Structural Modelling of Expansive Clay Subgrades Treated with Lime

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STABILISED PAVEMENTS OF AUSTRALIA PTY LTD

STRENGTH • FLEXIBILITY

PREAMBLE

In late 2017, Austroads released an updated version of their Guide to Pavement Technology Part 2: Pavement Structural Design.

One new addition to 'the Guide' was the introduction of a stabilised subgrade modelling procedure whereby the determination of a suitable treatment thickness and the corresponding design CBR are directly related to the bearing capacity of the underlying subgrade.

AGENDA

1. Background
2. Austroads Structural Design Method
3. Austroads Mix Design Method
4. Design Example

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BACKGROUND

Expansive Soils in Australia

Pavement Design

- Wetting and drying of expansive soils provides considerable challenges
- Very thick and expensive pavement structures often required
- Even with adequate cover, expansive soils can still affect the performance of new pavments

Effects of Expansive Soils

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PAVEMENT DESIGN (PRELIMINARY)

ROADS	–	ROAD 6
CLASS	–	COLLECTOR
ESA's	–	2.0×10^5
SURFACE	–	35mm AC
CBR 80	–	125mm
CBR 45	–	100mm
CBR 15	–	245mm
TOTAL BOX	–	505mm

ASSUMED CBR 3 SUBGRADE PRIOR TO TESTING

BACKGROUND – AGPT2

- 4TH Edition was published Oct 2017.
- Released Dec 2017.
- State Road Authorities commenced releasing their Pavement Design Supplements from 2018.

2

AUSTROADS STRUCTURAL DESIGN METHOD

Design Subgrade CBR v Stabilisation Thickness

The Austroads Guide to Pavement Technology, Part 2: Pavement Structural Design (2017), provides guidance to practitioners on methods for the selection and design of stabilised subgrade materials to improve the California Bearing Ratio (CBR) of the treated layer.

It is a tiered approach with iterations between design CBR and stabilisation thickness.

STABILISED SUBGRADE DESIGN CBR SELECTION

Minimum CBR of:

A. 15%;
B. Field Results or Presumptive Values;
C.

$$CBR_{\text{STAB. SUBGRADE}} = CBR_{\text{UNDERLYING MATERIAL}} \times 2^{(\text{STABILISED SUBGRADE THICKNESS} \,/\, 150)}$$

This approach did not exist in previous design guides

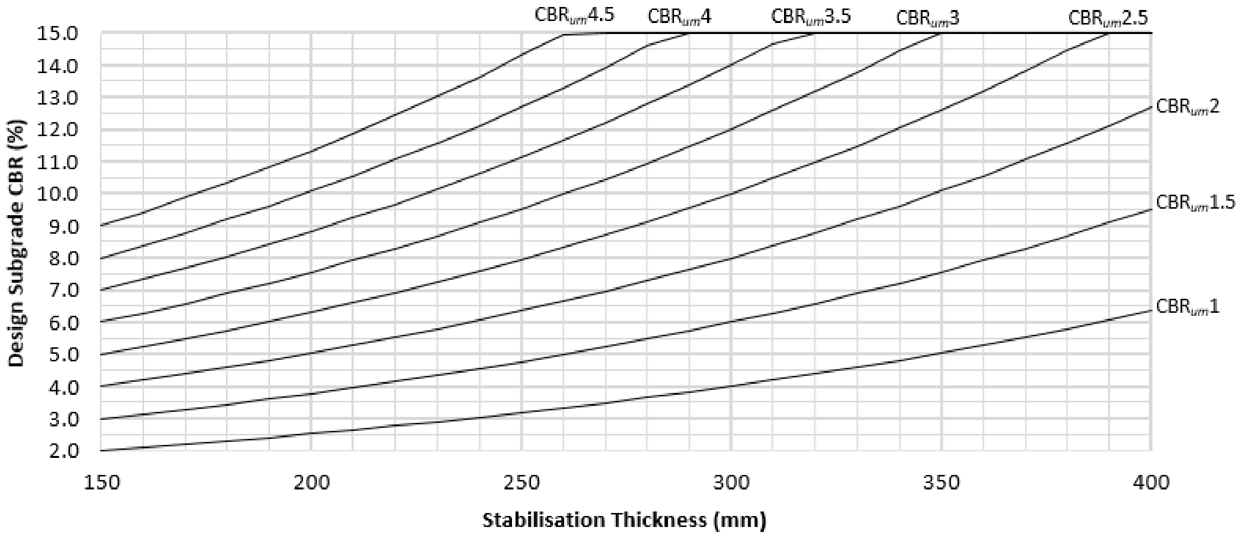
GOVERNING APPROACH…..*usually*

$$CBR_{\text{STAB. SUBGRADE}} = CBR_{\text{UNDERLYING MATERIAL}} \times 2^{(\text{STABILISED SUBGRADE THICKNESS} / 150)}$$

The following chart illustrates an iterative approach to selection of a design subgrade CBR and stabilisation thickness based on the above equation.

STABILISED SUBGRADE DESIGN

Selection of Design CBR for Stabilised Subgrades



Mechanistic LEA Properties

Once a design subgrade CBR has been selected, a vertical modulus (E_v) is established using the equation below for input into layered elastic analysis models (Austroads, 2017).

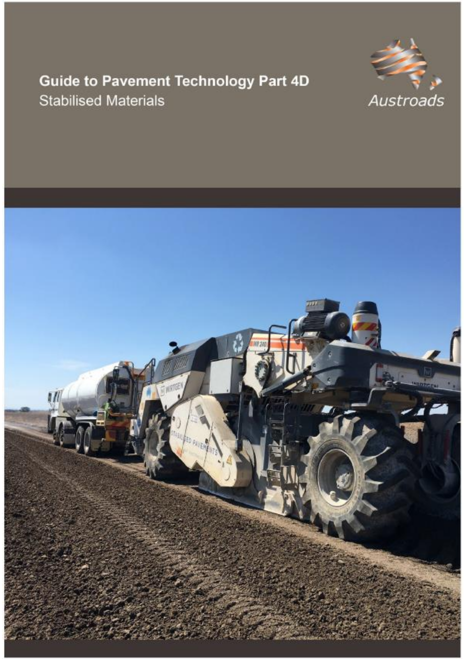
$$Modulus\ (MPa) = 10 \times CBR$$

A maximum value of 150MPa is normally adopted with a Poisson's ratio of:

- 0.45 for cohesive materials
- 0.35 for non-cohesive materials.

3

AUSTROADS MIX DESIGN METHOD



BINDER SELECTION

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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

Hydrated Lime v Quicklime

	Hydrated Lime, $Ca(OH)_2$	Quicklime, CaO
Composition	$Ca(OH)_2$	CaO
Form	Fine powder	Granular
Equivalent $Ca(OH)_2$ /unit mass	1.00	1.32
Bulk Density (t/m^3)	0.45 to 0.56	1.05
Used in Laboratory	Yes	No
Used in Construction	Yes (least common)	Yes (most common)

Lime slurry and agricultural lime are not used for conventional road stabilisation projects in Australia

Quicklime Conversion

If quicklime is specified for use in the field, a conversion factor 0.76 is applied to the laboratory determined hydrated lime application rate.

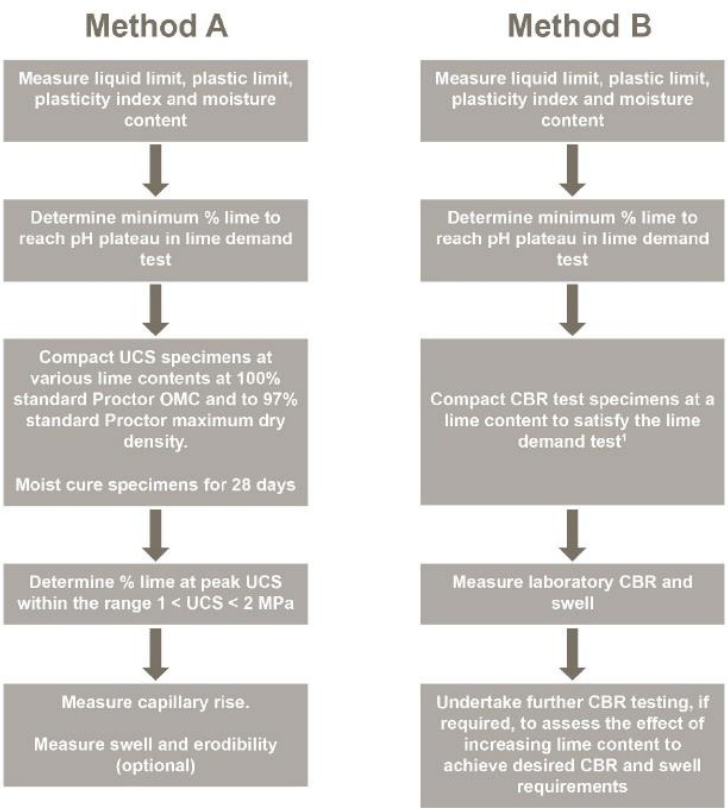
Quicklime (% in field) = Hydrated Lime (% in lab) x 0.76

Eg. If the lab determined application rate is 4% H/L by mass,

The field application rate can be: 3% Q/L by mass.

Mix Design Methods

Figure 4.4: Determination of lime content of earthworks materials



- ❑ Method A is traditionally only used by QLD DTMR
- ❑ Method B is the most common approach for local government

Lime Demand Testing

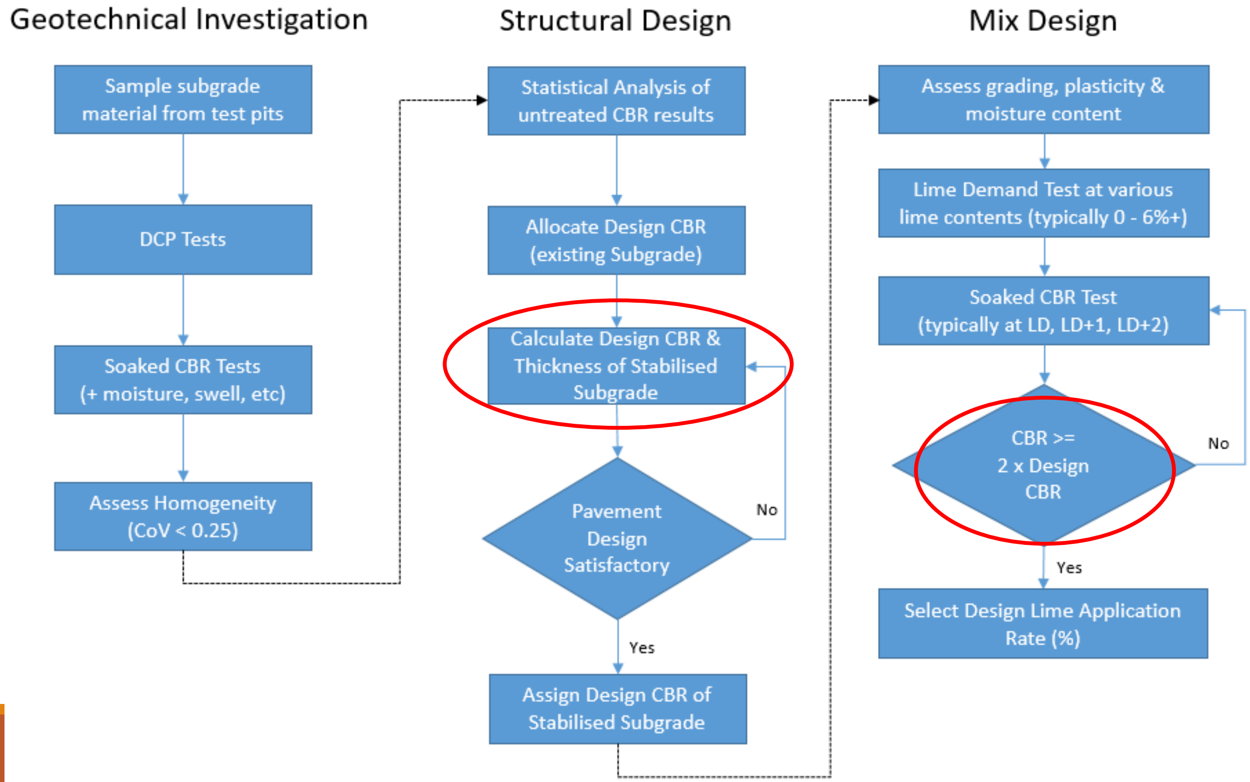
- Measures the pH of the clay at various lime contents.

- Lime demand value characterised as the minimum lime content to satisfy cation exchange by reaching a pH of 12.4 (Little, 1995).

- Lime application rates for CBR testing are recommended to be at LD, LD+1% and LD+2% as a minimum testing regime.

- Confirmation of a design application rate is then determined by selecting the lime content where the CBR exceeds the design CBR by a factor of 2 to account for variations in host material and lime properties.

Simplified Design Summary



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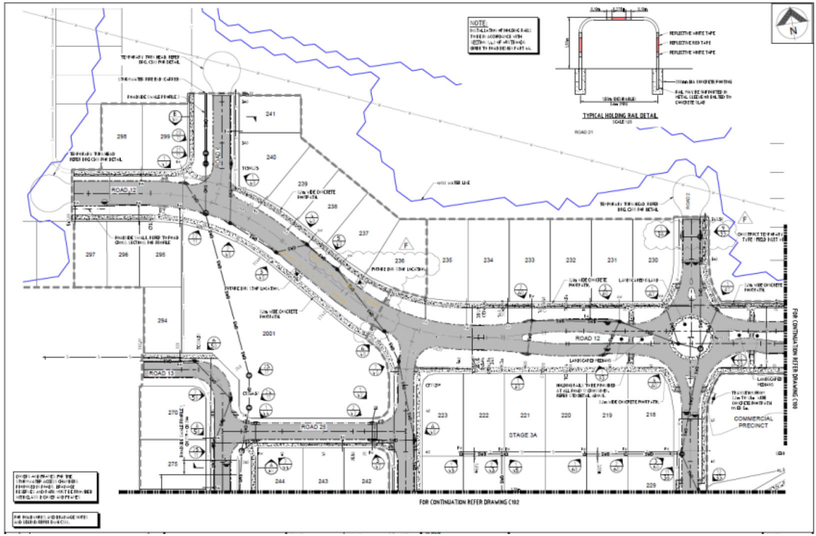
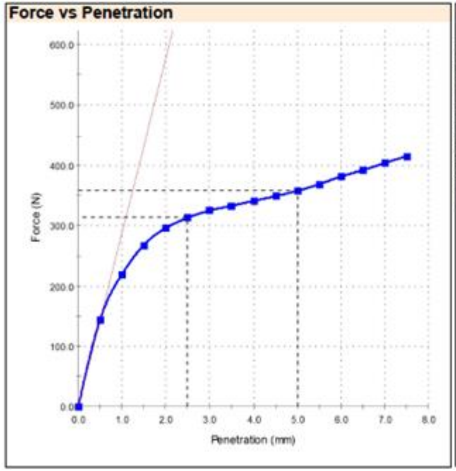
EXAMPLE


TYPICAL HOLDING RAIL DETAIL
ROAD 12
ROAD 13
ROAD 25
STAGE 3A
COMMERCIAL PRECINCT
FOR CONTINUATION REFER DRAWING C102

Design Example

A Consultant needs to design a pavement for a new subdivision development. The following design parameters have been assigned:

- Traffic loading: 9.0E+05 DESA
- Existing expansive clay subgrade: CBR2.5 (3.5% swell)



Test Results

Q113C

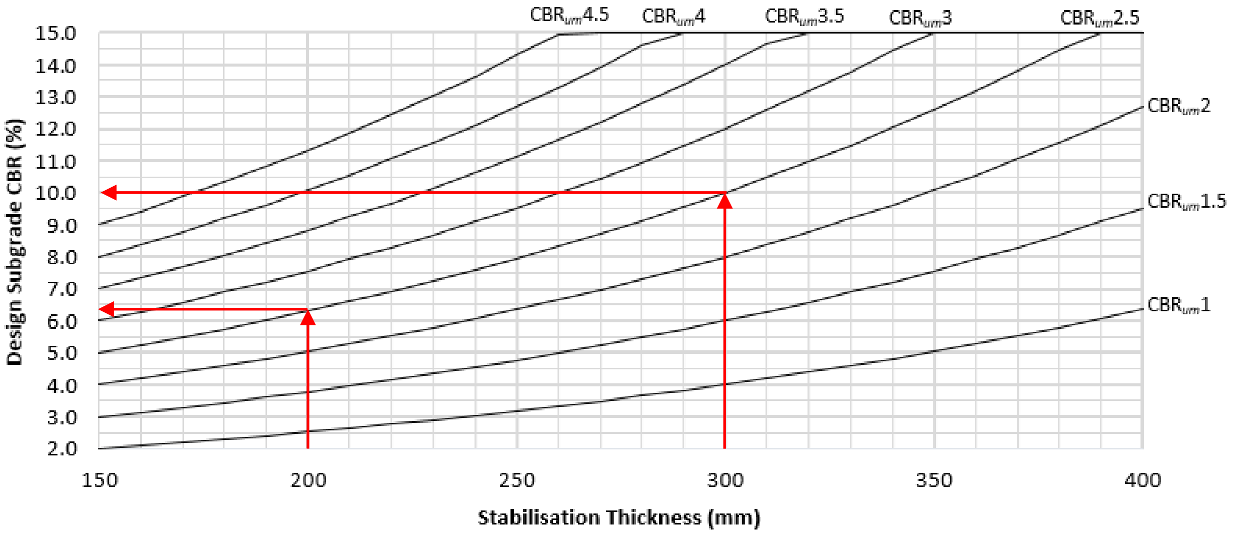
CBR:	**2.5**
CBR at 2.5:	2.5
CBR at 5.0:	2.0
Nominated Dry Density (t/m³):	1.664
Nominated Moisture Content (%):	20.1
Achieved Dry Density (t/m³):	1.663
Achieved Moisture Content (%):	20.2
Soaked:	Yes
Swell (%):	3.5
MC After Penetration (%):	21.7
MC After Penetration of Penetrated End (%):	29.0

Table 5.2: Guide to classification of expansive soils

Expansive nature	Liquid limit (%)	Plasticity Index	PI x % < 0.425 mm	Swell (%) (1)
Very high	> 70	> 45	> 3200	> 5.0
High	> 70	> 45	2200–3200	2.5–5.0
Moderate	50–70	25–45	1200–2200	0.5–2.5
Low	< 50	< 25	< 1200	< 0.5

Stabilised Subgrade

Selection of Design CBR for Stabilised Subgrades



The maximum allowable design CBR is:

- 10% for a 300mm treatment
- 6% for a 200mm treatment

Pavement Layer Thickness Determination

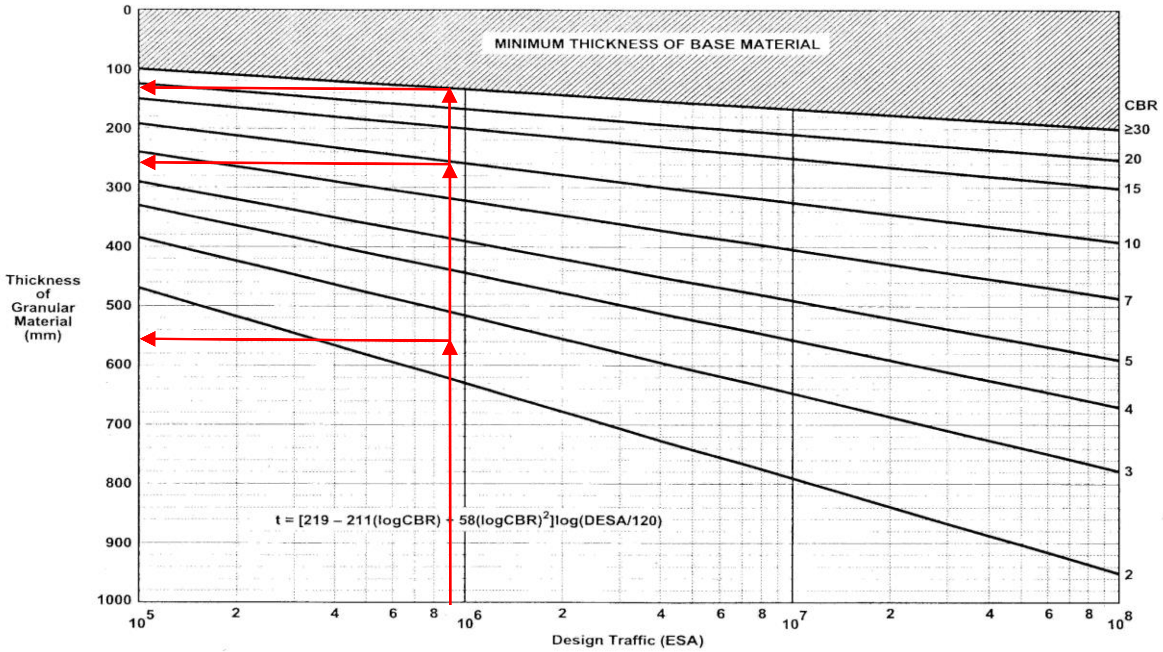


Figure 8.4 Design chart for granular pavements with thin bituminous surfacing

Minimum total cover over expansive clay subgrade CBR2.5 = 560mm

Minimum cover over 300mm Stabilised Subgrade CBR10 = 260mm

Minimum thickness of granular base CBR80 = 140mm

Balance thickness for granular subbase CBR30 = 120mm (260 – 140)

Step 2: Mix Design

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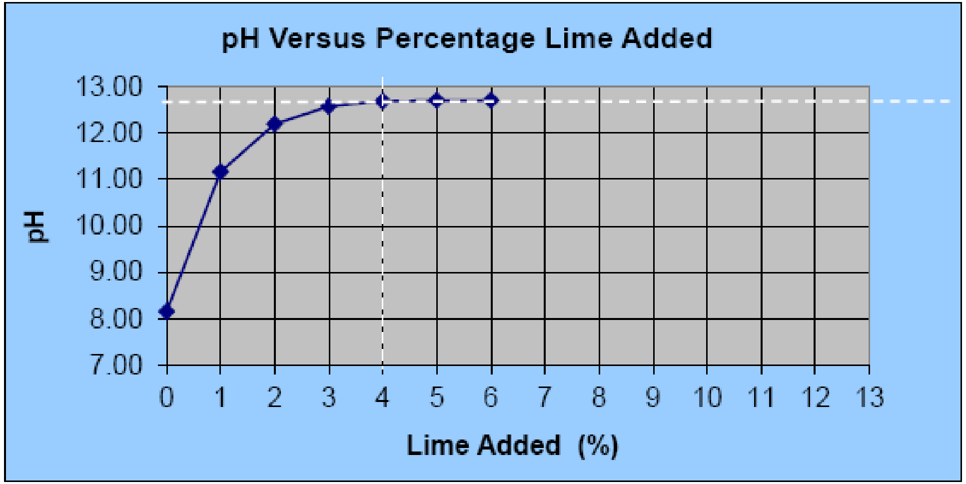
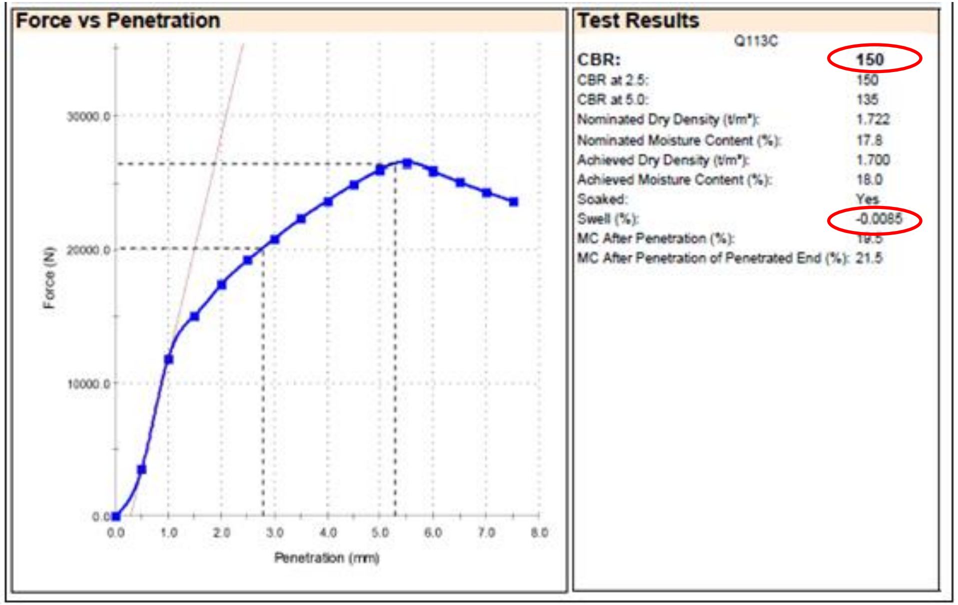
LIME DEMAND : 4.0 % (Hydrated Lime)



Lime demand testing resulted in LD=4%.

Step 2: Mix Design

CBR testing was carried out at LD=4% which resulted in CBR=150% and no Swell



Design Recommendation

As the CBR test result at LD (4%) exceeded the target strength of CBR20 (design CBR10 x 2), the final design is:

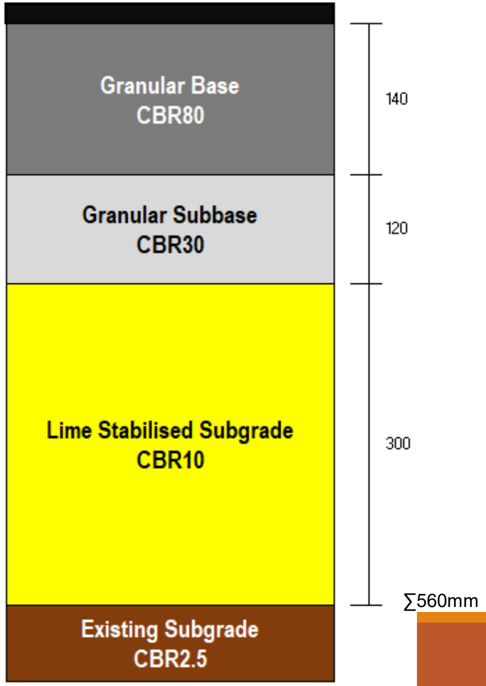
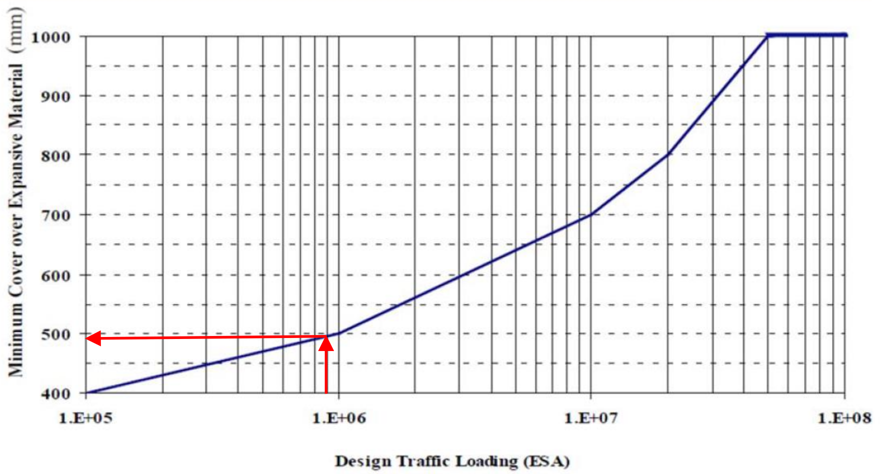


Figure 5.1 – Minimum Cover over Expansive Material



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SUMMARY

KEY TAKEAWAYS

- Lime stabilisation can be extremely effective to limit permanent deformation and reduce the overlying pavement thickness, as long as proper design methods are followed
- Revised 2017 Austroads Structural Design Guide
- Design CBR increases of approximately 200-400%.
- Stabilised Subgrade Design Approach

$$CBR_{\text{STAB. SUBGRADE}} = CBR_{\text{UNDERLYING MATERIAL}} \times 2^{(\text{STABILISED SUBGRADE THICKNESS} \;/\; 150)}$$

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