Using Recycled Materials in Stabilised Pavements

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Overview

- Outline and Acknowledgments
- Background
- Research Gaps
- Test program
- Results
- Summary
- Conclusions and Recommendations

Project Outline

Title: Using Recycled Materials in Stabilised Pavements

Key Contributing Staff:

Dr Negin Zhalehjoo (ARRB Project Leader), Meera Creagh (TMR Project Manager), Dr James Grenfell (ARRB Quality Manager), Dr Jaspreet Pooni (ARRB), Damian Volker (TMR)

Project Objective:

- The project aims to demonstrate recycled host material blends can meet the mix design requirements for foamed bitumen and cementitious stabilisation.

Acknowledgements:

- NACoE Project O24: Undertaken by ARRB and TMR through the National Asset Centre of Excellence (NACOE) Program
- TMR Bulwer Island Laboratory and Rockhampton Laboratory undertook the testing

Previous/Current Relevant NACOE and Austroads Projects Undertaken by ARRB|NTRO

- NACOE P94 – Optimising the Use of Recycled Materials in Queensland for Unbound and Stabilised Products
- NACOE P135 – Using Recycled Materials in Stabilised Pavements
  - Permissible blending proportions for crushed rock and recycled materials
- NACOE P122 – Improved Characterisation of Lightly Bound Materials
- Austroads TT1897 – Development of Design Procedures for Lightly Bound Cementitious Materials in Flexible Pavements
- Austroads APT6157 – Laboratory Fatigue Characterisation of Foamed Bitumen Stabilised Materials

024 – Stabilisation of Recycled Materials

What

Materials

- Type 2.3
- Three blends of Recycled concrete, glass, asphalt and brick.

Binders

- Cementitious stabilisation
- Foamed Bitumen stabilisation.

Why

Stabilisation forms a significant proportion of works on rural and urban networks.

TMR is aiming to improve the use of recycled materials.

Waste 2 Resource Strategy

Objectives

1. Minimise disposal to landfill
2. Achieve resource efficiency through circular economy practices
3. Facilitate market growth
4. Reduce greenhouse gas emissions from waste generation and resource use

Source: TMR.


Department of Transport and Main Roads

TMR's Waste 2 Resource Strategy

Resource efficiency through circular economy practices to minimise waste generation and maximise resource recovery

The Department of Transport and Main Roads (TMR) plans, manages and delivers Queensland's integrated transport system for road, rail and sea.

The Queensland Government has committed in the *Waste Management and Resource Recovery Strategy* to a more sustainable future, with a focus on a circular economy. The *Waste 2 Resource (W2R) Strategy* is how TMR will achieve this commitment.

TMR recognises that reducing Queensland's waste and ensuring all products and materials are managed as valuable and finite resources are shared responsibilities between government, industry and the community.

TMR's W2R Strategy sets the strategic direction and intent to minimise wastes and achieve a more sustainable use of resources across the department. The W2R Strategy sits under TMR's *Environmental Sustainability Policy*.

Vision

TMR will become a zero waste organisation and transport industry leader through circular economy practices

Queensland Government

Source: TMR.

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W2R Strategy pillars and O24

1. Specifications – already permitted
2. Engagement and collaboration – TMR, ARRB, industry
3. Market engagement – understand processes and barriers
4. Procurement – encouraging use and fostering demand
5. Data collection and analysis – demonstrate performance

Lightly-Bound (LB) Materials

- LB materials are granular materials with moderate amounts of stabilizing binder to improve modulus
- LB materials are characterized by 28-day UCS of 1.0 to 2.0 MPa
- Improves rut resistance and stiffness when used with thin bituminous surfacings
- LBC bases have shown good performance, reduced moisture sensitivity and improved resilience (reduced block or crocodile cracking) if appropriately designed and constructed

Foamed Bitumen Stabilisation (FBS)

- FBS introduces cohesion into non-plastic materials or to make a cohesive material less sensitive to loss of stability with increased moistures.
- Foamed bitumen is produced using air, water, and hot bitumen. After injecting small quantities of water and compressed air into hot bitumen, the water turns into vapour, resulting in the production of foamed bitumen.
- Particle size distribution (PSD) of the host material is an important factor affecting bituminous stabilisation.
  - Generally, well-graded PSD with a good particle shape (not rounded),
  - plasticity index (PI) of equal or less than 10, or
  - linear shrinkage of equal or less than 6

Source: Wirtgen Group (2017)

Research Gaps

- Increased focus on reducing the reliance on non-renewable resources.
- Performance and mechanical properties of stabilised recycled material blends have not been well studied.
  - Foamed bitumen
  - Cementitious
- Project aims to investigate the feasibility and optimisation of recycled material blends as host materials
  - Creating better opportunities
  - Significant environmental and cost benefits.

Selected Host Materials

- 3 blends types were selected for laboratory investigations:
  - Recycled materials blend: 100%RCC
  - Recycled maximum blend: 40%RCC, 20%RAP, 20%CB, and 20%RCG
  - Recycled minimum blend: 70%RCC, 10%RAP, 10%CB, and 10%RCG

    - *RCC: recycled crushed concrete*
    - *RAP: reclaimed asphalt pavement*
    - *CB: crushed brick*
    - *RCG: recycled crushed glass*

Testing Program

Testing	Method	Year 1	Year 2
particle size distribution	TMR Q103A (2021/22)	✓	✓
foreign materials content	TMR Q477 (2018)	✓	
compacted density of foamed bitumen stabilised materials	TMR Q147B (2018)	✓	✓
working time of cementitious stabilised materials	TMR Q136A (2021)	✓	✓
Atterberg limits	TMR Q104A (2020/22) TMR Q105 (2018), TMR Q106 (2021)	✓	✓
compaction properties (maximum dry density and optimum moisture content using standard compactive effort)	TMR Q142A (2021)	✓	✓
indirect tensile modulus (ITM) test of foamed bitumen stabilised (FBS) materials	TMR Q139 (2021/22)	✓	✓
indirect tensile cracking test of FBS materials	ASTM D8222 (2019)		✓
unconfined compressive strength (UCS) test of FBS materials	TMR Q115 (2022)		✓
UCS test of cementitious stabilised materials	TMR Q115 (2020/22)	✓	✓

Foamed Bitumen Stabilisation in the Laboratory and ITM Testing

Mixing FBS material – Wirtgen apparatus

Indirect tensile modulus testing of FBS samples

Source: Austroads 2022 "Laboratory Fatigue Characterisation of Foamed Bitumen Stabilised Materials"

Unconfined Compressive Strength (UCS)

- According to TMR Q115 (2020/22)
- Standard compaction
- Specimens cured following Q135b (2020/22)
  - 7-days
  - 28-days
- Load rate 1 ± 0.2 mm/min

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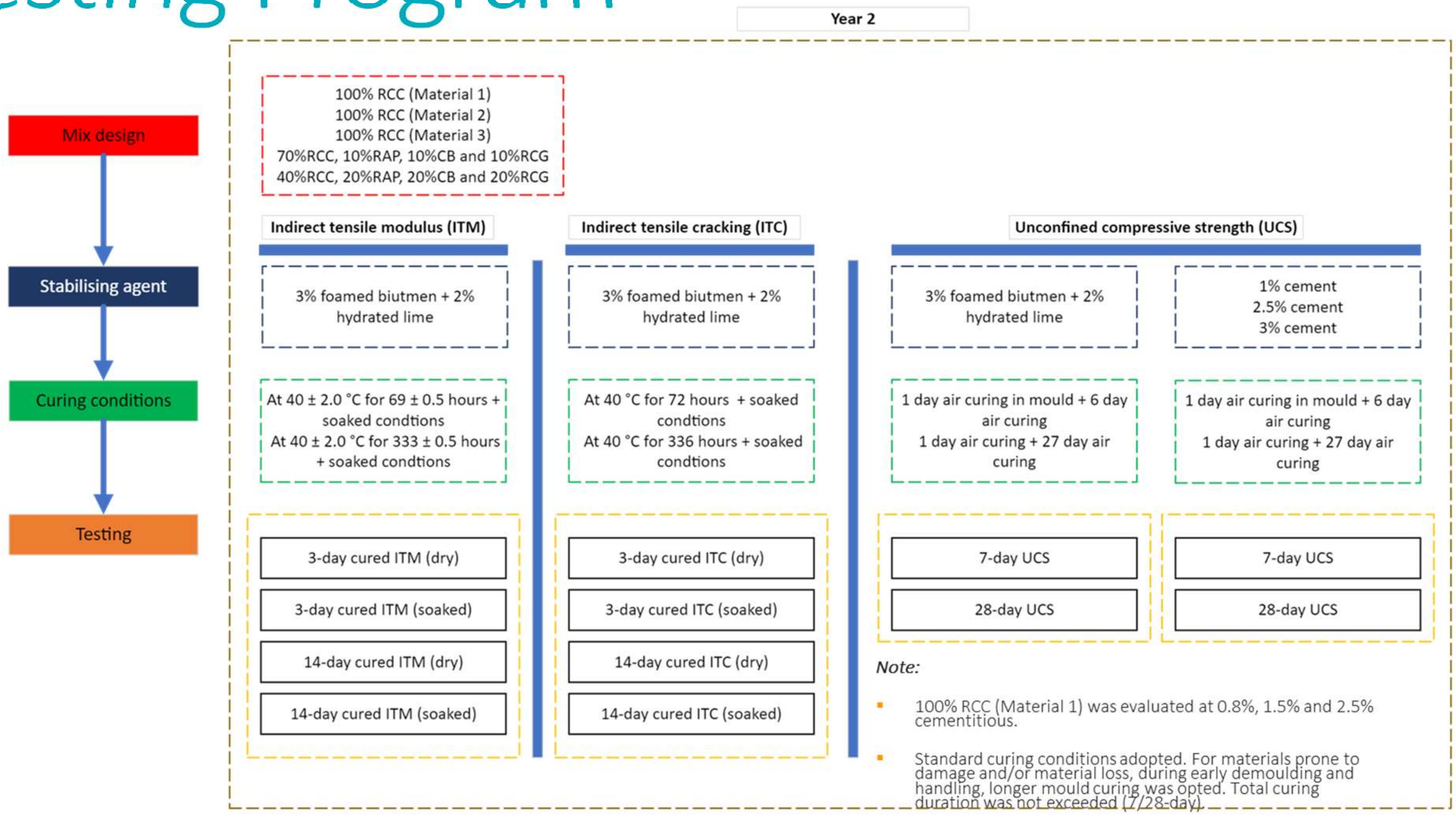
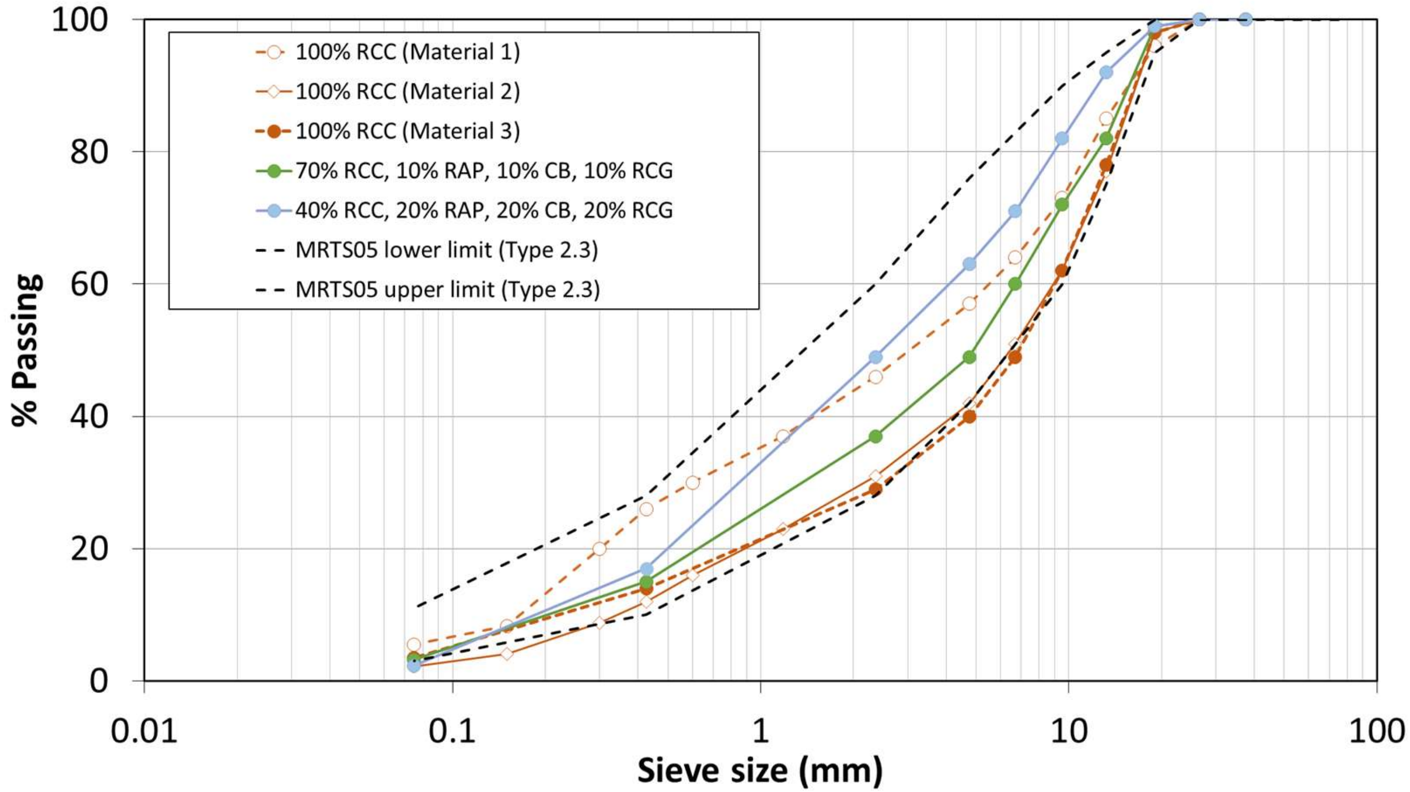
Testing Program



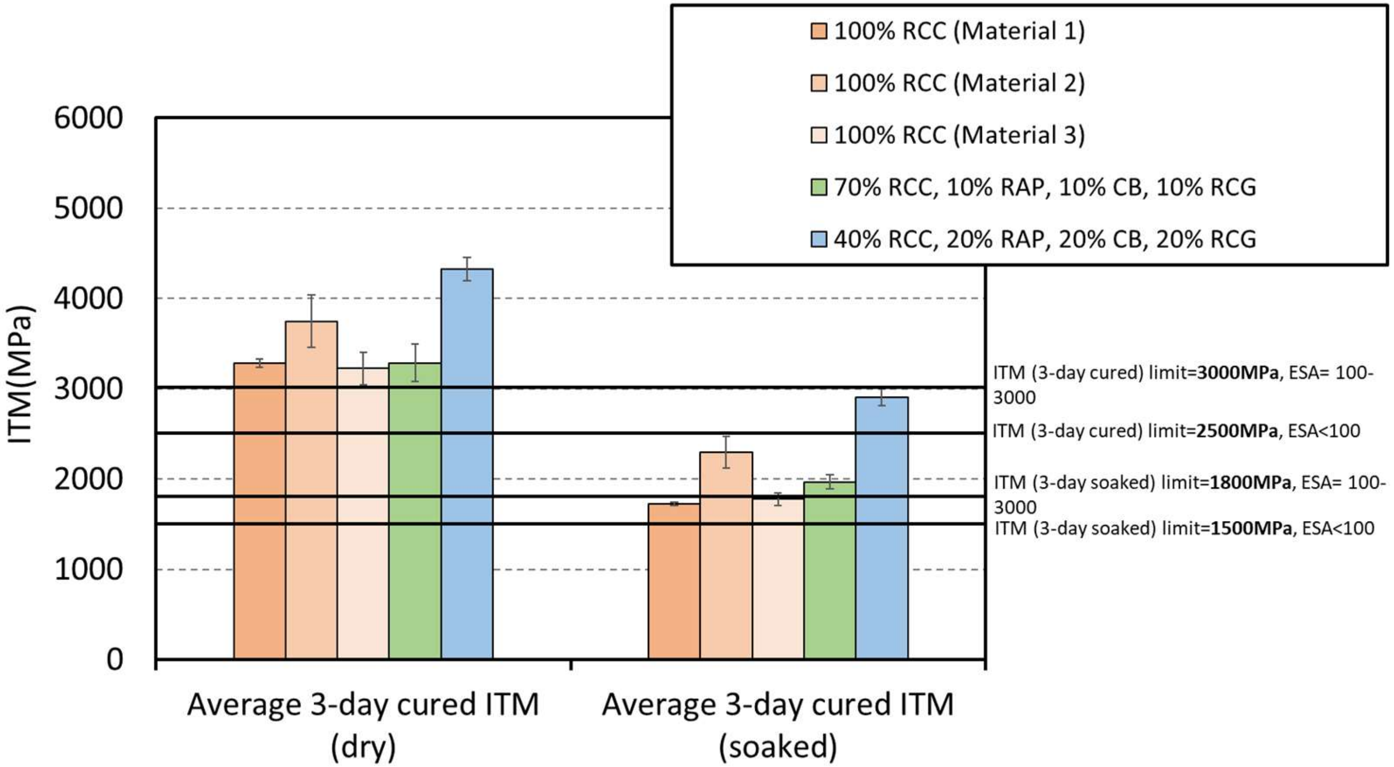
Materials

- Materials generally met MTRS05 grading specification.
- 100% RCC (Mat. 2) and 40% RCC blend had marginally lower fines content (<3%).
- Linear shrinkage limit for all recycled blends except 100% RCC (Mat.1) were lower than the 1.5% minimum requirement.
- All tested recycled blends had the liquid limit lower than the 35% maximum requirement (*MRTS05 requirement for Type 2.3 considered*).

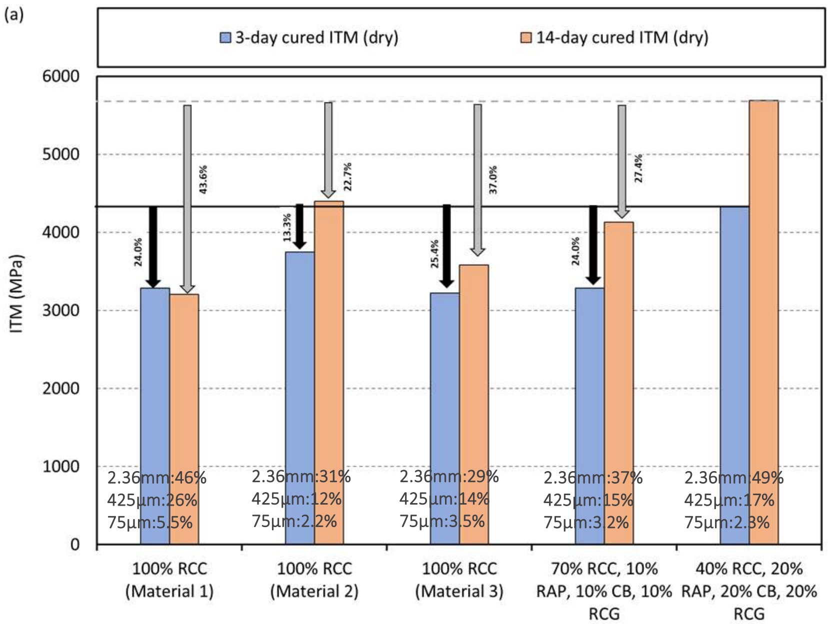


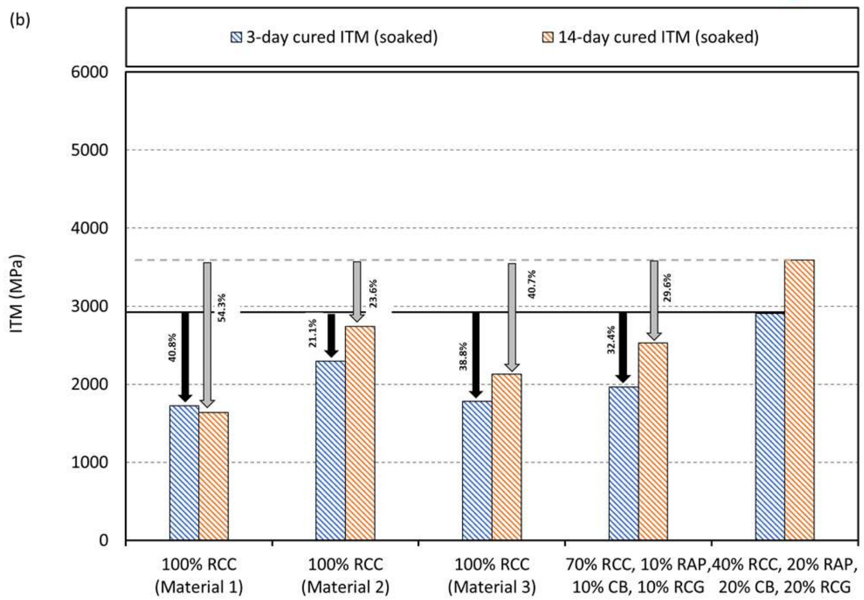
Indirect Tensile Modulus Results of FBS Samples

- All recycled blends met the ITM mix design requirements under dry conditions.
- All blends met the ITM requirements for soaked modulus for ESA>100 except the 100% RCC blend (Mat.1).
- Complied with the minimum retained modulus.
- As RCC proportions decrease and RAP, CB, and RCG blend proportions increase, the modulus overally increases.



Indirect Tensile Modulus Results of FBS Cured Samples

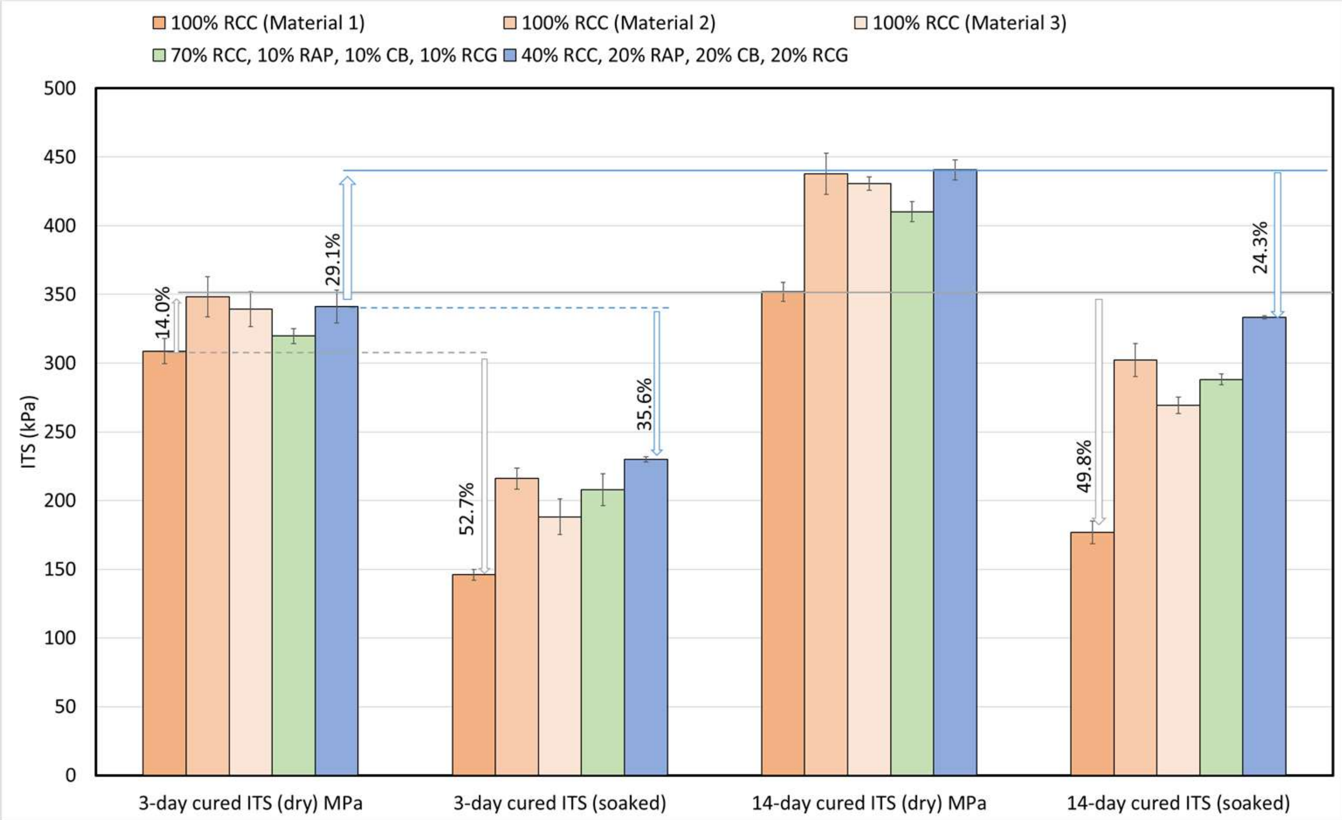




- Influence of curing became more pronounced as the proportion of RCC replaced with RAP, CB, and RCG increased; and greater rate of modulus gain.
  - Secondary binder contributes to long term strength gain
  - Improved gradation
- 14-day ITM (dry) of the maximum blend (40% RCC) is 44%, 23% and 37% greater than the 100% RCC from Material 1 and 2 and 3, respectively.
  - Similar trends with soaked ITM.
- Fines fraction passing 425µm and 75µm sieve seem to influence modulus for FBS materials. More prominent at 3-days.

Indirect Tensile Strength Results of FBS Samples

- Adopting the principles from ASTM D8225 (2019). Strain controlled loading.
- 40% RCC blend generally exhibited the greatest ITS.
  - 29.1% improvement in dry ITS after 14-day curing
- As the proportion of RCC decreased, the strength retention generally increases.
  - 100% RCC (Mat. 1) showed about 53% reduction in 3-day strength when soaked, while this value for 40% RCC blend is 36%.
- Possibly better bonding in foamed bitumen stabilization, as RAP content increases.



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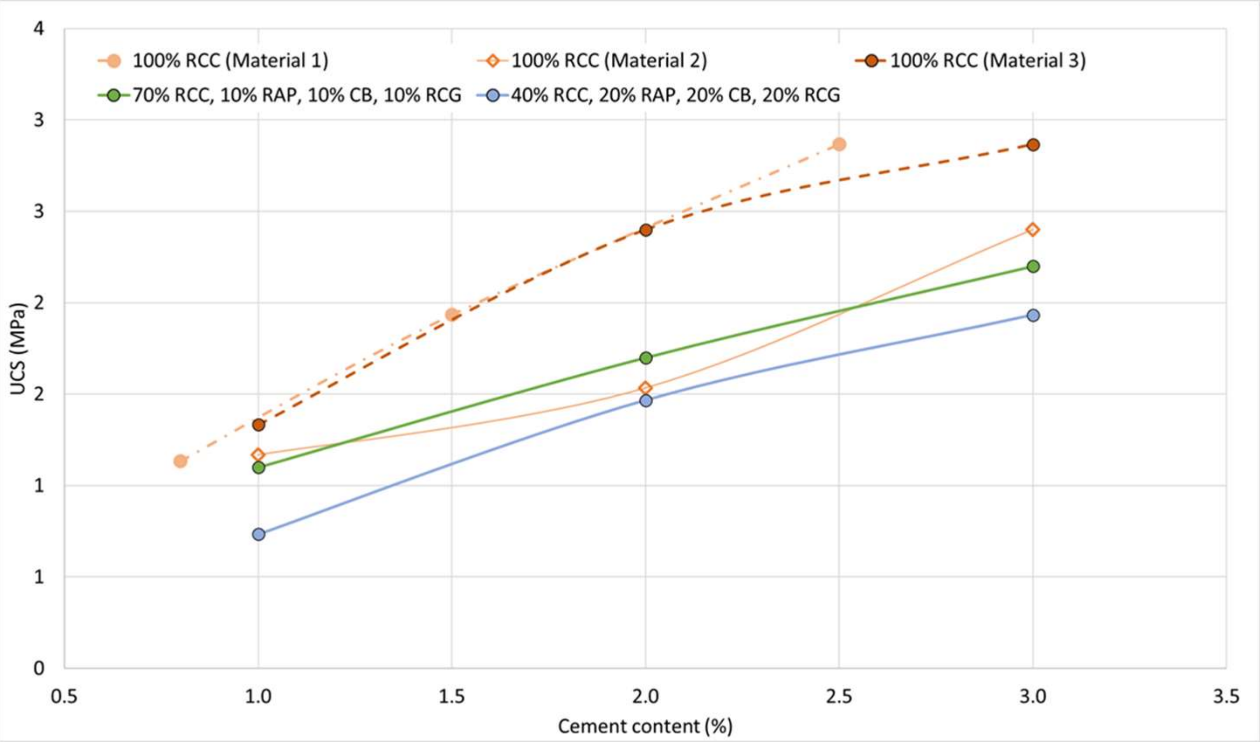
Summary – FBS Recycled Blends

- The FBS recycled blends generally met the ITM mix design requirements for dry and soaked modulus with limited exceptions.
  - Depends on the individual host material gradation and other physical characteristics
  - Individual assessments need to be undertaken

- Replacing RCC proportions with RAP, CB, and RCG in the recycled blends:
  - *Generally improves the ITM values and modulus gain over time.*
    - The fines content and the gradation in general, the compaction properties, and the residual bitumen coating of aggregates seem to be contributing factors.
    - Increasing the sand sized RCG aggregates in the mix could generally result in improved gradation.
    - A better performance in the blends including increased RAP content, possibly due to the contribution of and better bonding of the aged bitumen from RAP

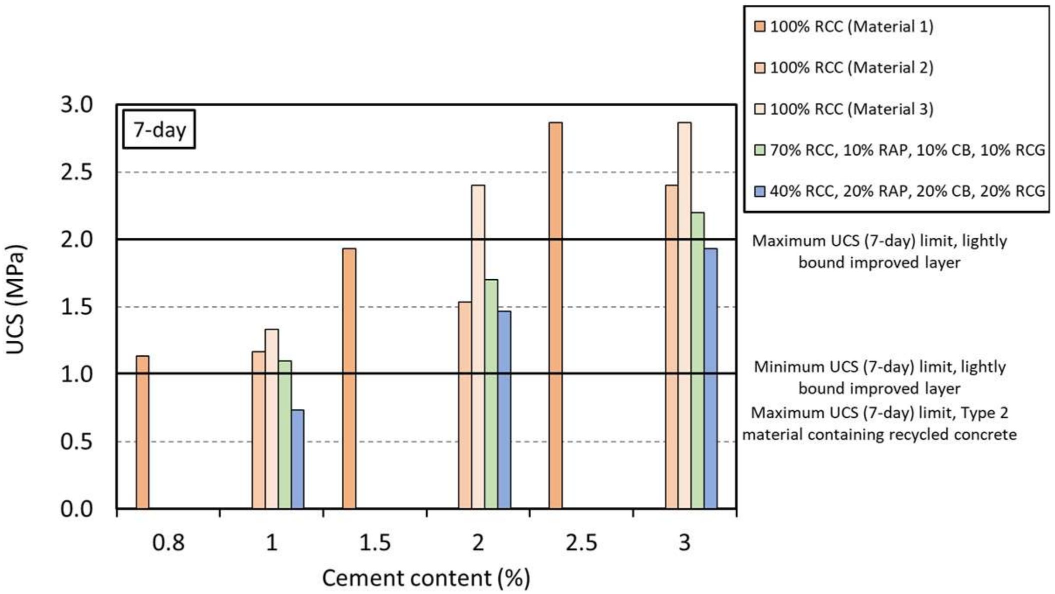
UCS of Cement Stabilised Samples

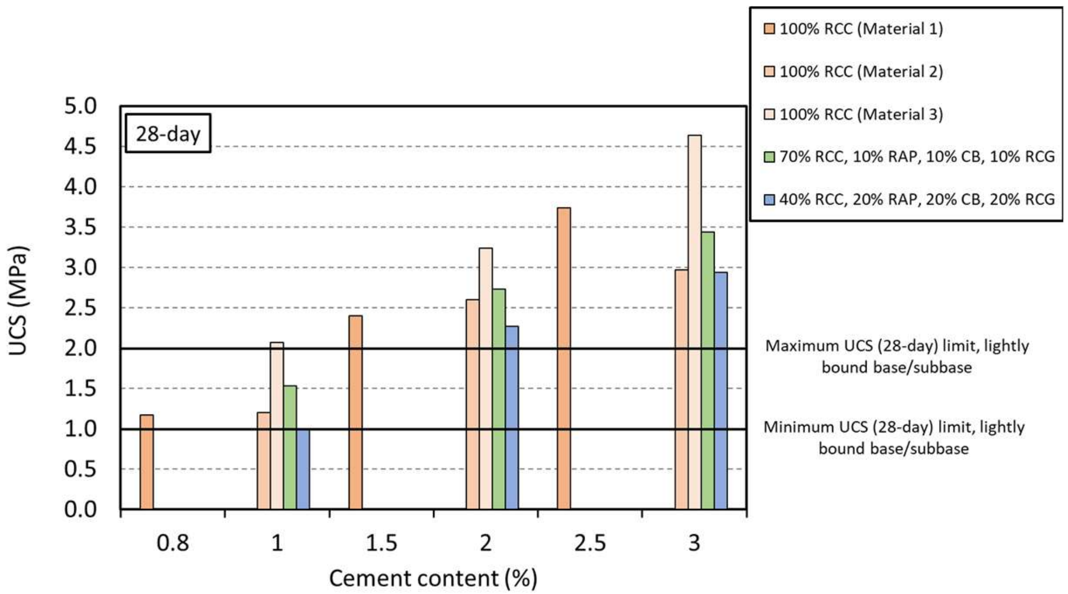
- UCS increases with cementitious content.
- Replacing the RCC with RAP, CB, and RCG in the blends seem to reduce the UCS.
- UCS seem to be influenced by fines content and host materials gradation in general



Parameter	100% RCC (Material 1)	100% RCC (Material 2)	100% RCC (Material 3)	70% RCC, 10% RAP, 10% CB, 10% RCG	40% RCC, 20% RAP, 20% CB, 20% RCG
Cement Content (%)	1	1.2	1.2	1.2	1.2
Allowable working time (h)	11	2	4.5	2.5	2.5

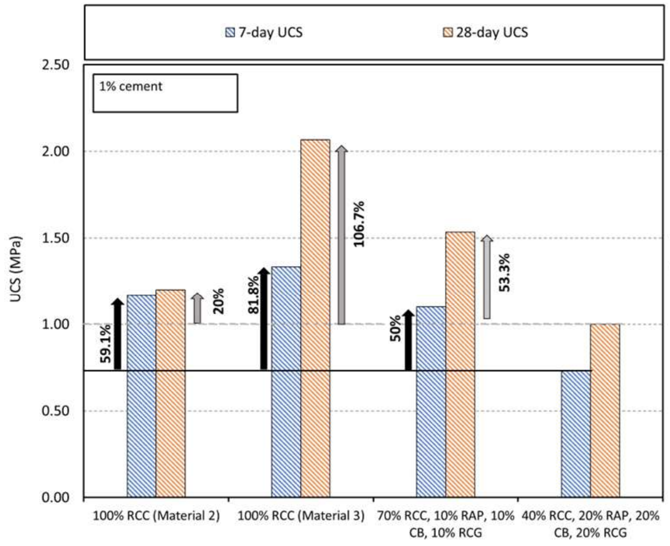
UCS of Cement Stabilised Samples – UCS Requirements

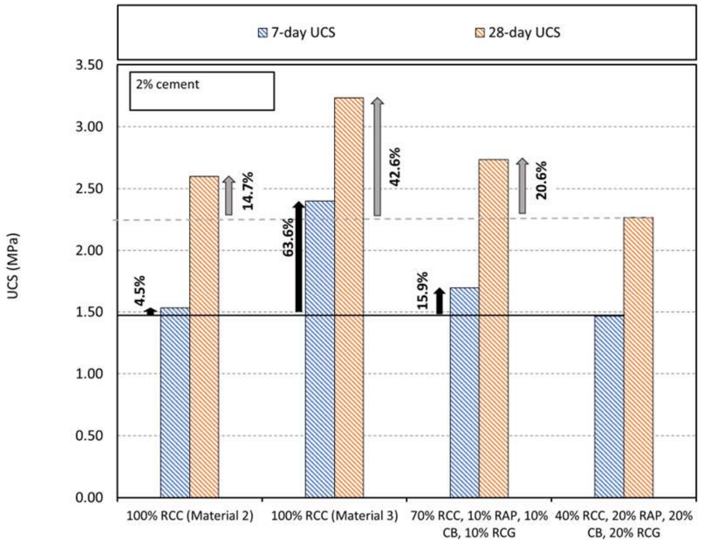


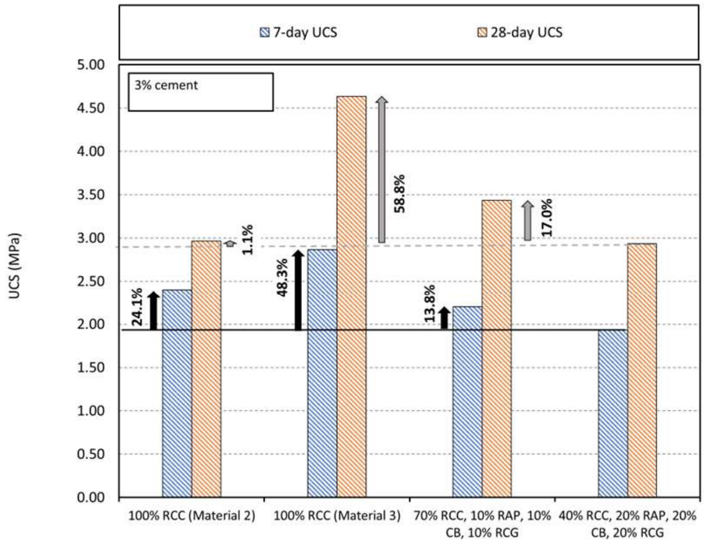


- Generally, materials with >~1% and < 2.5% cementitious compiled with MRTS10 requirements for lightly bound improved layer for 7-day UCS, with some exceptions depending on the blend.
  - 40% RCC blend met 7-day UCS criteria with 3% cementitious.
  - 100% RCC (Mat. 3) exceeded the 7-day UCS criteria with 2% cementitious

UCS of Cement Stabilised Cured Samples







- 28-day/7-day UCS values varied between 1.03 and 1.62 for different stabilised blends, depending on the host materials physical characteristics.
- It seems that there was not a noticeable trend in the strength gain ratios.
- As expected, the UCS of the blends increased with the curing time.

Summary – Cement Stabilisation of Recycled Blends

- Recycled blends can meet specification requirements for lightly bound materials
- UCS increases with cementitious content
- Replacing the RCC with RAP, CB, and RCG in the blends seem to reduce the UCS values.
- 28-day/7-day UCS values varied for different stabilised blends, depending on the host materials gradation and physical characteristics.
- The rate of strength gain varies for different stabilised blend with no specific trend observed.
- The trend in strength gain is dependent on the selection of the specific 100% RCC material to be used as the reference.

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Conclusions and Recommendations

- Suitability of the recycled material blends for stabilisation depends on several factors:
  - Fines content and PSD overall
  - Other physical properties (i.e. PI, LL, LS)
  - Recycled material type and source
  - Type of stabilisation
- Fines content seem to have greater sensitivity on foamed bitumen stabilisation of recycled materials than cementitious stabilisation
  - Lack of fines unable to bond with foamed bitumen.
  - Excess fines difficult to develop strong aggregate skeleton in FBS
  - Materials with similar fines content showed comparable performance
- Stabilised recycled blends generally met the current modulus/strength requirements with some exception, particularly in case when the materials PSD were not meeting the grading requirements
- Mix design is necessary to be undertaken individually for stabilisation of recycled materials
- Foamed bitumen stabilisation and cementitious stabilisation are feasible and viable methods to improve the engineering properties of recycled material blends.
- Further research is required to assess the individual effect of RAP, CB, or RCG on the mechanical performance of the blend.
- Further research is required to improve understanding of the performance of stabilised recycled host material blends using field trials.

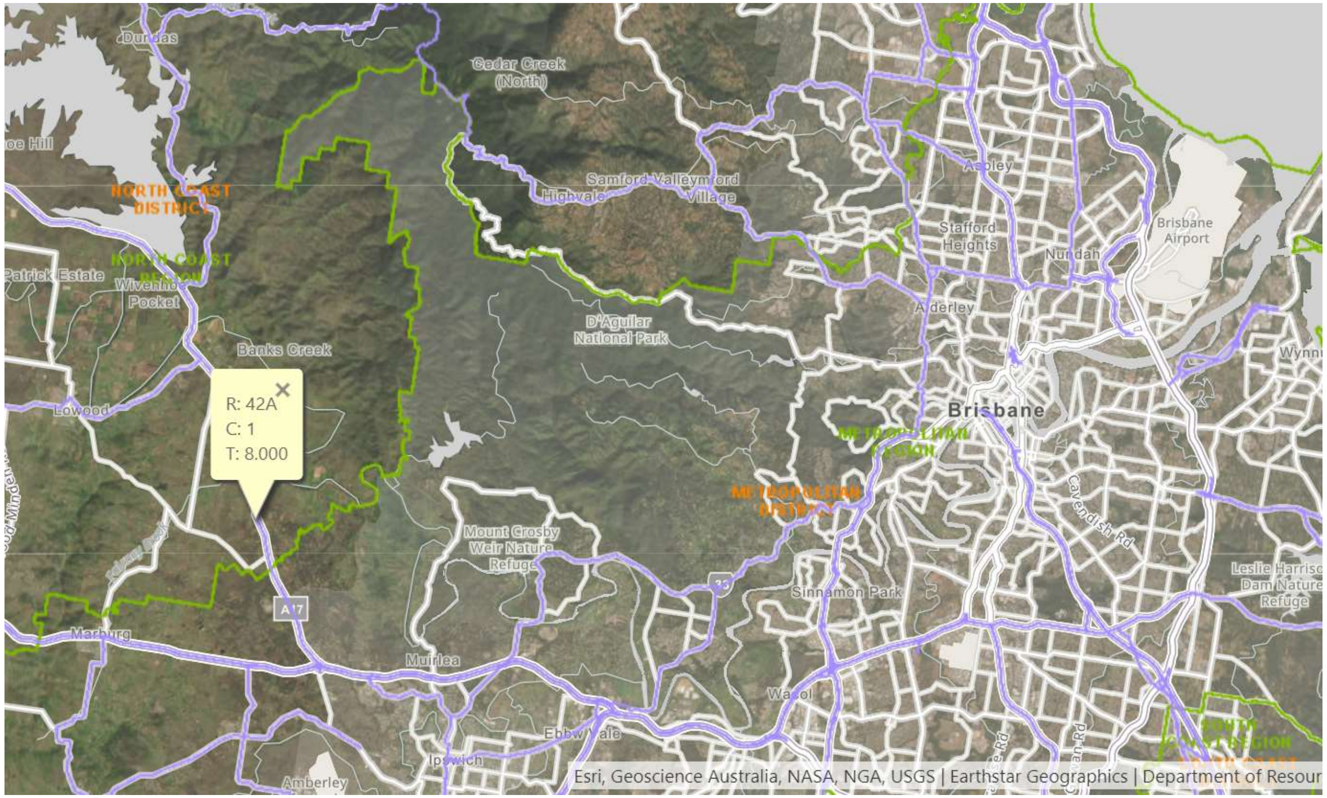
Y3 - O24 Field Trial

- Aims
  - construction process
  - Performance.
- Constraints
  - manage risk to TMR
  - minimise cost impacts
  - overall sustainability goals
  - maximise opportunities.
- 100% RCC lightly bound application
  - commercially produced blend
  - SEQ uses a lot of lightly bound materials
  - cementitious vs bitumen costs.

Material Sampling for TMR O24 Laboratory Testing

O24 Field Trial – Brisbane Valley Highway

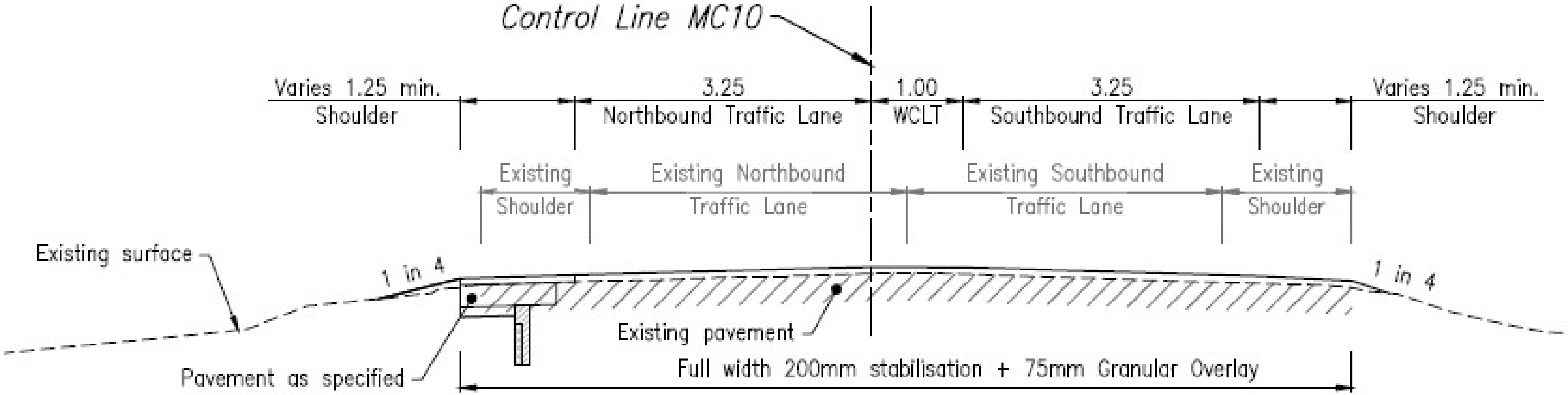
- Partnering across TMR – E&T, North Coast District and RoadTek.
- Brisbane Valley Highway - Between Ipswich and Wivenhoe Dam.
- Moderately loaded:
  - *AADT* - 4350
  - 15% heavy vehicles.



Project Location (TMR iMaps)

O24 Field Trial – Works Scope

- Insitu stabilisation.
- 1-2 lots of base as 100% RCC Type 2.1 full depth.
- Need to confirm support conditions and inundation risk.



TMR Project Drawing Type Cross Section

O24 Field Trial – Research Scope

- Mix Design testing.
- Confirm support conditions.
- Construction monitoring and support.
- Monitoring
  - visual
  - asset condition data.

Washed Sample Fractions (TMR)

Y3 - 024 Field Trials and the W2R Strategy

TMR prefers the use of recycled materials

- **Permitted**
- **Cost competitive**
- **Available**

Not mandated