A Simplified Approach to the Selection of Pavement Structures Containing Stabilised Materials

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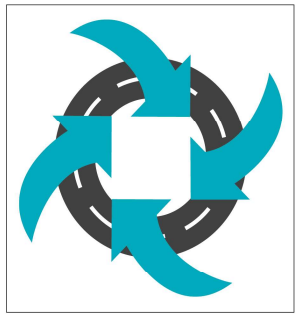
Apexx Engineering Consultants



AustStab
Pavement Recycling and Stabilisation Association

Presentation Structure

- Introduction and Project Background
- Research Project Overview
- Stabilisation 101
- Industry Survey
- Development of a Selection Framework
  - Graphical Flowchart
  - Pavement Type Cross Sections
- Worked Example
- Recommendations for Future Work
- Summary

Introduction and Project Background

"Can the use of stabilised material in pavement structures be categorized into a holistic pavement selection framework for use in the Australian context?"

- Research project was undertaken in fulfilment of a research thesis for a Masters of Pavement Technology via the Centre for Pavement Engineering Education (CPEE).
- Project topic from within the AustStab framework of existing research and development projects not requiring external funding.
- Benefits to the road pavement industry:
  - Pavement stabilisation will continue to increase in popularity as road asset owners seek more economical ways of maintaining networks.
  - Circular economy an increasing driver – less quarried material, more beneficial reuse.
  - Traffic volumes continuing to increase – mitigating impacts to road users a significant benefit of stabilising.

Centre for Pavement Engineering Education

Research Project Overview

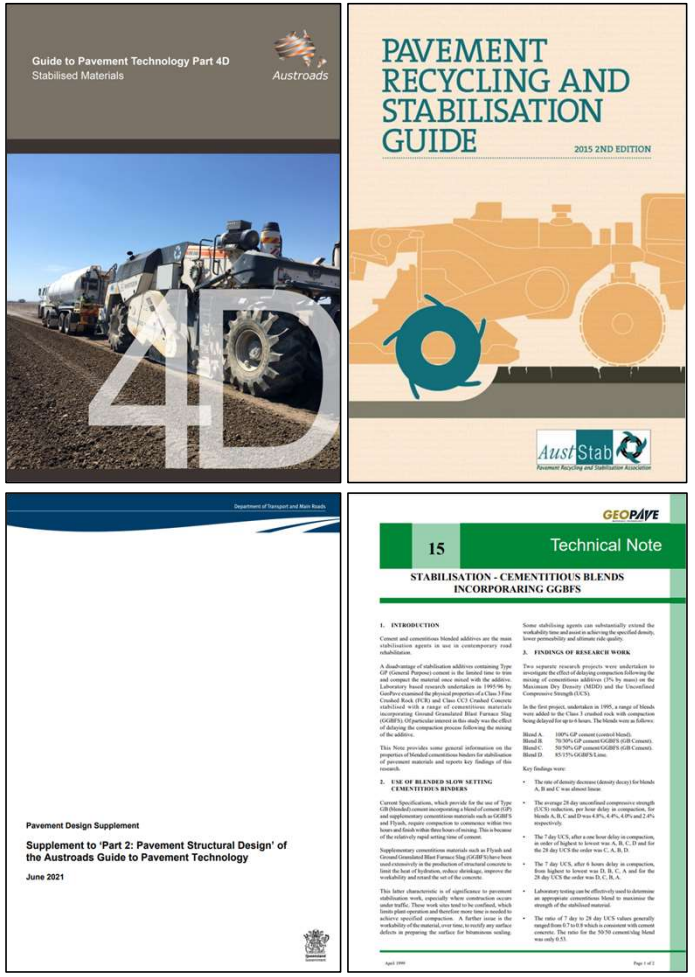
1. Background Information – ‘Stabilisation 101’
2. Literature Review
3. Industry Survey
4. Review of Current Selection Process
5. Development of a Streamlined Selection Framework

Stabilisation 101

Stabilisation: *'A process by which the intrinsic properties of pavement materials or earthworks materials are altered by the addition of a stabilisation binder or granular material to meet performance expectations in its operating, geological and climatic environment'* (Austroads 2019b, p. 1).

Stabilisation 101

- Common pavement rehabilitation techniques include reconstruction and overlay – generally not cost-effective.
- Stabilisation offers a cost-effective solution to rehabilitating pavements whilst reusing as much of the original material as possible.
- Austroads is the governing technical publication used in Australia for pavement design.
- Many SRAs/LGAs have their own technical guidelines or supplements.
- Australian literature is some of the most comprehensive and detailed in the world.



STABILISATION 101

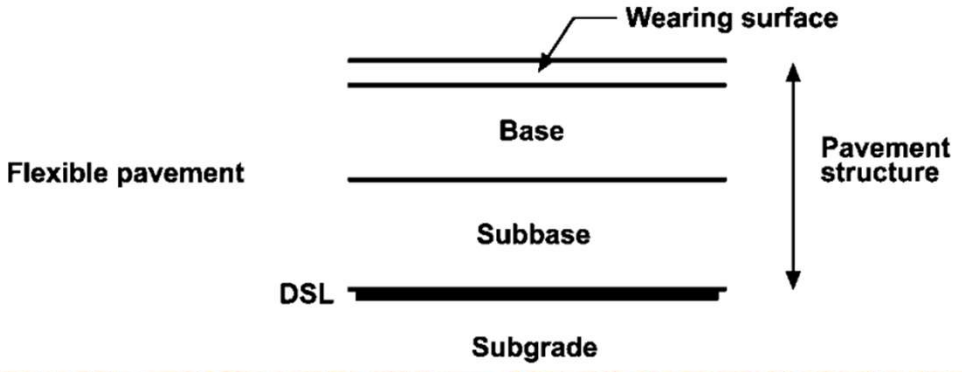
PAVEMENT LAYERS

- Subgrade
- Subbase
- Base

- Typical flexible pavement = subbase and base, overlying a natural subgrade.
- Some rural/low volume roads may simply have a base course overlying a natural subgrade.

- Subbase + Subgrade
- Base + Subgrade

Figure 1.1: Components of flexible and rigid road pavement structures



AGPT02-17 Figure 1.1 – Components of flexible road pavement structures (Austroads 2019b)

STABILISATION 101

STABILISATION CATEGORIES

- Subgrade Stabilisation
- Granular Stabilisation
- Modified Stabilisation (UCS ≤ 1 MPa)
- Lightly-Bound Stabilisation (1 ≤ UCS ≤ 2 MPa)
- Bound Stabilisation (UCS > 2 MPa)

Table 2.1: Stabilisation categories and characteristics

Category of stabilisation	Indicative laboratory strength after stabilisation	Binders adopted	Anticipated performance attributes[5, 4]
Subgrade and formation treatments			
Stabilised earthworks materials	1 < UCS[2,3] ≤ 2 MPa or CBR[1]	• Lime and/or cementitious binder (high plasticity soils) • Cement and/or cementitious binder (low plasticity soils)	• Improved constructability • Improved subgrade CBR and modulus • Improved shear strength • Reduced heave and shrinkage
Pavement material treatments			
Granular stabilisation	CBR[1] > 30%	• Blending other granular materials which are classified as binders in the context of this Part	• Improved pavement modulus • Improved shear strength • Improved resistance to aggregate breakdown
Modified materials	UCS[2] < 1 MPa	• Addition of small quantities of cement or cementitious binder • Addition of lime • Addition of chemical binder	• Improved long-term rut-resistance • Improved pavement layer modulus after curing • After curing, reduced sensitivity to loss of strength due to increasing moisture content • Similar to unbound granular materials, moisture content prior to sealing needs to be limited to inhibit premature distress • At low binder contents can be subject to erosion where cracking is present
Lightly-bound cemented materials	1 ≤ UCS[3] ≤ 2 MPa	• Addition of small quantities of cementitious binder, commonly less than 3% binder	• Greater rut-resistance than modified materials • May be susceptible to fatigue cracking but cracking finer than bound materials • At low binder contents can be subject to erosion where cracking is present
Bound cemented materials	UCS[4] > 2 MPa and/or flexural modulus and flexural strength	• Addition of greater quantities of cementitious binder, commonly binder content of 3% or more	• Increased pavement modulus • Thickness design needs to consider susceptibility to fatigue cracking • Some binders introduce transverse shrinkage cracking

AGPT04D-19 Table 2.1 – Stabilisation categories and characteristics (Austroads 2019)

Stabilisation 101

Stabilising Binders

- Granular/Mechanical
- Lime
- Cement/Cementitious Blends
- Bituminous
- Chemical/Other

- Helpful chart in Austroads 4D – but reliant on a designer already knowing what they want/need to achieve.

Table 2.4: Preliminary selection of binder/additive type

Particle size	More than 25% passing 75 µm sieve			Less than 25% passing 75 µm sieve		
Plasticity index (PI)	PI ≤ 10	10 < PI < 20	PI ≥ 20	PI ≤ 6 & PI x %passing 75 µm ≤ 60	PI ≤ 10	PI > 10
Binder type						
Cement and cementitious blends[1,3]	Usually suitable	Doubtful	Usually not suitable	Usually suitable	Usually suitable	Usually suitable
Lime	Doubtful	Usually suitable	Usually suitable	Usually not suitable	Doubtful	Usually suitable
Bitumen	Doubtful	Doubtful	Usually not suitable	Usually suitable	Usually suitable	Usually not suitable
Bitumen/ lime blends	Usually suitable	Doubtful	Usually not suitable	Usually suitable	Usually suitable	Doubtful
Granular	Usually suitable	Usually not suitable	Usually not suitable	Usually suitable	Usually suitable	Doubtful
Dry powder polymers	Usually suitable	Usually suitable	Usually unsuitable	Usually suitable	Usually suitable	Usually not suitable
Other proprietary chemical products[2]	Usually not suitable	Usually suitable	Usually suitable	Usually not suitable	Doubtful	Usually suitable

1. *The use of some chemical binders as a supplementary addition can extend the effectiveness of cementitious binders in finer soils and soils with higher plasticity.*
2. *Should be taken as a broad guideline only. Refer to trade literature for further information.*
3. *TMR uses triple blend and have a method based on % passing 0.425 mm sieve and linear shrinkage (Volker & Hill 2016).*

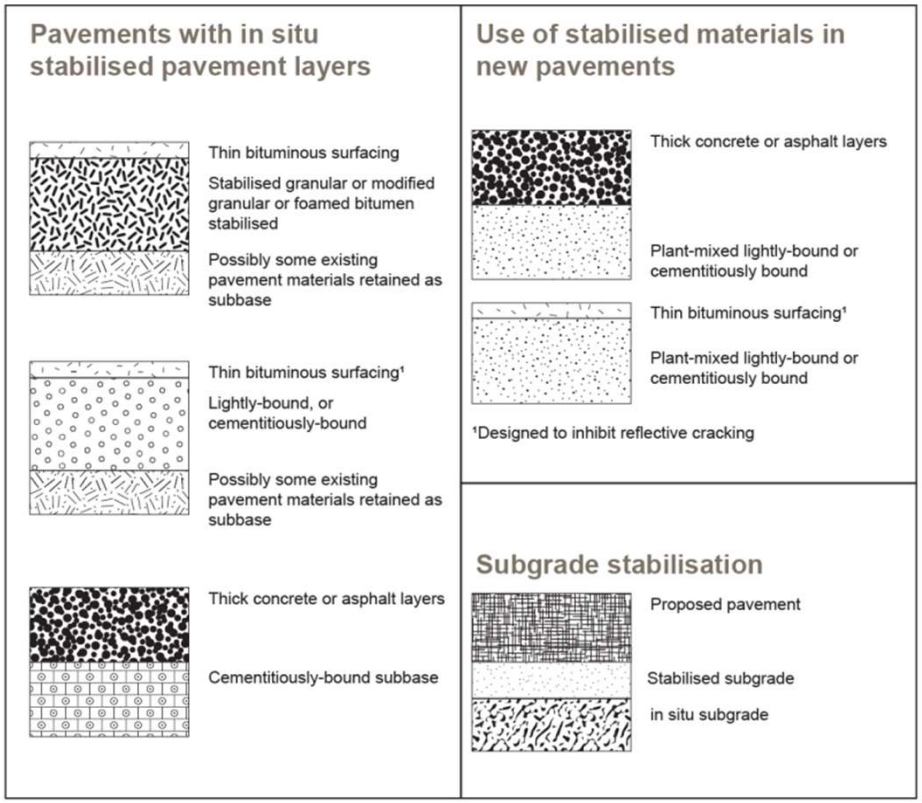
AGPT04D-19 Table 2.4 – Preliminary selection of binder/additive type (Austroads 2019b))

Stabilisation 101

Stabilised Pavement Structures

- Limited type cross sections specified in Austroads.
- Doesn't specify WHY a pavement designer should select a specific treatment.
- Confusion or limited available options often leads to undesirable pavements selected in the concept phase (such as reconstruction or overlay).

Figure 2.2: Typical pavement configurations incorporating stabilised materials



AGPT04D-19 Figure 2.2 – Typical pavement configurations incorporating stabilised materials (Austroads 2019)

Industry Survey

- A paper titled '*Survey results on stabilisation methods and performance of local government roads in Australia'* was published by Chakrabarti, Kodikara and Pardo in 2001.
- This paper surveyed LGAs in QLD, NSW, VIC and SA – being 'the main states using stabilisation'.
- 455 invitations, 162 responses – response rate of 36%.
- Anecdotal evidence and author experience indicated there was general doubt when specifying stabilised pavement materials, leading to poor outcomes.
- The 2001 survey was 'refreshed' in 2022 to understand current selection processes.
- The 2022 survey confirmed that selection processes varied significantly:
  - 'Pavement Experts' undertaking detailed design using Austroads specification supplemented with industry publications.
  - 'General Practitioners' adopting historical designs or relying on local knowledge, often resulting in suboptimal outcomes.

SurveyMonkey

SO WHICH ONE SHOULD I CHOOSE?

Development of a Selection Framework

- When considering the use of stabilisation in either rehabilitation or new pavements, the following analytical process is required:

1. Which pavement layer is deficient and requires treatment or strengthening?
2. If that layer is going to be stabilised, what is the desired outcome for that layer in terms of strength/stiffness/performance characteristics?
3. What is the most suitable binder to use to stabilise that layer?

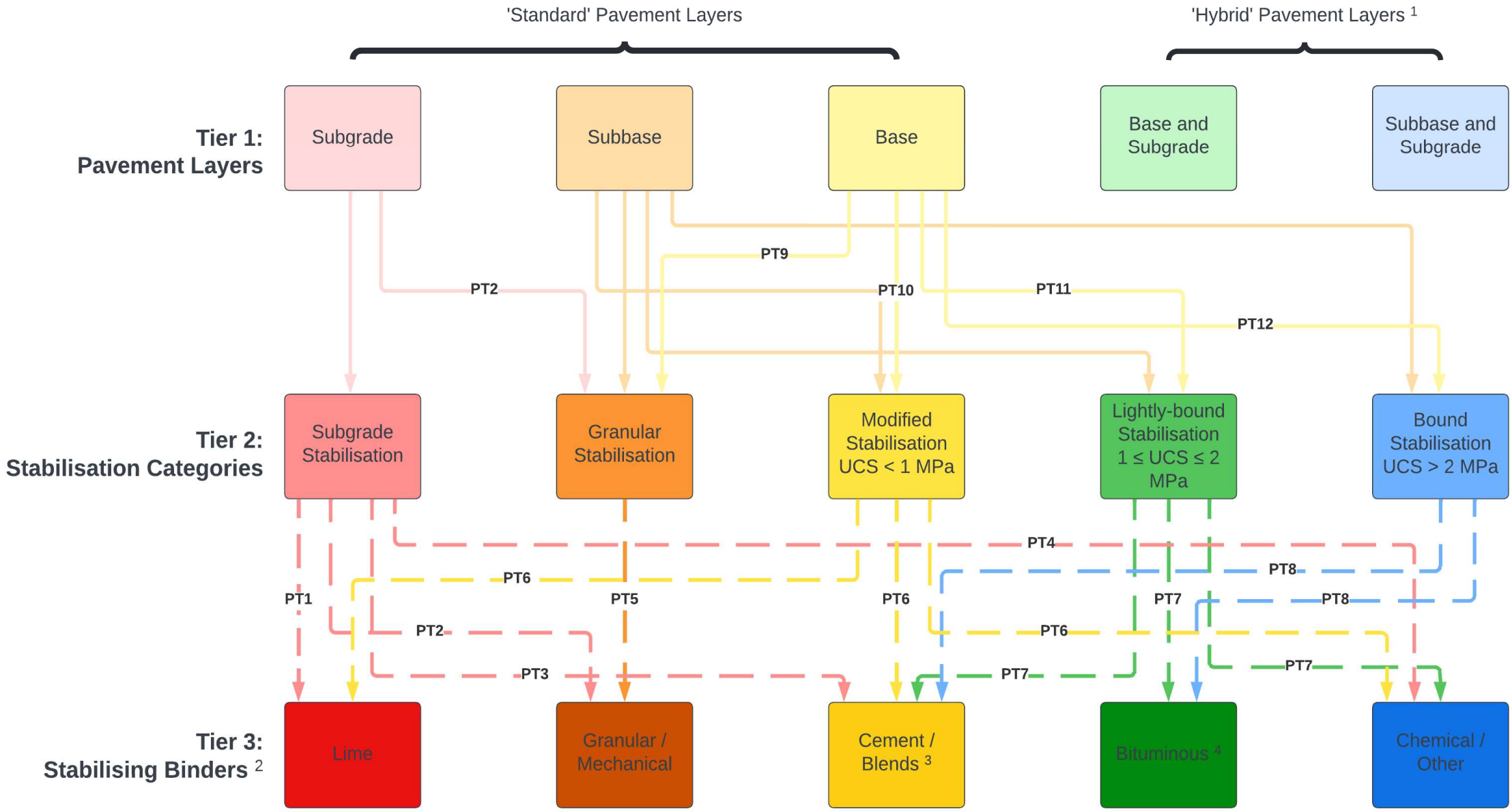
Development of a Selection Framework

TIER 1 - PAVEMENT LAYERS

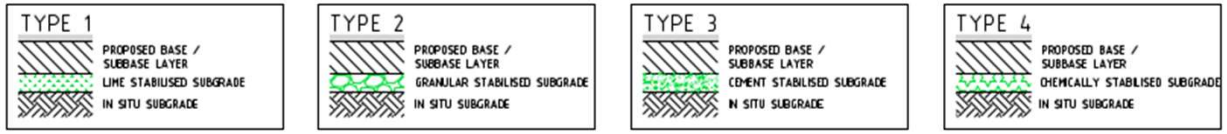
TIER 2 - STABILISATION CATEGORIES

TIER 3 - STABILISING BINDERS

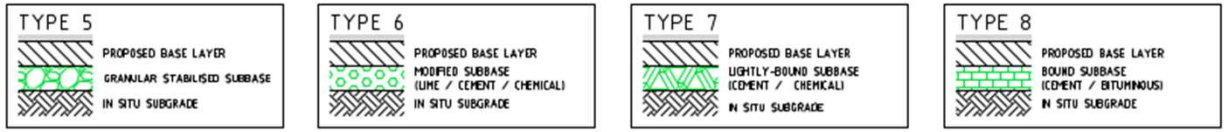
1. GRAPHICAL FLOWCHART
   - Sequentially step through the process of selecting a pavement layer to be stabilised, then a stabilisation category, then binder selection.
2. TYPICAL PAVEMENT SECTIONS
   - Pre-determined type cross sections allow a designer to shortlist a single (or multiple) pavement configuration for further design investigation.


'Standard' Pavement Layers
'Hybrid' Pavement Layers 1
Tier 1: Pavement Layers
Subgrade
Subbase
Base
Base and Subgrade
Subbase and Subgrade
PT2
PT9
PT10
PT11
PT12
Tier 2: Stabilisation Categories
Subgrade Stabilisation
Granular Stabilisation
Modified Stabilisation UCS < 1 MPa
Lightly-bound Stabilisation 1 ≤ UCS ≤ 2 MPa
Bound Stabilisation UCS > 2 MPa
PT1
PT2
PT3
PT4
PT5
PT6
PT7
PT8
Tier 3: Stabilising Binders 2
Lime
Granular / Mechanical
Cement / Blends 3
Bituminous 4
Chemical / Other

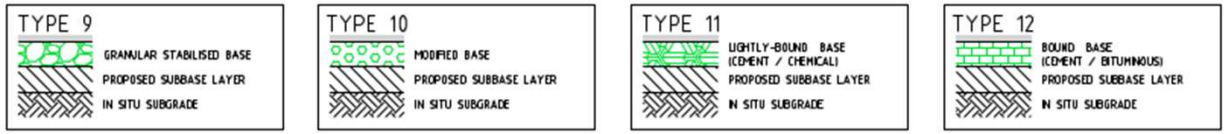
SUBGRADE



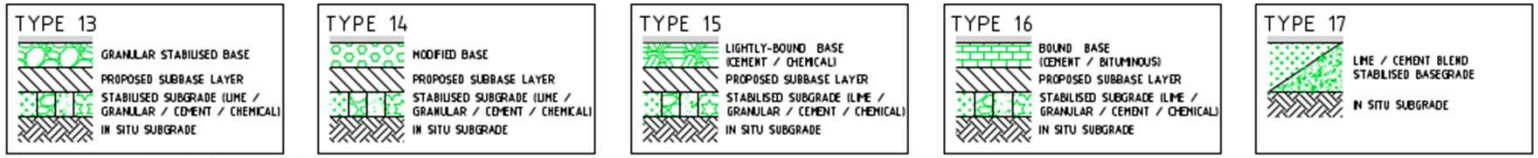
SUBBASE



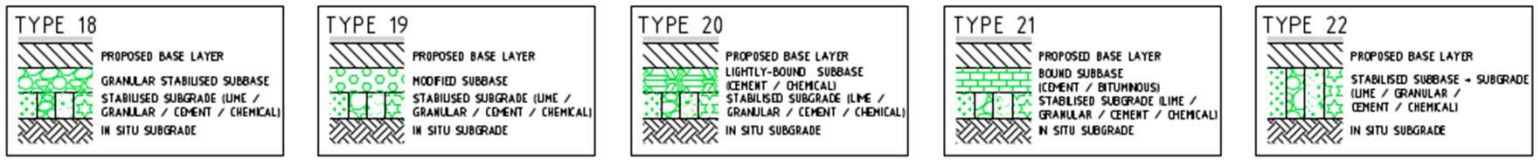
BASE



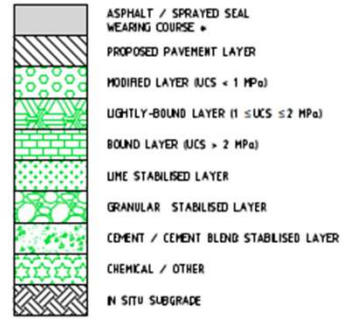
BASE AND SUBGRADE



SUBBASE AND SUBGRADE



LEGEND



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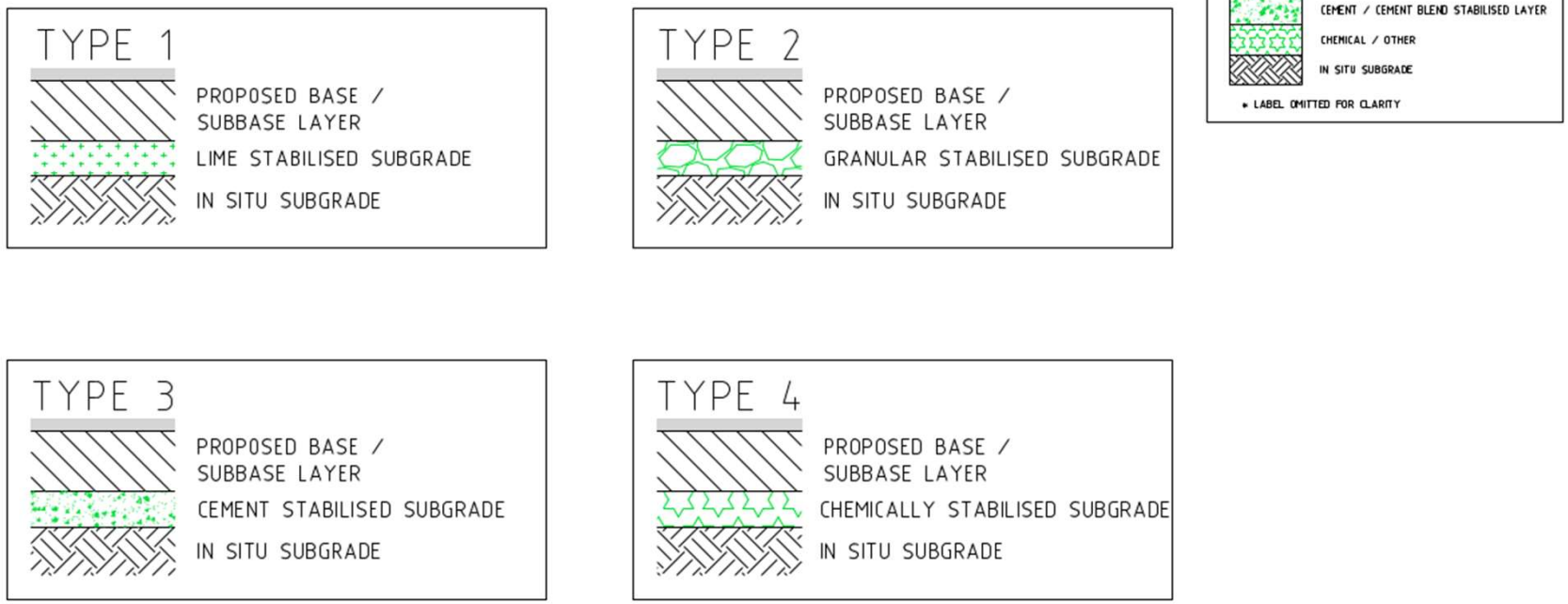
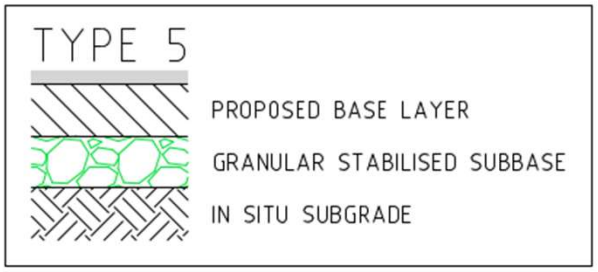
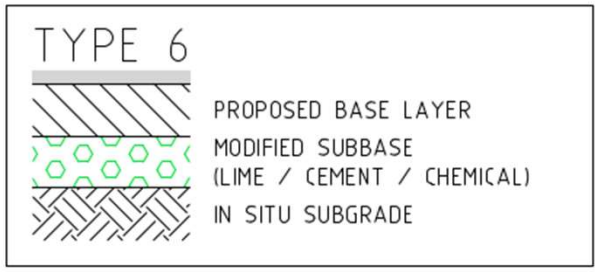
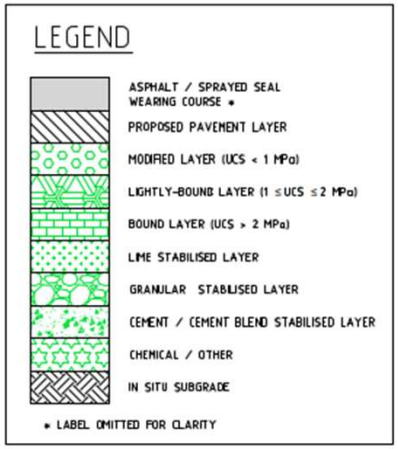
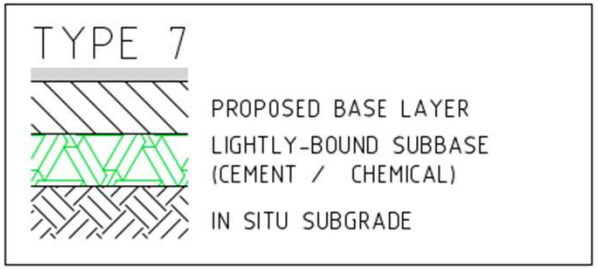
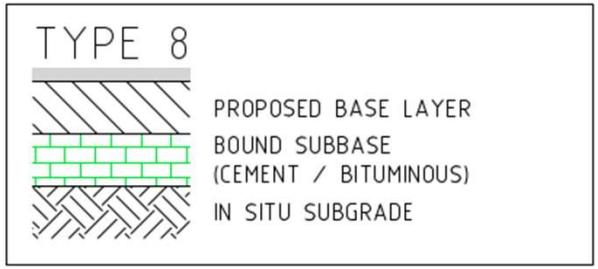

LEGEND
ASPHALT / SPRAYED SEAL WEARING COURSE *
PROPOSED PAVEMENT LAYER
MODIFIED LAYER (UCS < 1 MPa)
LIGHTLY-BOUND LAYER (1 ≤ UCS ≤ 2 MPa)
BOUND LAYER (UCS > 2 MPa)
LIME STABILISED LAYER
GRANULAR STABILISED LAYER
CEMENT / CEMENT BLEND STABILISED LAYER
CHEMICAL / OTHER
IN SITU SUBGRADE
* LABEL OMITTED FOR CLARITY
TYPE 1
PROPOSED BASE / SUBBASE LAYER
LIME STABILISED SUBGRADE
IN SITU SUBGRADE
TYPE 2
PROPOSED BASE / SUBBASE LAYER
GRANULAR STABILISED SUBGRADE
IN SITU SUBGRADE
TYPE 3
PROPOSED BASE / SUBBASE LAYER
CEMENT STABILISED SUBGRADE
IN SITU SUBGRADE
TYPE 4
PROPOSED BASE / SUBBASE LAYER
CHEMICALLY STABILISED SUBGRADE
IN SITU SUBGRADE
SUBGRADE


TYPE 5
PROPOSED BASE LAYER
GRANULAR STABILISED SUBBASE
IN SITU SUBGRADE

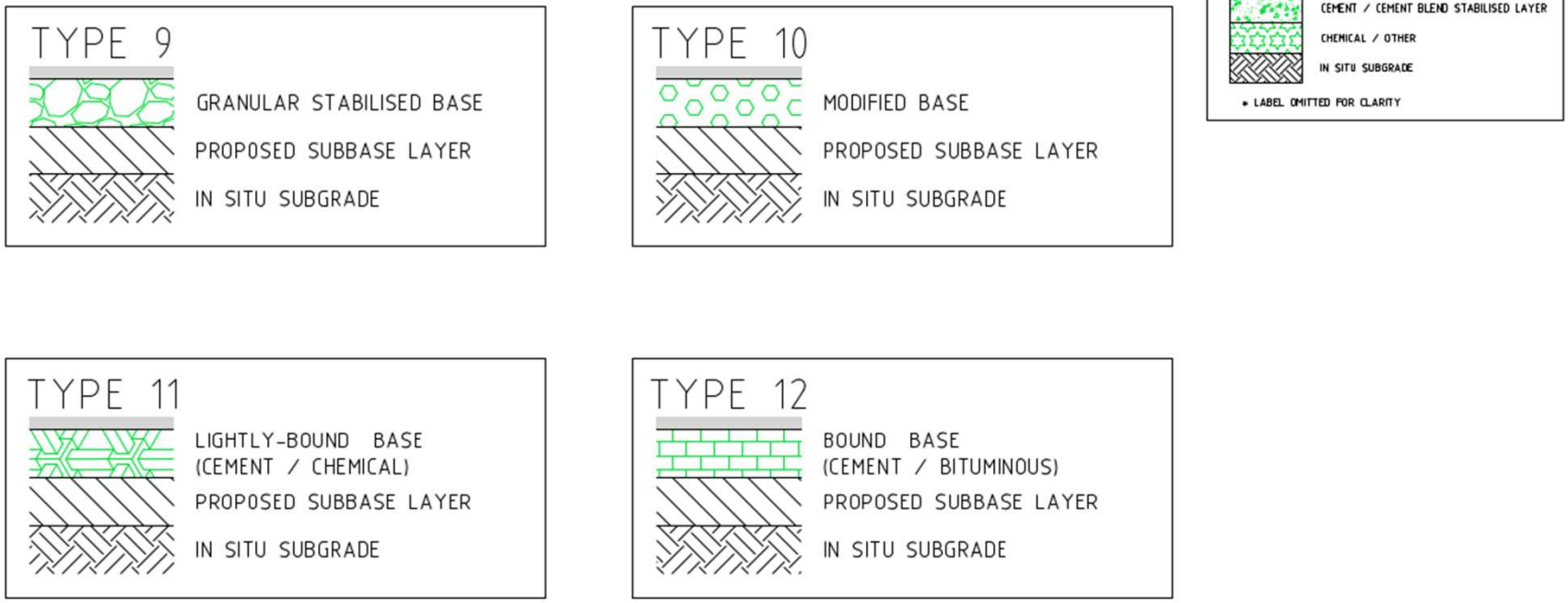

TYPE 6
PROPOSED BASE LAYER
MODIFIED SUBBASE
(LIME / CEMENT / CHEMICAL)
IN SITU SUBGRADE


LEGEND
ASPHALT / SPRAYED SEAL WEARING COURSE *
PROPOSED PAVEMENT LAYER
MODIFIED LAYER (UCS < 1 MPa)
LIGHTLY-BOUND LAYER (1 ≤ UCS ≤ 2 MPa)
BOUND LAYER (UCS > 2 MPa)
LIME STABILISED LAYER
GRANULAR STABILISED LAYER
CEMENT / CEMENT BLEND STABILISED LAYER
CHEMICAL / OTHER
IN SITU SUBGRADE
* LABEL OMITTED FOR CLARITY

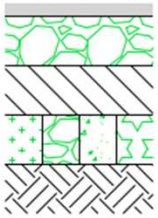

TYPE 7
PROPOSED BASE LAYER
LIGHTLY-BOUND SUBBASE
(CEMENT / CHEMICAL)
IN SITU SUBGRADE


TYPE 8
PROPOSED BASE LAYER
BOUND SUBBASE
(CEMENT / BITUMINOUS)
IN SITU SUBGRADE

SUBBASE


LEGEND
ASPHALT / SPRAYED SEAL WEARING COURSE *
PROPOSED PAVEMENT LAYER
MODIFIED LAYER (UCS < 1 MPa)
LIGHTLY-BOUND LAYER (1 ≤ UCS ≤ 2 MPa)
BOUND LAYER (UCS > 2 MPa)
LIME STABILISED LAYER
GRANULAR STABILISED LAYER
CEMENT / CEMENT BLEND STABILISED LAYER
CHEMICAL / OTHER
IN SITU SUBGRADE
* LABEL OMITTED FOR CLARITY
TYPE 9
GRANULAR STABILISED BASE
PROPOSED SUBBASE LAYER
IN SITU SUBGRADE
TYPE 10
MODIFIED BASE
PROPOSED SUBBASE LAYER
IN SITU SUBGRADE
TYPE 11
LIGHTLY-BOUND BASE (CEMENT / CHEMICAL)
PROPOSED SUBBASE LAYER
IN SITU SUBGRADE
TYPE 12
BOUND BASE (CEMENT / BITUMINOUS)
PROPOSED SUBBASE LAYER
IN SITU SUBGRADE
BASE

TYPE 13



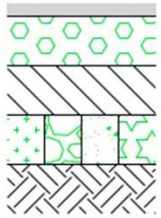
GRANULAR STABILISED BASE

PROPOSED SUBBASE LAYER

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

TYPE 14



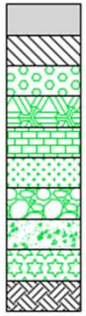
MODIFIED BASE

PROPOSED SUBBASE LAYER

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

LEGEND



ASPHALT / SPRAYED SEAL WEARING COURSE *

PROPOSED PAVEMENT LAYER

MODIFIED LAYER (UCS < 1 MPa)

LIGHTLY-BOUND LAYER (1 ≤ UCS ≤ 2 MPa)

BOUND LAYER (UCS > 2 MPa)

LIME STABILISED LAYER

GRANULAR STABILISED LAYER

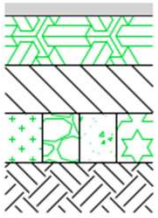
CEMENT / CEMENT BLEND STABILISED LAYER

CHEMICAL / OTHER

IN SITU SUBGRADE

* LABEL OMITTED FOR CLARITY

TYPE 15



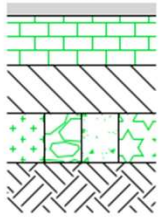
LIGHTLY-BOUND BASE (CEMENT / CHEMICAL)

PROPOSED SUBBASE LAYER

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

TYPE 16



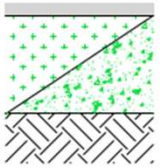
BOUND BASE (CEMENT / BITUMINOUS)

PROPOSED SUBBASE LAYER

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

TYPE 17

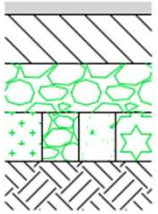


LIME / CEMENT BLEND STABILISED BASEGRADE

IN SITU SUBGRADE

BASE AND SUBGRADE

TYPE 18



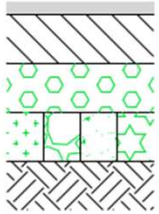
PROPOSED BASE LAYER

GRANULAR STABILISED SUBBASE

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

TYPE 19



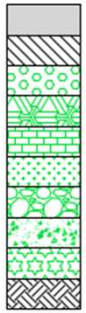
PROPOSED BASE LAYER

MODIFIED SUBBASE

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

LEGEND



ASPHALT / SPRAYED SEAL WEARING COURSE *

PROPOSED PAVEMENT LAYER

MODIFIED LAYER (UCS < 1 MPa)

LIGHTLY-BOUND LAYER (1 ≤ UCS ≤ 2 MPa)

BOUND LAYER (UCS > 2 MPa)

LIME STABILISED LAYER

GRANULAR STABILISED LAYER

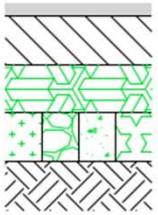
CEMENT / CEMENT BLEND STABILISED LAYER

CHEMICAL / OTHER

IN SITU SUBGRADE

* LABEL OMITTED FOR CLARITY

TYPE 20



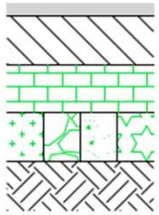
PROPOSED BASE LAYER

LIGHTLY-BOUND SUBBASE (CEMENT / CHEMICAL)

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

TYPE 21



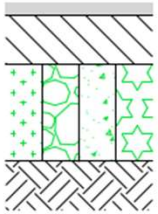
PROPOSED BASE LAYER

BOUND SUBBASE (CEMENT / BITUMINOUS)

STABILISED SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

TYPE 22



PROPOSED BASE LAYER

STABILISED SUBBASE + SUBGRADE (LIME / GRANULAR / CEMENT / CHEMICAL)

IN SITU SUBGRADE

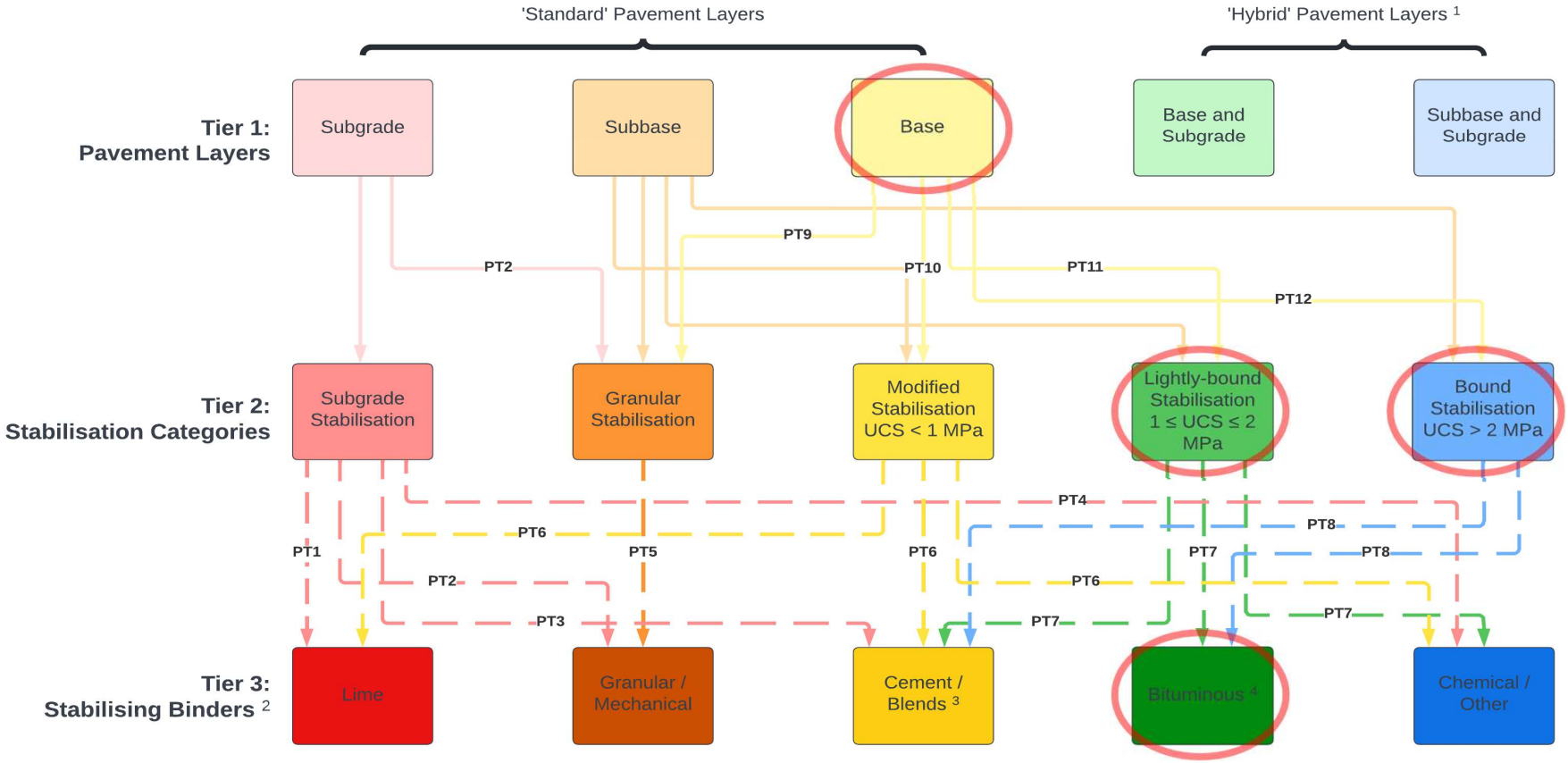
SUBBASE AND SUBGRADE

Worked Example

- Consider a local council that has an existing flood affected rural road that is exhibiting signs of fatigue cracking in the wheel paths and is beyond maintenance activities of pothole repairs and patching.
- Council's design engineer is considering a number of treatment options and believes that pavement stabilisation will provide good sustainability and commercial benefits.
- Using the selection framework presented above, the 'pathway' adopted by the design engineer for suitable stabilisation options is illustrated below.

Example rural pavement (Google 2022)

Worked Example



Worked Example

A summary of the process that the design engineer followed is described below:

1. Tier 1 – The existing base layer was deemed to be prioritised for treatment.
2. Tier 2 – Four stabilisation categories were available (Granular, Modified, Lightly-Bound, Bound). After the design engineer ran various thickness designs for the four options, a decision was made to focus on either a Lightly-Bound or Bound solution due to the available pavement thickness.
3. Tier 3 – The Bound solution was considered more appropriate in this situation as a resilient pavement was deemed superior to address the regular flood events in the area. Therefore, a bituminous binder would be trialled at the mix design phase of the project.

Recommendations for Future Work

- Opportunity to refine flowchart into an electronic/interactive application to simplify user experience.
- Inclusion of ‘hybrid’ layers, including base/subgrade (basegrade) and subbase/subgrade – attempted throughout the research project, but too difficult to clearly define the selection process without an electronic model.
- Implementation of current Austroads binder selection process (accounting for material Plasticity Index and Particle Size Distribution) in between Tier 2 and Tier 3 (electronic process).
- Inclusion of some additional aspects of the Austroads detailed design methodologies into software to enable full development of a pavement design for checking via mechanistic methods.

Summary

- Stabilisation has been documented as an effective treatment for rehabilitation of road pavements since the 1950s and is increasing with circular economy a driver.
- Austroads and industry bodies publish a wealth of technical information relating to the design of stabilised pavements.
- However, this information is technical/detailed and the preliminary processes for selecting a stabilised pavement profile are scarce.
- Stabilisation is often conceived to be ‘too expensive’ or ‘too difficult’ leading to pavement designers ignoring in favour of less suitable options.
- The process can be simplified to improve user confidence and ‘demystify’ the selection.
- The selection tools developed are not intended to replace the detailed technical guidance available – merely supplement to improve the uptake of stabilisation as a practice.

Thank You

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