Guideline

Structural design procedure for lime stabilised subgrade

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Queensland Government

Contents

1 Introduction

Subgrade stabilisation can be defined as a means of enhancing soil strength and stiffness properties by adding a hydraulic binder (substances which harden to a water-resistant building material following the addition of water) such as lime. Correctly applied, stabilisation can also decrease the subgrade's water sensitivity and volume changes during wet / dry cycles.

The design procedures in this guideline are intended for soil that is to be stabilised with lime. These procedures do not apply where drying or soil modification is the overall goal; however, modification should be applied with caution, as it can increase soil permeability, and seriously compromise pavement life.

Lime is a popular subgrade stabilisation additive because of its slow strength gain characteristics. Transport and Main Roads' established testing protocol and mix design procedure is available and should be applied to determine the optimum amount of lime required to stabilise the subgrade. Ideally, the depth of subgrade to be stabilised should be 300 mm.

2 Purpose

The aim of this guideline is to specify the structural design procedure to be applied when designing a lime stabilised subgrade as a permanent structural pavement layer.

3 Referenced documents

This guideline should be read in conjunction with the following documents listed in Table 3.

Table 3 – Referenced documents

Reference	Title
MRTS07A	Technical Specification *Insitu stabilised subgrades using quicklime or hydrated lime* (inclusive of MRS07A, MRTS07A.1 and MRS07A.1) (see www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Specifications/5-Pavements-Subgrade-and-Surfacing#MRTS07A)
Pavement Design Supplement	*Supplement* to *Part 2: Pavement Structural Design* of the Austroads *Guide to Pavement Technology* (see https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Pavement-design-supplement)
Pavement Rehabilitation Manual	Provides guidance and gives requirements for the evaluation of existing pavements and design of rehabilitation treatments for road infrastructure projects. (see www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Pavement-Rehabilitation-Manual)
Materials Testing Manual	*Materials Testing Manual Part 2 – Application, Section 7 – Testing of materials for lime stabilisation* (see https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Materials-testing-manual)
TN192 *Pavement rehabilitation - Investigation and analysis*	Provides guidance to Project Managers, pavement designers and pavement material testing personnel and Contractors on how to assess the available pavement information and Site conditions to plan and undertake pavement investigation work more accurately and efficiently. (see www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Technical-Notes/Technical-Notes-Index*)*

4 Information

Lime has a number of effects when added to soil. These effects can be categorised as soil drying, soil modification and soil stabilisation:

- **Soil drying** is a rapid decrease in soil moisture content due to the chemical reaction between water and lime following the addition of lime into a moist soil.
- **Modification** effects include reduction in soil plasticity, improved compactability, reduction of the soil’s capacity to swell and shrink and improved strength and stability after compaction. These effects generally happen within a short time period, typically 1–48 hours after the introduction of lime. The effects are more pronounced in soils with sizable clay content. The effects may not be permanent, and significantly increased permeability of the subgrade can jeopardise pavement life.
- **Lime stabilisation** can take place in soils containing a suitable amount of clay with the appropriate mineralogy to produce long-term permanent strength gains. Effective lime stabilisation requires additional lime, and a longer time period of 'curing'.

A soil that is lime stabilised benefits initially from soil drying and modification, but the additional lime delivers a proven permanent reduction in shrinkage, swelling and soil plasticity which can mitigate the effects of prolonged soaking.

5 Field results and analysis

Transport and Main Roads has completed field testing on several Queensland projects which have lime stabilised subgrades. This involved conducting Unconfined Compressive Strength (UCS) and Capillary Rise tests on cores extracted from the stabilised subgrade.

These projects included:

- Cunningham Highway (17B), Freestone Creek–'8-mile' intersection, constructed in 1997.
- Leichhardt Highway (26C) Murri-Murri section, constructed in 2002.
- Warrego Highway (18B) Toowoomba–Dalby, constructed in 2009.

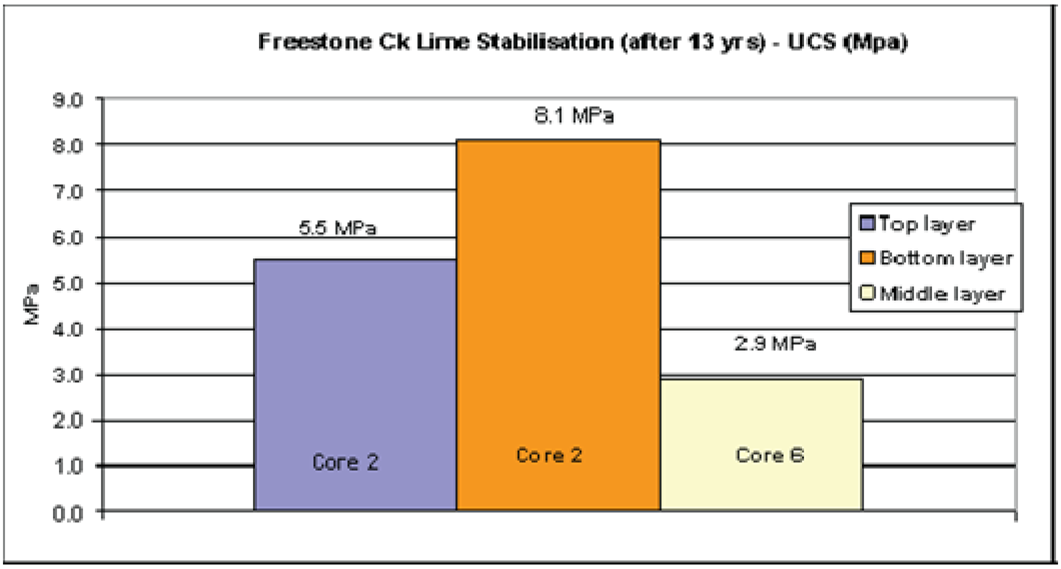
5.1 Cunningham Highway (17B)

The Cunningham Highway Site has the following characteristics:

- subgrade stabilised for widening existing road
- 300 mm of granular pavement in the widening
- constructed 1997
- wearing surface was 100 mm asphalt
- after eight years (2005), a further 100 mm asphalt, and
- pavement performing very well.

Six cores were extracted from the lime stabilised subgrade in 2012 (15 years after completion of construction). Three of these were successfully tested to determine UCS as shown in Figure 5.1:

Figure 5.1 – Freestone Creek lime stabilisation (after 15 years) – UCS (MPa)

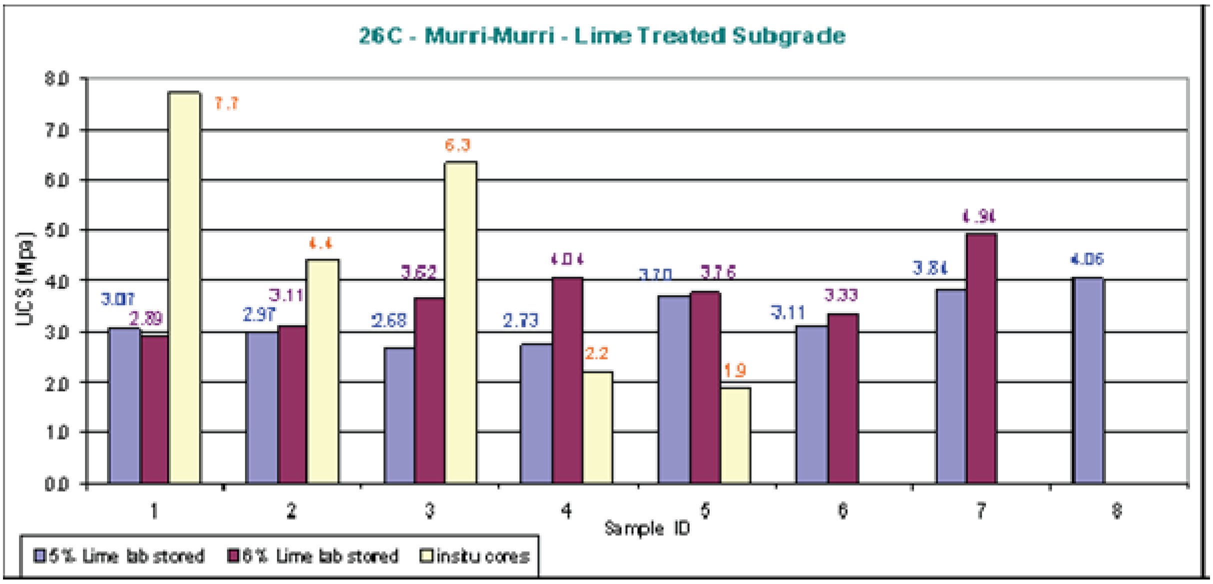


All results are above 2.50 MPa.

5.2 Leichhardt Highway (26C) Murri-Murri

Results were taken from cores taken insitu and also from stored cores left over from the mix design stage of the construction project. The stored cores either had 5% or 6% lime added. See Figure 5.2.

Figure 5.2 – 26C – Murri-Murri – lime treated subgrade

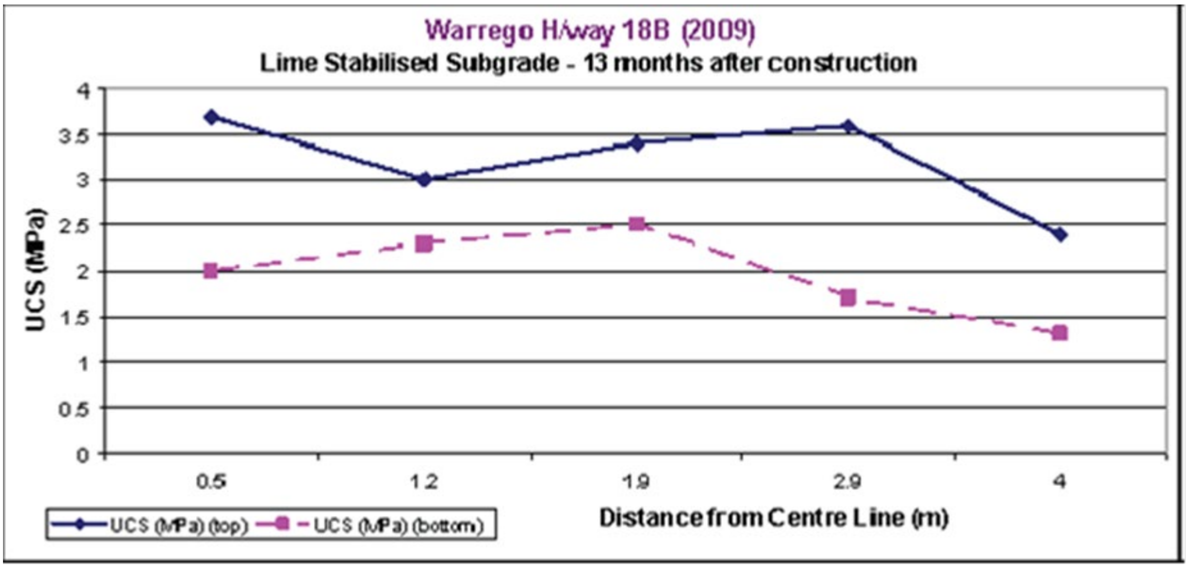


For the 20 cores tested, all results were above 2.0 MPa except for one. It was noted that the exception had the largest length to diameter ratio of all cores.

5.3 Warrego Highway (18B) Toowoomba–Dalby

The results of cores taken from one trench on the Warrego Highway (18B) Toowoomba–Dalby, 13 months after construction are shown in Figure 5.3.

Figure 5.3 – Warrego Highway 18B lime stabilised subgrade – 13 months after construction



All but one of these results is above 1.50 MPa.

6 Design parameters

Lime stabilisation can be considered when there is sufficient clay for the lime to react. This typically requires a Plasticity Index (PI) above 20%. Stabilisation of clayey material with lime generally results in pavements that have a much lower cracking potential than if the subgrade has been cement stabilised. Lime stabilised subgrades are also more durable as the effect of the clay has been reduced, rather than masked, as is the case with cement stabilisation.

The dosage rates of lime for construction (also referred to as additive content by mass (%)), will be the greatest of the lime demand test results and the lime required to achieve the target UCS of 1.5 MPa at 28 days. The range of UCSs should be between 1.0–2.0 MPa with a target UCS of 1.5 MPa at 28 days to make the lime stabilisation successful. Refer to *Materials Testing Manual Part 2 – Application, Section 7 – Testing of materials for lime stabilisation* for further details on material testing and mix design requirements.

Based on the Transport and Main Roads' field research, refinement of the mix design methodology and improvements to construction Technical Specification (MRTS07A *Insitu stabilised subgrades using quicklime or hydrated lime*), the current Austroads design methodology for lime stabilised subgrades considerably underestimates the structural strength and benefit provided to the pavement system. The department's design procedure to exploit more of the subgrade strength as a structural layer is fully explained in the following sections.

6.1 Requirements for lime stabilised subgrade

Where a lime stabilised subgrade is used:

- There shall be only one monolithic layer of lime stabilised subgrade. Multiple layers of lime stabilised subgrade shall not be constructed for road pavements as multiple thin layers are significantly more prone to fatigue as compared to a single monolithic layer. Multiple lime stabilised layers have been constructed to help support structures (for example, silos); however, this approach is not applicable for road pavements and this guideline.
- The preferred thickness of the lime stabilised subgrade layer shall be 300 mm.

6.2 Material suitability for lime stabilised subgrade

Appropriate uses for stabilisation of clay subgrades using lime include the following:

- where the materials to be stabilised are suitable (for example, have enough suitable pozzolans, the amount of organic carbon is not excessive) and the dosage rate required is acceptable, and
- for treatment of subgrades under existing pavements, only where removal and replacement (or reinstatement) of the existing pavement can be tolerated (for example, in terms of traffic management, cost).

Lime stabilisation can be adversely affected by any of the following:

- a lack of suitable pozzolans
- the presence of excessive organic carbon
- the presence of soluble Sulphates, and/or
- the presence of highly weathered soils with high ferric-oxide levels (for example, some lateritic soils).

Stabilisation of unsuitable soils can lead to serious problems which, at times, can only be rectified by removing and replacing the treated materials. If such problems occur, the overlying pavement layers must be removed. This can be a very expensive consequence of simply not undertaking adequate and appropriate testing.

It is crucial that adequate material sampling and testing is undertaken prior to the commencement of construction Works to confirm the suitability for lime stabilisation. Refer to *Materials Testing Manual Part 2 – Application, Section 7 – Testing of materials for lime stabilisation* for further details on material testing requirements.

Reference should also be made to Transport and Main Roads' *Pavement Rehabilitation Manual* and Technical Specification MRTS07A *Insitu stabilised subgrades using quicklime or hydrated lime.*

6.3 Structural design parameters

Like lime stabilised subgrades, lightly bound materials target a UCS strength range of 1.0–2.0 MPa. Further to this, the behaviour of lime stabilised subgrade can be considered to behave somewhat similar to a lightly bound subbase or improved layer. For a lightly bound subbase or improved layer manufactured with a lower quality granular host material, a vertical modulus of 210 MPa applies, regardless of the thickness and modulus of the overlaying bound materials and the underlying support conditions. Therefore, for the purposes of mechanistic-empirical design, lime stabilised subgrade shall be modelled with the following parameters shown in Table 6.3.

Table 6.3 – Design Parameters of Lime Stabilised Subgrade

Design Modulus	Poisson's Ratio	Degree of anisotropy	Sub-layering
210 MPa	0.45	2	NOT sub-layered[1]

Note:

[1] Apply a single vertical design modulus for the full depth of the lime stabilised subgrade layer.

In designing the pavement thickness, permanent deformation is assessed using the vertical compressive strain at the top of the underlying untreated subgrade, rather than at the top of the lime stabilised layer.

6.4 Minimum overlying pavement thickness

The minimum overlying pavement thickness shall be as per the requirements of Table 6.4.

Table 6.4 – Minimum pavement thickness overlying lime stabilised subgrade

Average daily ESA in design year of opening	Minimum pavement thickness overlying lime stabilised subgrade (mm)
<100	150
100–1000	200
>1000	250