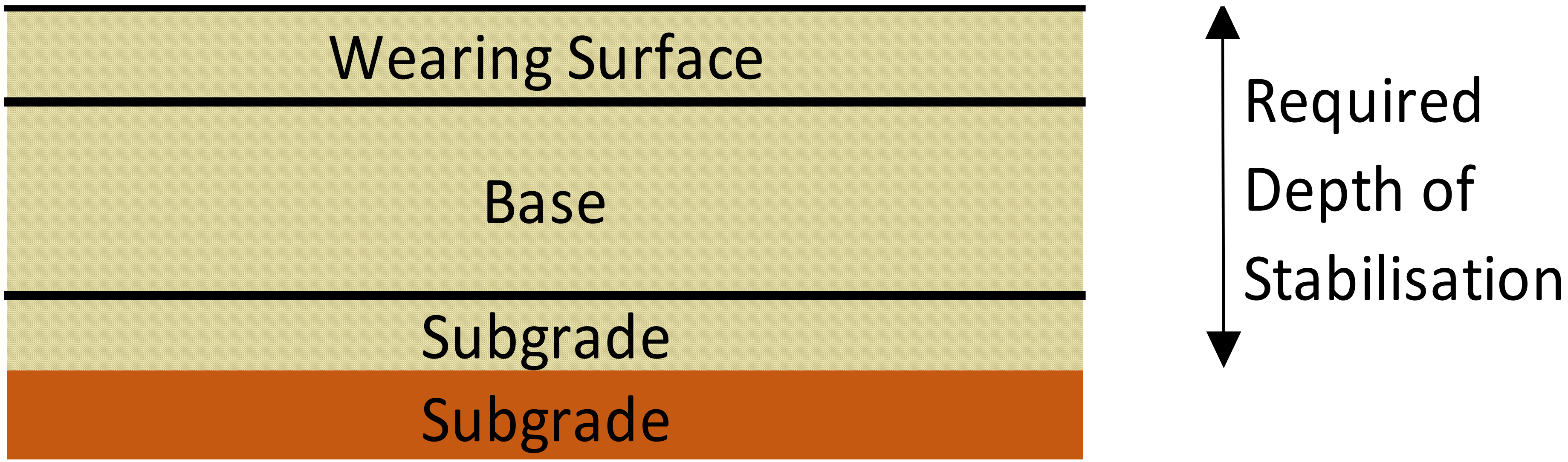
Project Overview

- This project was the result of a Masters Research Thesis completed in 2020 by Scott Young
  (available at: www.stabilisedpavements.com.au/wp-content/uploads/documents/CPEE630_Thesis_Scott_Young.pdf)
- Basegrade Stabilisation as a treatment type is not new, however the name 'Basegrade Stabilisation' and the Mix Design Procedure is new.



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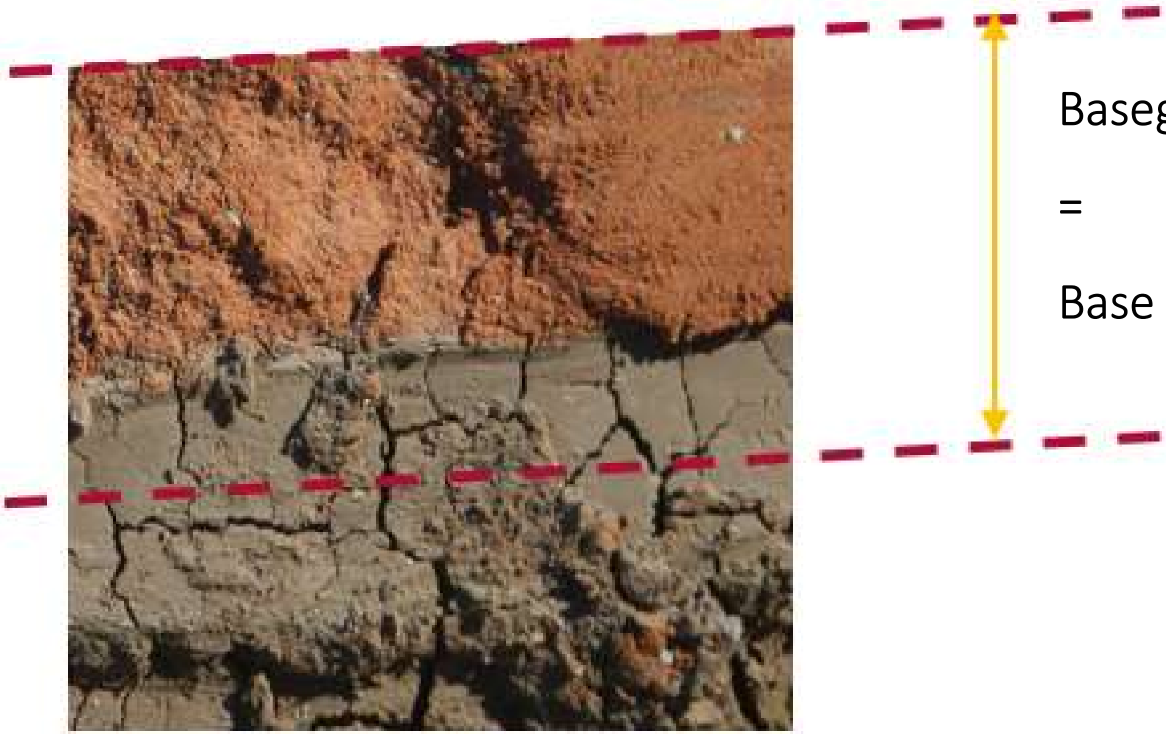
Research Objective

- To develop a mix design procedure for basegrade stabilisation treatments on local government pavement rehabilitation projects identified in lightly trafficked environments



Basegrade Stabilisation Thickness

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Base Thickness + Subgrade Thickness

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Project Challenges

- Experimental testing only considered 1 base gravel and 3 subgrade materials
- Additional binders and blends could have been used, including more recycled products
- No field trials were performed to validate the proposed mix design procedure

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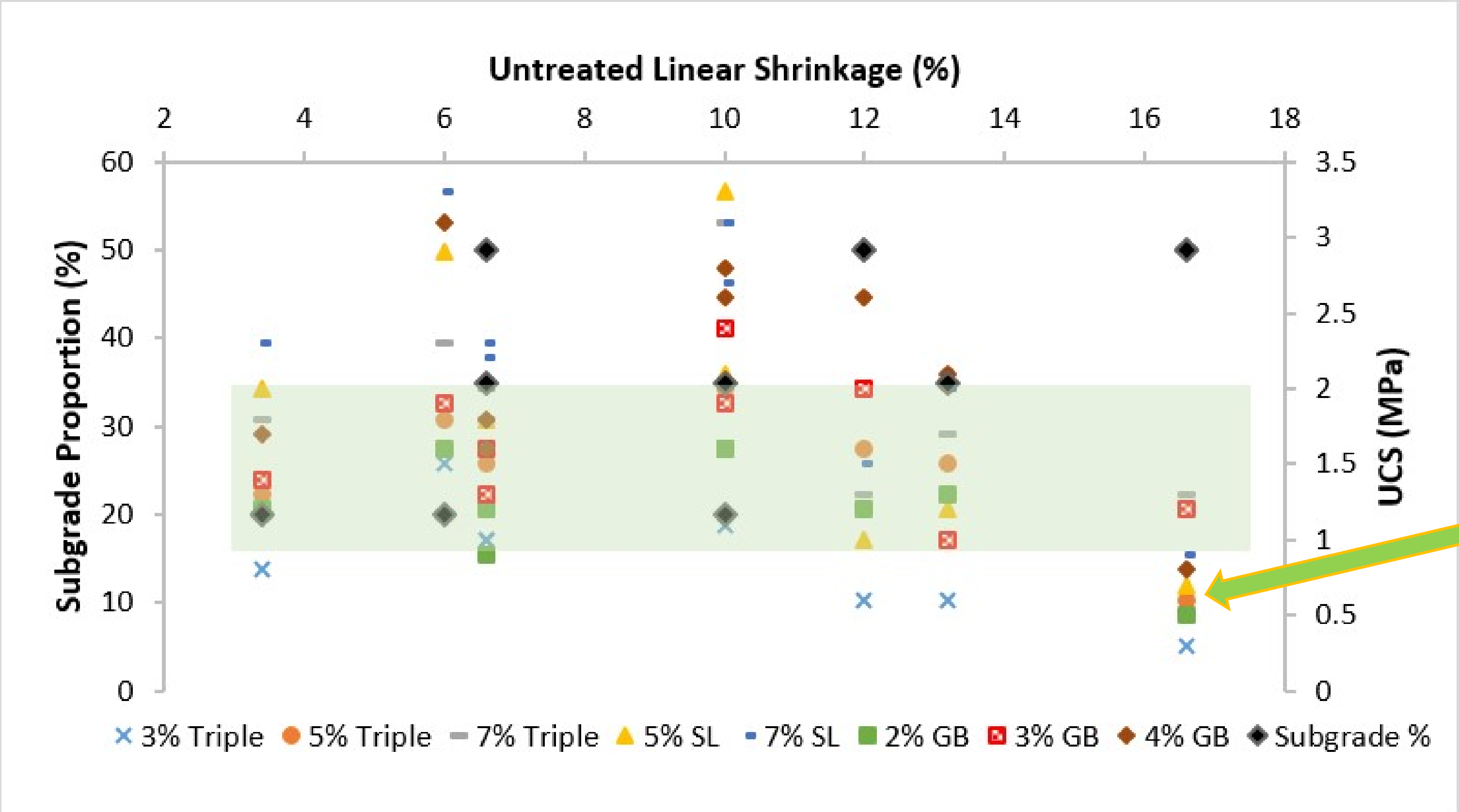
Key Points of Interest



- This plot shows the linear shrinkage of the untreated materials against the UCS of the treated materials. This was an important plot that revealed a variable that became part of the final mix design procedure, i.e. an upper limit of 14% for linear shrinkage of an untreated basegrade blend was adopted.
- Linear shrinkage of the untreated materials produced positive results (i.e. no less than 1MPa) for all pavement types and binder trials, with the exception of the trials that had a linear shrinkage of 16.6%. This was for pavement type PT3 which was a 50/50 blend of pavement gravel and the Pittsworth Alluvial. Therefore, an upper limit of 14% for linear shrinkage of untreated materials was adopted.
- Numerous other plots and data analysis was undertaken post laboratory testing to assist in the development of the mix design procedure.

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Experimental Testing Program

UNTREATED MATERIALS					
Phase 1 Testing	Phase 1 Tests	Phase 2 Testing			Phase 2 Tests
Raw Materials	PSD, Atterbergs, MDR, CBR	**Pavement Type**	**Base 1**	**Subgrade 1**	PSD, Atterbergs, MDR, CBR on all Pavement Types
Type 2.3 Gravel		PT1	80%	20%	
		PT2	65%	35%	
		PT3	50%	50%	
Pittsworth Alluvial		**Pavement Type**	**Base 1**	**Subgrade 2**	
		PT4	80%	20%	
		PT5	65%	35%	
Redlands Silt		PT6	50%	50%	
		Pavement Type	**Base 1**	**Subgrade 3**	
Wallum Court Clay		PT7	80%	20%	
		PT8	65%	35%	
		PT9	50%	50%	

	TREATED MATERIALS									
	Phase 3a Testing			Phase 3b Testing		Phase 3 Tests	Phase 4 Testing			Phase 4 Tests
	Lime/Cement/Flyash Triple Blend			**60/40 Slag/Lime**		UCS on all samples	**Day 1: Lime Day 2: 70/30 GB Cement**			UCS on all samples
Pavement Type	**3%**	**5%**	**7%**	**5%**	**7%**					
PT1	30/40/30	30/40/30	30/40/30	60/40	60/40		3% lime/ 2% GB	3% lime/ 3% GB	3% lime/ 4% GB	
PT2	40/40/20	40/40/20	40/40/20							
PT3	50/30/20	50/30/20	50/30/20							
Pavement Type	**Lime/Cement/Flyash Triple Blend**			**60/40 Slag/Lime**		MDR Atterbergs on Pavement Types PT2, PT5, PT8 (65/35 blend)	**Day 1 Lime / Day 2 Cement**			MDR Atterbergs on Pavement Types PT2, PT5, PT8 (65/35 blend)
PT4	30/40/30	30/40/30	30/40/30	60/40	60/40		3% lime/ 2% GB	3% lime/ 3% GB	3% lime/ 4% GB	
PT5	40/40/20	40/40/20	40/40/20							
PT6	50/30/20	50/30/20	50/30/20							
Pavement Type	**Lime/Cement/Flyash Triple Blend**			**60/40 Slag/Lime**			**Day 1 Lime / Day 2 Cement**			
PT7	30/40/30	30/40/30	30/40/30	60/40	60/40		3% lime/ 2% GB	3% lime/ 3% GB	3% lime/ 4% GB	
PT8	40/40/20	40/40/20	40/40/20							
PT9	50/30/20	50/30/20	50/30/20							
	1 Day Process						**2 Day Process**			

- There were 4 discrete phases of laboratory testing. This top table shows the first 2 phases. Phase 1 was to characterise the 4 raw materials separately. The 2nd phase was to characterise the 9 pavement types in their untreated state.
- The bottom table shows test phases 3 and 4. Three binder categories were added to the 9 pavement types in these test phases.
- The binders used were lime/cement/flyash triple blends, slag/lime blends and cement/flyash blends after lime pre-treatment. These are shown as test phases 3a, 3b and test phase 4.
- You can see that the distinguishing feature between test phases 3a/3b and test phase 4 is that specimens from test phase 3a/3b were blended and moulded at the same time. This represents a typical, or normal stabilisation process in the field.
- Test phase 4 however is where the material was treated with a constant 3% hydrated lime, left to ameliorate (or cure) for 24 hours, and then the mould was broken down and cement/flyash was added at application rates of 2%, 3% and 4%.

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Evidence of Success

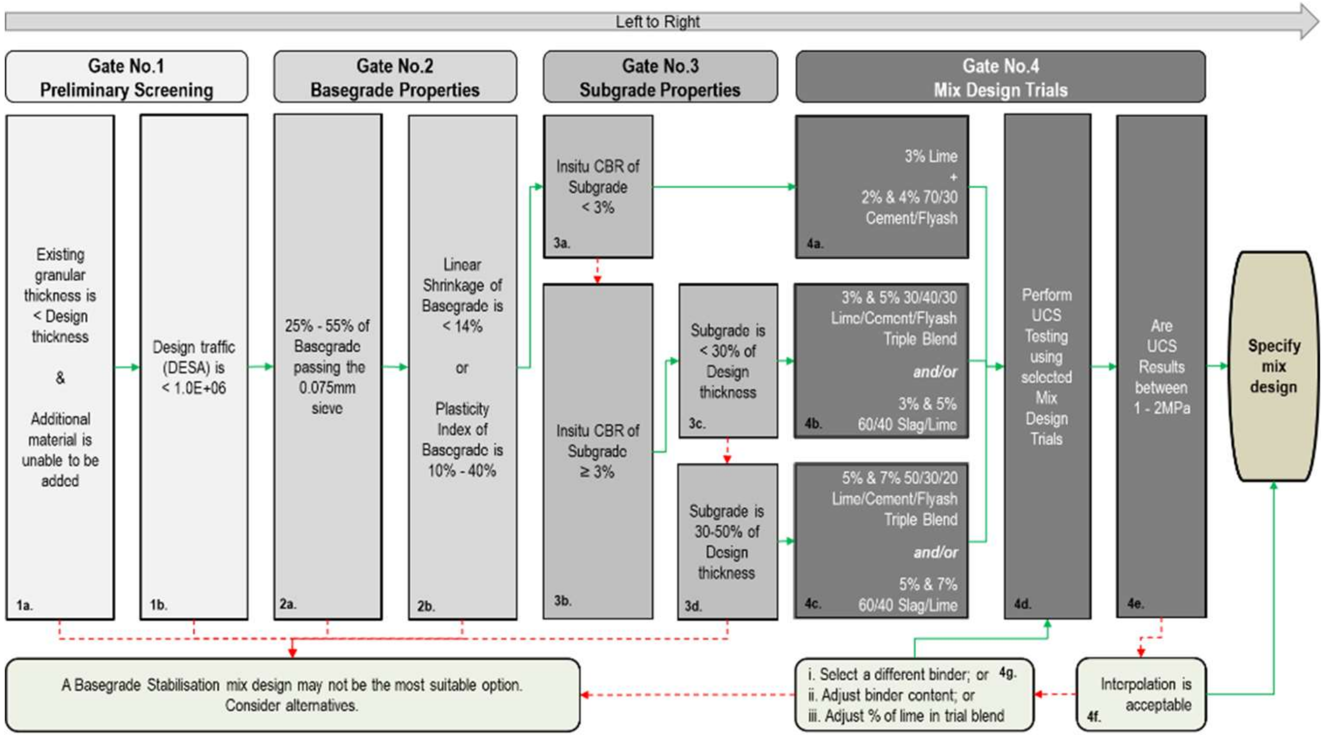
- Unconfined compressive strength testing was the principal test used with all 72 tests occurring after 28 days of curing at 23°C.
- All 72 UCS results are shown in this table. Cells highlighted in green illustrate the UCS results that were within the target strength range of 1-2MPa. The 9 pavement types noted PT1 through PT9 run in the left to right direction. The 8 trial mix designs are listed vertically on the left of the table, showing the 3 triple blends, the 2 slag/lime blends and the 3 cement/flyash blends pre-treated with lime.
- 86% of the experimental results exceeded 1MPa. The lowest result was 0.3MPa and the highest result was 3.3MPa.
- The sensitivity of subgrade type within the basegrade stabilised blends was considered low.

Averages	1.5			2.0			1.5				
	2.3	1.4	0.8	2.5	2.0	1.5	1.6	1.6	1.5		
	PT1	**PT2**	**PT3**	**PT4**	**PT5**	**PT6**	**PT7**	**PT8**	**PT9**	Averages	
3% Triple Blend	1.5	0.6	0.3	1.9	1.1	0.6	0.8	1.0	1.0	1.0	1.5
5% Triple Blend	1.8	1.5	0.6	2.0	1.9	1.6	1.3	1.5	1.3	1.5	
7% Triple Blend	2.3	1.7	1.3	3.1	1.9	1.3	1.8	2.0	1.8	1.9	
5% 60/40 Slag/Lime	2.9	1.2	0.7	3.3	2.1	1.0	2.0	1.8	1.3	1.8	2.0
7% 60/40 Slag/Lime	3.3	2.0	0.9	3.1	2.7	1.5	2.3	2.3	2.2	2.3	
3% Lime + 2% 70/30 GB	1.6	1.3	0.5	1.6	1.6	1.2	1.2	0.9	1.2	1.2	1.7
3% Lime + 3% 70/30 GB	1.9	1.6	1.2	2.4	1.9	2.0	1.4	1.3	1.6	1.6	
3% Lime + 4% 70/30 GB	3.1	2.1	0.8	2.8	2.6	2.6	1.7	1.8	1.6	2.1	
Subgrade %	20	35	50	20	35	50	20	35	50		

- One of the most encouraging trends in the results was the relatively small change in UCS with variations in the basegrade materials. This concept can be reflected in field conditions, usually under two situations. The first is when changes in material type occur within a project site (eg. from a clay to a silt). This was represented in the experimental research by assessing the test results against the three different subgrade materials (Pittsworth Alluvial v Redlands Silt v Wallum Court Clay). The average change in UCS regardless of binder type was approximately 0.25-0.5MPa for every +/-1% change in binder application rate.
- The second situation to present variations in basegrade material properties is when the proportion of subgrade changes in the field. This is relatively common where the thickness of existing pavement gravels vary along the length of a site. The average change in UCS regardless of binder type or application rate was approximately 0.5MPa for every +/- 15% absolute change in the amount of subgrade included in the mixture.

Mix Design Procedure

- The mix design procedure consists of 4 primary gates that go from left to right. Each gate contains a number of boxes with questions that relate to the engineering properties of the pavement being considered for basegrade stabilisation.
- The 1st gate is a preliminary screen, to check that the fundamental recommendations for implementation of basegrade stabilisation have been satisfied. Those being that the existing pavement has inadequate thickness to satisfy the design thickness and the design traffic does not exceed 1.0E+06 DESA.
- The 2nd gate evaluates the actual basegrade properties, being the PSD of the combined mixture and either the linear shrinkage or the plasticity index.
- The 3rd gate presents a consideration of the underlying subgrade, what it's bearing capacity is and how much of it is anticipated to be brought into the pavement structure.
- The 4th gate presents 10 mix design trials, all encompassing the 3 binder types and application rates which are intended to optimise the outcome (defined as achieving the target strength with the least amount of binder).



- Once the trial mix designs are assessed from UCS testing, a mix design can be confidently specified.
- However – there are options for exiting the mix design procedure when certain elements within gates are not satisfied, or provision of alternatives to trial different binders, different application rates or results interpolation.
- A comprehensive set of user notes accompany the procedure which are presented in the research thesis. They contain a series of Specific Notes that align with each of the boxes in the mix design procedure.

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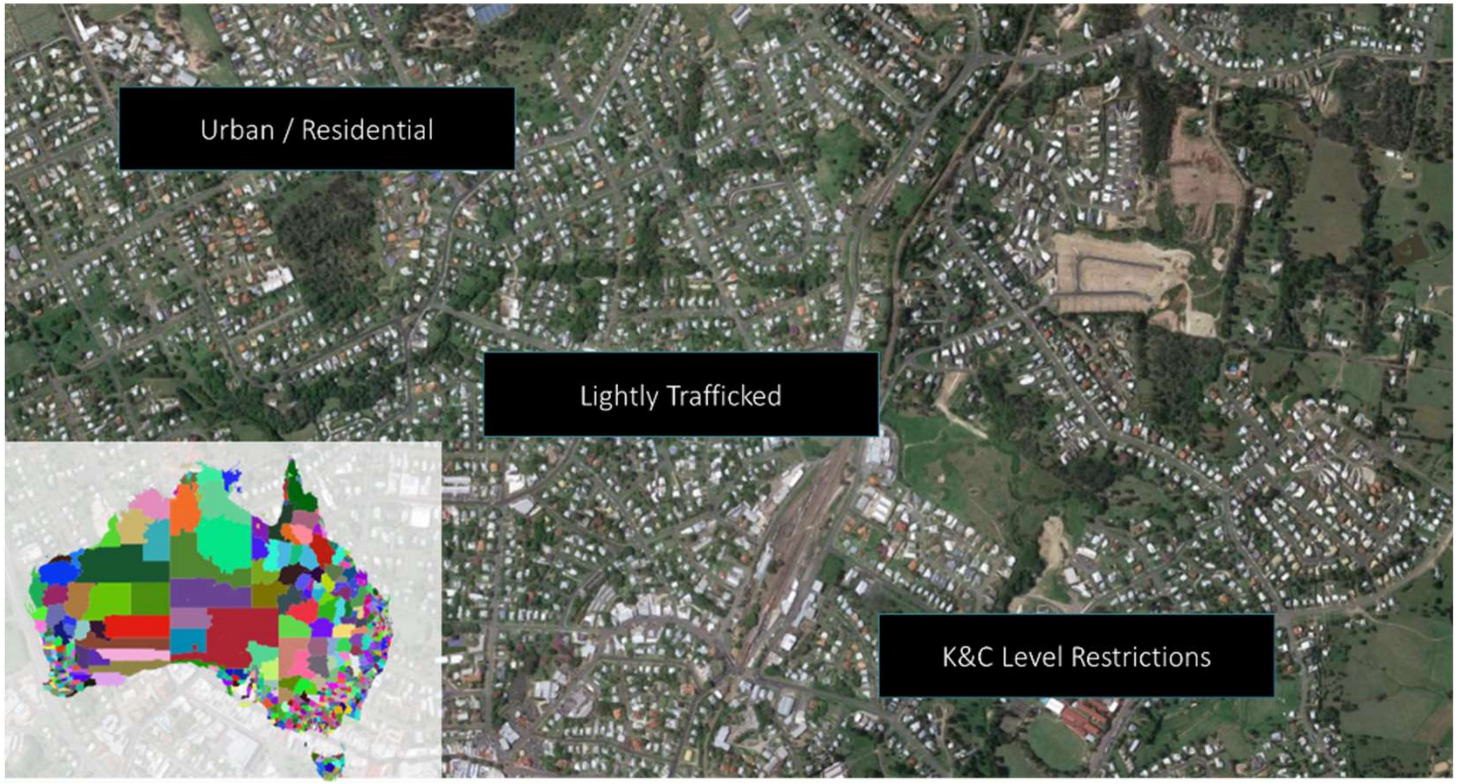
Benefits

- The primary beneficiary of adopting Basegrade Stabilisation is local government because they are known to have significant amounts of existing lightly trafficked roads that are too thin to stabilise before encroaching into the subgrade. As a result, the default treatment selection is often a granular reconstruction which is costly, time consuming and unsustainable.



- Now with a comprehensive mix design procedure for Basegrade Stabilisation, local government roads with insufficient basecourse gravels can still be recycled with confidence in achieving a lightly bound layer, by following the mix design procedure developed in this research.

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Demonstration of Project Initiative in Use – Sunshine Coast Council, Queensland

- The above images display a 200m long residential street near Caloundra on QLD's Sunshine Coast that was treated using Basegrade Stabilisation due to the existing gravel being thinner than the rehabilitation design required. As the insitu and design subgrade CBR was <3%, the construction process involved a lime treatment initially, followed by a cementitious treatment (4% 70/30 Cement/Flyash). The trial mix design in the laboratory achieved a UCS of 1.5MPa.

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Demonstration of Project Initiative in Use – Port Macquarie Hastings Council, NSW

- This image shows the town of Wauchope. The highlighted streets are from Councils 2017/18 capital works program. All sites had thin existing gravels and were treated using a basegrade stabilisation strategy. However since the Basegrade Stabilisation mix design procedure did not exist at that time, the adopted mix design was selected from trial and error. It ultimately became a 60/40 slag/lime and various application rates.