Effect of Removing the Amelioration Period on Design & Construction of Lime Stabilised Subgrades in Local Government

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OBJECTIVE

➢ To explore and compare strength gain measured by UCS and CBR on single day and multiple day mixing processes with lime stabilised subgrade materials.

➢ The outcomes will allow local government to confidently specify subgrade stabilisation construction methods that meet their design criteria whilst reducing the construction time and ultimately the corresponding cost.
AGENDA

1. Background
2. Problem Statement
3. Research Program
4. Material Samples
5. Material Testing Program
   a. Untreated Material Characteristics
   b. Treated Material Characteristics
6. Case Study Example
7. Conclusions & Recommendations
Lime stabilisation of subgrades to improve the California Bearing Ratio (CBR) in local government roads is not a new concept and has been widely used and accepted for many decades in QLD.

Spreading and mixing lime into non-compliant subgrade materials is simple and effective where permanent improvements of existing CBR’s can commonly be increased by a factor of 5 -10 and sometimes up to 25.
Little 1995 references the use of Two-Stage Mixing whereby 100% of the required lime is mixed on the first day with a second pulverising mix carried out on the second, third or even fourth day.

This ‘mellowing’ or amelioration period between mixes is designed to allow the clay particles to achieve effective breakdown through optimisation of the chemical reactions between the plastic particles and the lime. Little also notes that the mellowing period is best suited to heavy, plastic clays.

Austroads 2006 suggests that amelioration periods from 4 to 72 hours are considered with the lime being added in two stages.

TMR follow the Austroads guidance but have supported research carried out to optimise the amelioration period.
Wilson 2011 found that a 14 hour amelioration period provided the maximum UCS results and in fact were equivalent to the results obtained at 24 hours.

TMR state in their mix design and construction specifications that lime is to be added in two stages to facilitate an amelioration period of at least one day and up to 3 days for heavy clays.

The primary desire for this is to ensure there is adequate breakdown of the clay particles (100% passing 19mm sieve and >60% passing 9.5mm sieve) to allow effective chemical reactions and hence strength gain, with the latter being a target UCS of 1.5MPa.

Many local government areas follow the above construction principle of specifying a two stage mixing process. Townsville City Council is one example who note, ‘Lime stabilisation of subgrade material shall be carried out as a 2 day operation to a minimum depth of 250mm...’ in their Lime Stabilisation sub section of Council’s City Plan.
BACKGROUND

- Most local councils model subgrade materials using CBR, not UCS as does TMR.

**Brisbane City Council:**

3.5.4 Subgrade evaluation
3.5.4.1 General

(1) The design parameter for the subgrade is the California Bearing Ratio (CBR). The pavement design must be based on the soaked CBR tests being representative of the subgrade over the various lengths of road at the box depth.

**Western Downs Regional Council:**

1.13.2 Subgrade Evaluation

The Subgrade Evaluation shall adhere to the following requirements:

- A design CBR is to be determined for each identifiable unit defined on the basis of topography, geotechnical and drainage condition of the site.

**Mackay Regional Council:**

1.5.2 Subgrade Evaluation

Except where a mechanistic design approach is employed using Aust Roads Pavement Design Manual, the measure of subgrade support shall be the California Bearing Ratio (CBR). Where a mechanistic design approach using linear elastic theory is employed for flexible pavements, the measure of subgrade support shall be in terms of the elastic parameters (modulus, Poisson’s ratio).

**Gladstone Regional Council:**

9.4.1 PAVEMENT DESIGN BASIS

General - Pavements shall be designed for a 20 year life in service. The total pavement depth shall be based on the soaked California Bearing Ratios (CBR) of the subgrade material, the thickness and CBR of the various pavement layers (base, sub-base, etc.), and the number of repetitions of equivalent Standard Axles (ESA) for the life of the pavement.
PROBLEM STATEMENT

- TMR target compressive strengths of 1.5MPa whilst most local council’s design their pavements based on CBR modelling of subgrade materials.

- The problem is that local government in most cases are over specifying the construction requirements. Given local government only require their subgrades to achieve a CBR of with an upper limit of 15-20%, the question is whether or not the two stage mixing process currently being specified by councils is necessary to achieve these CBR’s.
Based on the current TMR laboratory testing requirements for lime stabilised materials, samples will be tested for UCS and CBR:

- with no amelioration period
- with 24 hours amelioration period.

The objective is to explore the effect on not only UCS and CBR strength gains, but other characteristics such as material breakdown with both amelioration periods.

Comparison will be made with the common local government design parameter to use CBR for subgrade modelling rather than UCS.
MATERIAL SAMPLES

**NQ Soil**: Exposed subgrade at Stockland Northshore development, Townsville.
MATERIAL SAMPLES

SQ Soil: Exposed subgrade at Warrego Hwy on the Charlton Upgrade Stage 2, ~1.7km west of Kingsthorpe Haden Rd, E/B carriageway slow lane (~20km west of Toowoomba).
TMR’s Technical Note 151: Testing of Materials for Lime Stabilisation

**MATERIAL TESTING PROGRAM**

<table>
<thead>
<tr>
<th>Untreated Material</th>
<th>Treated Material</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test ID</strong></td>
<td><strong>Test Type</strong></td>
</tr>
<tr>
<td>A</td>
<td>PSD</td>
</tr>
<tr>
<td>B</td>
<td>MDD &amp; OMC</td>
</tr>
<tr>
<td>C</td>
<td>Atterberg Limits</td>
</tr>
<tr>
<td>D</td>
<td>Organic Content</td>
</tr>
<tr>
<td>E</td>
<td>Sulfate Content</td>
</tr>
<tr>
<td>F</td>
<td>Ferrous Oxide (FeO)</td>
</tr>
<tr>
<td>G</td>
<td>4 day soaked CBR</td>
</tr>
<tr>
<td>H</td>
<td>Lime Demand (LD)</td>
</tr>
<tr>
<td>I</td>
<td>Capillary Rise</td>
</tr>
</tbody>
</table>

- No Amelioration Period
- 24 Hours Amelioration Period
# LABORATORY TEST RESULTS

## Untreated Material Properties

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Spec Requirement</th>
<th>NQ Soil</th>
<th>SQ Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSD</td>
<td>&gt; 25% passing 0.425mm</td>
<td>87%</td>
<td>78%</td>
</tr>
<tr>
<td>MDD</td>
<td>1.744 t/m³</td>
<td></td>
<td>1.468 t/m³</td>
</tr>
<tr>
<td>OMC</td>
<td>17.2%</td>
<td></td>
<td>29.9%</td>
</tr>
<tr>
<td>Atterberg Limits</td>
<td>PI &gt; 10%</td>
<td>21.2%</td>
<td>27.2%</td>
</tr>
<tr>
<td>Organic Content</td>
<td>&lt; 1.0%</td>
<td>0.8%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Sulfate Content</td>
<td>&lt; 0.3%</td>
<td>0.16%</td>
<td>0.43%</td>
</tr>
<tr>
<td>Ferrous Oxide (FeO)</td>
<td>&lt; 2.0%</td>
<td>0.05%</td>
<td>2.28%</td>
</tr>
<tr>
<td>4 day soaked CBR</td>
<td></td>
<td>3.0%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Lime Demand (LD)</td>
<td></td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Capillary Rise</td>
<td>Time to 100%</td>
<td>2.0 hrs</td>
<td>2.5 hrs</td>
</tr>
</tbody>
</table>
LIME DEMAND

*(minimum % of lime required for permanent reaction)*

Eades and Grim, 1966 refer to lime demand as being the least amount of lime required when the pH is above 12.4 and three consecutive results are within 0.05 of each other.
TREATED MATERIAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Lime Contents</th>
<th>SQ Soil</th>
<th>NQ Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR</td>
<td>0%, 3%, 5%, 7%</td>
<td>0%, 1%, 3%, 5%, 7%</td>
</tr>
<tr>
<td>UCS</td>
<td>3%, 5%, 7%</td>
<td>1%, 3%, 5%, 7%</td>
</tr>
<tr>
<td>PSD</td>
<td>0%, 5%</td>
<td>0%, 3%</td>
</tr>
</tbody>
</table>

SQ Soil: AR = LD + 1%
AR = 6%

NQ Soil: AR = LD + 1%
AR = 4%
UCS REVIEW

SQ Soil: the ameliorated samples were approximately 10-30% higher than the non-ameliorated samples, apart from the 7% application rate which showed no difference.

NQ Soil: there was no distinct pattern showing an increase from no amelioration to 24 hours of amelioration.

- Prior studies with two soils from Barcaldine and Emerald examined by Gallage et. al 2012 showed the difference in UCS based on a 5% application rate (LD was 4%), was in the range 25% to 60% higher for the ameliorated samples.
GRADINGS
## PSD REVIEW

<table>
<thead>
<tr>
<th></th>
<th>No Amelioration</th>
<th>24 Hrs Amelioration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Passing 19mm</td>
<td>% Passing 9.5mm</td>
</tr>
<tr>
<td>SQ Soil (@ 5% LD)</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>NQ Soil (@ 3% LD)</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>Spec Requirement</td>
<td>100</td>
<td>60-100</td>
</tr>
</tbody>
</table>
Swell Results - NQ Soil

Swell Results - SQ Soil

\[ R^2 = 1 \]

\[ R^2 = 0.9751 \]

\[ R^2 = 0.7213 \]
Swell Review

- Swell was higher for the non-ameliorated samples at all application rates.

- Both samples indicated lowest swell characteristics at approximately Lime Demand percentage + 1.0%.

- This provides confidence that upon selection of application rates at mix design stage of LD + (0.5 - 1.0%), swell characteristics are at their lowest point.
CAPILLARY RISE

Capillary Rise Results

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Non Ameliorated</th>
<th>Ameliorated</th>
</tr>
</thead>
<tbody>
<tr>
<td>NQ SOIL</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>SQ SOIL</td>
<td>1.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

- 0% Lime
- 3% Lime (LD)
- 5% Lime (LD)
CASE STUDY EXAMPLE

Scenario:
A local council designs a new pavement for a residential development that resembles the schematic shown in Figure 10, with a design subgrade of CBR 5.

Consider the materials described in this research from SQ and NQ which have insitu CBRs of 3.5% and 3% respectively.

Given these characteristics do not meet the design CBR of 5%, the local council has decided to stabilise the subgrade to a thickness of 300mm.
The design CBR of each selected subgrade and stabilised subgrade material is the minimum of (1) 15%, (2) the value determined from CBR tests or presumed CBR, and (3) the value determined from the support provided by the underlying material (i.e. in situ subgrade, selected subgrade or stabilised subgrade material) using (Equation 25):

\[ CBR_{selected \ or \ stab. \ subgrade} = CBR_{underlying \ material} \times 2^{\left(\frac{300}{150}\right)} \]

SQ Soil: \( CBR_{SS} = 3.5 \times 2^{\left(\frac{300}{150}\right)} = 14\% \)

NQ Soil: \( CBR_{SS} = 3.0 \times 2^{\left(\frac{300}{150}\right)} = 12\% \)
CASE STUDY EXAMPLE

Unbound Granular Base

Stabilised Subgrade
Design CBR 12% / 14%
Satisfies CBR > 5 CBR3/3.5

Field results
22% < CBR < 55%
CONCLUSIONS & RECOMMENDATIONS

❑ In most local government cases, lime stabilisation of subgrades is implemented to improve CBR’s up to values of at least 5% in order to meet design assumptions and provide suitable working platforms.

❑ Regardless of the soil improvement characteristic, the minimum amount of lime to be used should always be at least the Lime Demand percentage, often with 0.5 - 1.0% added to ensure the engineering property improvements are permanent.

❑ The use of TMR guidelines for design purposes in local government provides a conservative outcome (lime stabilised subgrades only).

❑ The use of TMR specifications for construction of lime stabilised subgrades with a minimum 2 day mixing process in local government is unnecessary.
CONCLUSIONS & RECOMMENDATIONS

❑ There was no conclusive evidence of any well correlated rise in UCS between 0 and 24 hours amelioration.

❑ The difference in CBR obtained by using Lime Demand +1% application rates with or without an amelioration period has no effect on the ability of the stabilised subgrade to meet the CBR design requirements. Using the Austroads design approach is conservative with a maximum permitted stabilised subgrade design CBR of 15%, where field results in heavy clays ranged from 22% to 55%.

❑ Local government authorities should specify in their construction documents amendments to the current TMR specifications that incorporation of 100% of lime can be carried out without applying an amelioration period. The use of Annexure MRTS07A.1 can satisfy this change. Alternatively local government should specify this in their own documentation.