Renolith

Resilient, Sustainable,
Nanoengineered Roads

Design Guide - Simplified

PEOPLE

No ruts. No potholes.
Durable for decades.

PLANET

100% recycled roads.
Low carbon. No waste.

PROFIT

Rapid, low-cost
construction.

Executive Summary

Stabilisation is the improvement of a soil or pavement material usually through the addition of a binder. In-situ recycling of pavement material via stabilisation with low-carbon cementitious binders is a highly sustainable and cost-effective approach to the construction of road pavement base layers.

Renolith 2.0 is a nanopolymer admixture. Its super-pozzolanic behaviour significantly improves the engineering properties of cementitiously bound materials and reduces the risk of shrinkage cracking. It enables a resilient pavement base layer to be constructed from any inorganic soil or recycled material. The technology has been proven in more than 70,000,000m2 of pothole-free roads around the world.

Pavements are designed and constructed using standard stabilisation (cold recycling) methods. Refer to AustStab and Austroads for best practice guidance, or applicable state/local government technical specifications where relevant. In most cases, a 200mm Renolith-enhanced bound layer with spray seal wearing course is an economical approach to producing a resilient road with high fatigue life.

Renolith 2.0 admixture is applied during the wet-mix phase of the cementitious stabilisation process. The recommended dosage is 5% w/w cementitious binder. GP, GB or slag/cement binders are preferred.

CONTENTS

1. Introduction

Context

Stabilisation is the improvement of a soil or pavement material usually through the addition of a binder. The most common methods of stabilisation involve the incorporation of small quantities of binders. These binders include cement (Portland, Blended Cements and Cementitious blends with slag and/or fly ash); lime; bitumen and miscellaneous chemicals. In-situ stabilisation techniques have long been used by engineers in Australia and many places throughout the world for pavement (usually roads) construction and rehabilitation. These techniques have historically been chosen by managers of pavements because of their significant cost advantages [1]. The economic and sustainability benefits of in-situ recycling and stabilisation are compelling. Nonetheless, more expensive and environmentally destructive pavement construction methods are still commonplace. The underutilisation of stabilisation is partly attributable to the performance limitations of stabilised materials. In short, some soils make poor pavements and cracking is always hard to prevent, particularly at high binder content.

Renolith 2.0 is a nanopolymer admixture. Its super-pozzolanic behaviour significantly improves the engineering properties of cementitiously bound materials; notably concrete and bound pavement layers. It enables a simple, versatile and proven approach to pavement nanoengineering. It enables durable pavements to be constructed from any in-situ soil or recycled material. It ensures a greatly reduced susceptibility to shrinkage cracking, which allows higher binder content and strength than is otherwise possible. The technology has been proven in more than 70,000,000m^2 of pothole-free roads around the world.

Purpose

This document is a simplified guide intended to:

- Provide guidance on mix design, pavement thickness and construction process.
- Support pavement design.

This simplified guide covers only the most common applications. Refer to the full Renolith 2.0 Design Guide for more comprehensive guidance.

2. Renolith 2.0 Product

Purpose: Admixture for cementitious binders, typically used pavement stabilisation applications.

Chemistry: Colloidal suspension comprising a latex emulsion and stable colloidal dispersion of nanosilica and nanocellulose

Supply: 1000L IBCs and 5L containers.

3. Construction Guidance

Construction Process

Renolith 2.0 pavements are constructed using standard soil stabilization (cold recycling) methods. Refer to AustStab [2] and Austroads [3] for best practice guidance. Refer to regional technical specifications if applicable (eg. WA [4], NSW [5], QLD [6], VIC[1]) or AustStab Model Specification [7]. QLD TMR Specification MRTS07B [6] provides a comprehensive process for cementitious stabilisation of insitu materials which may be suitable for adaptation if no extant specification is applicable.

The figure below shows the key activities: spread binder, dry mix, wet mix (water+admixture), trim, compaction. See Table 3: Plant and equipment for further details.

Figure 1 Renolith 2.0 Pavement Continuous Construction Process

Pavement design

Depth Quick Estimator

Pavement thickness is project specific; refer to Austroads guidance [8] & [9]. The AustStab *Pavement design guide for a cement stabilised base layer for light traffic* [10] provides the design thickness of stabilised local roads using an empirical approach, based on experience from a range of local government practices in Australia. Renolith improves the tensile strength and elastic modulus of bound materials, thereby reducing pavement deflection and fatigue damage incurred. This means that the AustStab guide [10] will yield highly conservative designs. For most roads, a 200mm Renolith-enhanced bound layer with spray seal wearing course is an economical solution. If the subgrade is very poor or higher fatigue life is required, pavement thickness and/or binder content can be increased. For high load (eg. mine haul) or

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[1] Victorian Department of Transport (previously VicRoads) Codes of practice, Technical bulletins & reports, Technical notes and Test Methods https://www.vicroads.vic.gov.au/business-and-industry/technical-publications/pavements-geotechnical-and-materials

high fatigue (eg. freeway) applications, a thicker layer may be required. For low load applications (eg. cycleway), a 120mm layer may suffice.

Mix Design

Renolith 2.0 dose = 5% of binder

Renolith 2.0 is applied at 5% of the mass of cementitious binder to achieve optimum flexibility, tensile & flexural strength, (im)permeability and freeze/thaw resistance.

Binder ratio

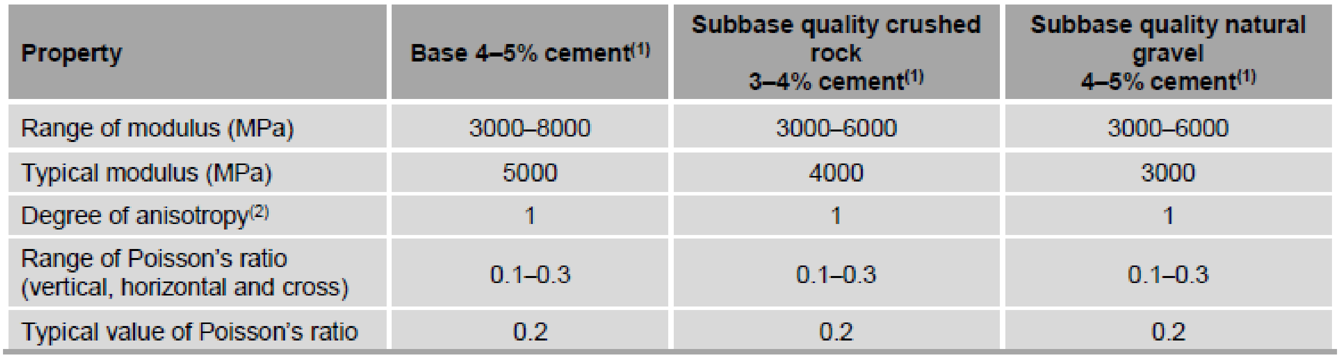
Cementitious binder ratio depends on the soil/aggregate type and desired strength. The addition of Renolith 2.0 admixture will increase the compressive strength, flexural strength, elastic modulus and fatigue life whilst reducing permeability and shrinkage effects.

Option 1: Lightly bound+

To mitigate the effects of shrinkage cracking, many stabilisation projects, such as rehabilitation of local government roads, specify a low quantity of binder (typically 2-3%) to achieve a lightly-bound (UCS 1-2MPa) material. With Renolith 2.0 admixture, the UCS will typically increase by 40%-80% and may become bound. Shrinkage cracking risks are reduced.

Option 2: Heavily bound

Austroads AGPT02-17 [8] Table 6-7 (copy below) details the presumptive values for elastic characterisation of cemented granular materials.



Property	Base 4–5% cement(1)	Subbase quality crushed rock 3–4% cement(1)	Subbase quality natural gravel 4–5% cement(1)
Range of modulus (MPa)	3000–8000	3000–6000	3000–6000
Typical modulus (MPa)	5000	4000	3000
Degree of anisotropy(2)	1	1	1
Range of Poisson's ratio (vertical, horizontal and cross)	0.1–0.3	0.1–0.3	0.1–0.3
Typical value of Poisson's ratio	0.2	0.2	0.2

For materials not covered above, a high-performing heavily bound material (typical 28d UCS 3-15MPa) may be achieved using the mix ratios per Table 1. Problematic shrinkage cracking is unlikely when mixed thoroughly with Renolith 2.0 admixture at the recommended dose.

See *AustStab TN5* [2] and *Austroads AGPT04D-19* [3] for further guidance.

Table 1: Recommended Mix Design for Various Soil Types

AASHTO soil classification	ASTM soil classification	Binder - as % of aggregate weight		AS2870-2011 Site class
	typical	Min	Max	typical
A-1-a / cold recycling	GW, GP, GM, SW, SP, SM	3%	8%	A
A-1-b	GM, GP, SM, SP	5%	9%	A
A-2	GM, GC, SM, SC	5%	10%	A-S
A-3	SP	7%	11%	A
A-4	CL, ML	7%	12%	S-M
A-5	ML, MH, CH	10%	14%	S-H1
A-6	CL, CH	10%	15%	M-H2
A-7	MH, CH	10%	16%	M-E
Organic	OH, OL, PT	20%	*20+%	E-P

Notes:

- Table 1 mix design is adapted from laboratory testing of samples compacted in a mould (per AASHTO T180), 7 days curing, 2 hours soak in water, then Unconfined Compressive Strength (UCS) test (per AASHTO T208) exceeding 1.7MPa[2].
- UCS values achieved with cement plus Renolith 2.0 is higher (typically approx. 50-80% higher) than those achieved with cement-only stabilisation.
- The binder application rate range shown in Table 1 assumes ordinary Portland cement (OPC). Binder application rates for slow and medium setting binder blends are likely to be similar, but check with the binder supplier to confirm comparable performance/strength.
- Highly organic soils are theoretically possible to use in pavement layers but are generally not viable or not permitted.

Cement/Binder type

AustStab recommends that cement used for stabilisation should ideally conform to *AS 3972, 'Portland and Blended Cements' or NZS 3122 Specification for Portland and blended cements (general and special purpose)* [2]. Alternate cementitious blends will usually be viable (see *Austroads AGPT4L-09* [11]); slag[3]/cement blends are preferred[4] per Table 2.

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[2] *Austroads AGPT04D-19* [4] characterises the behaviour of lightly-bound cemented materials (1MPa < UCS < 2MPa, <3% binder) and bound cemented materials (UCS > 2MPa, >3% binder), with values determined from test specimens stabilised with General Purpose (GP) cement and prepared using 100% standard Proctor compactive effort at 100% standard optimum moisture content, normal curing for a minimum 28 days in moist condition without soaking in water. 7 day soaked UCS values are much lower than 28 day unsoaked UCS values. Renolith pavements using the recommended mix will behave like bound material, except with significantly reduced susceptibility to shrinkage cracking and premature fatigue cracking.

[3] Ground-granulated blast-furnace slag (GGBFS or GGBS or slag)

[4] Most empirical and experimental data for Renolith 2.0 mixes used Portland cement as the binder. GGBS chemical composition is quite similar to OPC, so its behaviour in a mix with Renolith 2.0 is more predictable.

Table 2: Recommended binders for use with Renolith 2.0 admixture

Binder type per Austroads	GP	GB	SSC50	SSC30	Stabilment
Approx EN 206 / BS 8500 equivalent	CEM I	CEM II	CEM III/A	CEM III/B	NA
Approx Composition	>95% OPC	<10% MS, >5% GGBS or FA	50% GGBS / 50% OPC	70% GGBS / 30% OPC	85% GGBS / 15% lime
Binder setting	Fast	Fast	Medium	Slow	Very Slow
Strength 0-3d	Fair	Fair	Low	Very low	Very low
Strength 7d	Good	Good	Fair	Fair	Fair
Strength 28d	Good	Good	Very good	Very good	Good
Strength 180d	Very good	Very good	Best	Excellent	Excellent
Typical binder embodied CO_2e (kg CO_2 / Tonne)	860	700	500	300	200
Key advantages	Early strength, cold curing conditions	Early strength, widely available	Best long term strength	Low carbon, high strength	Lowest carbon

Notes:

- Historically, General Purpose (GP) Portland cement Type I (per ASTM C150) has been most often used. General Purpose Blended Cements (GB) are suitable and may offer some advantages; see *Austroads AGPT4L-09* Section 4 [11].
- In general, binder blends with reduced cement content cure more slowly, have slower strength onset and are less susceptible to shrinkage cracking than GP cement [12]. With Renolith 2.0 admixture:
  - cure time is reduced
  - strength onset is earlier
  - shrinkage cracking risks are further reduced
- See also applicable regional specifications[5] for guidance on suitable binders.

Design Tips

The following tips are suggested for achieving an optimal balance of whole-of-life costs, carbon footprint, durability, and pavement life:

- Use a lower carbon binder where practical
  - Blended cements consisting of GP cement, slag and fly ash have been used successfully in Australia since the 1990s. [1] These lower carbon binder blends can cut greenhouse gas emissions from construction considerably. Binders with less Portland cement tend to set slower, have reduced susceptibility to reflective cracking and [eventually] achieve comparable strengths. Renolith is generally more effective with slag blends than fly ash blends.

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[5] e.g. Victorian Department of Transport and Planning Standard Section 307 Insitu Stabilisation of Pavements with Cementitious Binders https://webapps.vicroads.vic.gov.au/VRNE/csdspeci.nsf/

    - The embodied carbon footprint of various blends can be estimated and compared using Austroads AGPT04-07 [13] data or a calculator such as: https://circularecology.com/concrete-embodied-carbon-footprint-calculator.html
    - Remember to consider the lifecycle emissions impact of mix design choices. A high strength pavement will typically have lower embodied carbon over the long term than a low strength (shorter life) mix.
- For fine soils (silts, clays), consider supplementing the mix with aggregates (ie. granular stabilisation)
    - Fine poorly graded soils require much more binder (and Renolith 2.0) than coarse well graded soils, which means higher costs and carbon footprint. Aggregates can improve the soil grade and significantly reduce binder demand.
    - Site-won aggregates are typically the lowest cost and lowest carbon option. Recycled materials such as low grade recycled concrete aggregate (RCA) often work well.
    - Regional specifications may require fine, poorly graded and high plasticity soils to be improved for use in certain stabilisation applications (e.g. [12])
    - Refer to Austroads AGPT04D-19 [3] for guidance.
- In light traffic applications, critically assess whether a separate surface seal and wearing course is required
    - Renolith 2.0 admixture reduces permeability by two orders of magnitude compared to cement-only stabilisation. A surface seal may be redundant for water resistance.
    - Coarse grained soils often provide adequate wear and skid resistance.
    - For fine grained soils
        - One pass construction: gravel or RCA can be embedded into the upper surface of the pavement during compaction to improve wear and skid resistance.
        - Two pass construction: use fine grained soil for the sub-base and a combined base layer / wearing course constructed from gravel or RCA.
    - Higher binder content may be required to reduce erosion. If so, a spray seal and aggregate wearing course may be more cost effective than increasing binder content.
    - Consider deferring a decision on application of a spray seal unless this is impractical (eg. safety, performance, dust, construction efficiency).
    - Where a separate surface seal and wearing course is required, consider more sustainable options such as a spray seal with crumb rubber from recycled tyres.

Water

From an earthworks perspective, a paving water content near OMC[6] is best. For Renolith 2.0 and cementitious binder hydration, a higher water content is preferred. In practice, a paving water content on the wet side of the Proctor curve at around 98% of the maximum dry density has been found to be a good compromise.

Field QC (heuristic): if you press the ready mix in the hand, it should form a cohesive ball. If it crumbles, add more water. If it sticks to the hand or moisture oozes out, use less water.

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[6] The Optimum moisture content (OMC) is the moisture content at which the soil attains maximum dry density. This OMC value is with respect to the specific amount of compaction energy applied to the soil.

Renolith 2.0 admixture reduces evaporation losses. However, if high evaporation takes place in the field, add more water to prevent the pavement drying out during curing.

Constraints

Many regional standards and specifications impose constraints on soil stabilisation. Constraints may apply many aspects of the design, such as the application/layer (eg. base, subbase, subgrade), maximum binder content, binder set times, soil grade, maximum soil plasticity etc. These constraints exist to reduce the likelihood of failure (eg. cracking). The performance improvements achieved with the use of Renolith 2.0 admixture typically make these constraints technically redundant. Nonetheless, constraints imposed by any relevant specifications take precedence over information in this guide unless appropriate waivers/approvals have been obtained.

Example mix design

In-situ aggregate maximum dry density (MDD) = 2000kg/m^3
Pavement layer thickness = 200mm
Cementitious binder application rate = 3%

- Binder spread rate = 2000kg/m^3 * 3% * 0.20m = 12kg/m^2
- Renolith 2.0 spread rate (@5% w/w binder) = 12kg * 5% = 0.6kg/m^2

Laboratory tests

The AustStab Pavement Recycling and Stabilisation Guide [14], NZ Transport Agency Best practice guide for pavement stabilisation [15] and AustRoads Guide to Pavement Technology Part 4D: Stabilised Materials [3] provide guidance on mix design and laboratory testing. AustStab Pavement Recycling and Stabilisation Guide [14] table 3.3 and Austroads AGPT04D-19 [3] table 8.1 list appropriate laboratory test methods for stabilised materials.

Labour and Equipment

The recommended equipment for pavement construction is summarised in Table 3 below, adapted from QLD TMR MRTS07B [6]. Actual equipment requirements may vary depending on project specifics and regional specifications.
Minimum labour estimates should be based on 1 operator for each of the major plant items and 1 supervisor or engineer (8 personnel for the recommended equipment).

Table 3: Plant and equipment

Major plant	Description
Reclaimer / stabiliser or Integrated spreader / reclaimer / stabiliser	Optimal Modern self-propelled machine with computerised liquid injection and the ability to mix to the design depth in a single pass (eg. Wirtgen, Bomag). Suggested specification a) Minimum power capacity of 155 kW/m of the drum width. b) Capable of mixing to the specified depth. c) Capable of supplying water such that incorporation rates can be varied across the full width of the stabilising box and incrementally across the box. d) Calibrated and capable of uniformly spreading stabilising agent to varying widths (if integrated spreader / reclaimer / stabiliser).
Cement spreader	Bulk cement spreader truck with flow control Eg. Calibrated with load cells and capable of uniformly spreading stabilising agent using a fixed bulk bin feeding a mechanical or hydraulic driven spreading rotor to varying widths. 15+ tonne recommended.
Water tankers	Two 6000L+ water trucks with spray bars and stabiliser coupling (one for water and one for Renolith 2.0 emulsion).
Grader	Caterpillar 140M or equivalent
Vibrating pad foot roller[7]	For layer thickness up to 200 mm: not required For layer thickness 200 - 300 mm: 21 tonnes
Vibrating smooth drum roller	12+ tonne, ideally with Intelligent Compaction (IC)
Multi-tyre roller	Minimum 12 tonnes
Miscellaneous equipment	
Forklift or mobile crane	For IBC/pallet and cement handling
Pump	For liquid transfers
Piping and connectors	To connect water tanker(s), stabiliser, and liquid storage

The recommended equipment in Table 3 is optimised for achieving a superior pavement quality at a high daily construction rate via in-situ stabilisation. Plant substitutions are possible, provided that accurate dosing, thorough mixing and full compaction is achieved. Mixing via mobile mixing plant has been specified and used successfully in the past; see [16]. See also Austroads [2] for further guidance.

See https://renolith.com.au/news-media/ for budget plant options.

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[7] The latex in Renolith admixture reduces friction and compaction effort. Padfoot compaction is unlikely to be required for 200mm layers unless mandated by the applicable specification.

4. Important Notice

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[12] VicRoads, *Specification - Section 307 - In situ stabilisation of pavements with cementitious binders,* Melbourne: Victorian Department of Transport and Planning, 2023.

[13] Austroads AGPT04-07, “AGPT04-07, Guide to Pavement Technology Part 4: Pavement Materials, Ed1.1,” Austroads Ltd, Sydney NSW, 2007.

[14] AustStab, Pavement Recycling and Stabilisation Guide, Cherrbrook NSW: AustStab, 2015 2nd Ed.

[15] W. Gray, “Best practice guide for pavement stabilisation,” NZ Transport Agency, Wellington, 2017.

[16] Rus-Rezotek, *GOST Standard 81329147-012-2008 Arrangement of bases strengthened with polymer cement mixture with polymer additive NTS,* Tyumen, 2008.

6. Table of Figures

7. Document control

Change History

Date	Version	Notes / changes
Oct 23	1.0	Key details summarised from Renolith 2.0 Design Guide v3.0.

Distribution

Available on request