AustStab

**Low Volume Roads Technology Projects**

Department of Infrastructure, Transport, Regional Development
and Local Government
and
Australian Stabilisation Industry Association Limited

**Recycling unsealed roads to reduce dust & maintenance using insitu stabilisation**

# LABORATORY INVESTIGATION REPORT FOR THE INSITU STABILISATION OF UNSEALED ROAD TRIALS USING LIME, CEMENTITIOUS AND POLYMERS BINDERS

# Preface

## AusLink

AusLink is Australia's first National Land Transport planning, funding and investment decision making framework. By linking transport performance outcomes to projected economic growth and development, it is transforming the way Australian Governments plan and fund major road and rail systems infrastructure. This project is funded by the Australian Government as part of AusLink.

## Department of Infrastructure, Transport, Regional Development and Local Government

The Department is responsible for:

- infrastructure planning and coordination;
- transport safety, including investigations;
- land transport;
- civil aviation and airports;
- transport security;
- delivery of regional and rural specific services;
- maritime transport including shipping;
- regional development;
- matters relating to local government; and
- major projects facilitation

## Australian Stabilisation Industry Association (AustStab)

The Australian Stabilisation Industry Association was formed to promote and enhance the soil stabilisation and road recycling industry in Australia. The Association, commonly known as AustStab, has the following objectives:

- promote road recycling and environmental sustainability,
- set national standards of design and construction performance,
- maintain standards by operating a contactors accreditation scheme
- assist and coordinate research to make improvements, and
- educate and train people in the industry so that stabilisation is well understood.

## Research Project Team

The project team consists of:

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| Research project manager: | George Vorobieff, Project Director, AustStab |
| Financial manager: | Warren Smith, President AustStab (Stabilised Pavements of Australia) |
| Operations manager: | Scott Young, Downer EDI Works |
| Construction manager: | Andrew Middleton, Stabilised Pavements of Australia |
| Mix design specialist: | Peter Sheen, Testrite |


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# Executive Summary

Five potential sites in four Shires in South West NSW were chosen for detailed site investigation and laboratory testing of materials extracted from the site. The following information was sought at each site:

- Description of the subgrade and pavement materials
- Depth of pavement material
- Insitu subgrade CBR to a depth up to 600 mm
- Particle size distribution to AS 1289.3.6.1
- OMC and MDD to AS 1289.5.1.1
- Plasticity Index (PI) to AS 1289.3.3.1

As each trial site was between 1.0 to 1.25 km in length, a minimum of four pits were sought to assess the variation of the materials along the trial section. The selection of the test pits were done in conjunction with Aitken Rowe.

Sufficient material was also extracted from the pits to allow the following tests to be carried out:

- CBR of subgrade material to AS 1289.6.1.1
- Lime Demand of pavement material[1] to the Eades and Grim
- Unconfined compressive strength test

The Lime Demand and UCS testing during the mix design phase were carried out by Testrite and reported in Section 4.

The binders chosen for the trials were (refer to Appendix A for more details):

- Lime – Hydrated lime and quicklime
- Cementitious – GP cement and slag blend
- Insoluble dry powdered synthetic polymer (IDPSP) – Polyroad and hydrated lime blend

The aim of the laboratory test program was to understand the materials that will be stabilised and to make informed decisions on the appropriate binder type and application rate for the site. Table I outlines the binder types and application rates chosen for the construction of the trial sites. It is noted that the proportion of binder is by mass of the sample and not volume. Where hydrated lime has been specified, quicklime had been used on site.

**Table I** Binder type and application rate selected for the unsealed road sites.

| Road Name | Town | Binder type | Application rate |
|---|---|---|---|
| Barber Rd | Griffith | Hydrated lime | 3% |
| Woodlands Rd | Wombat | Cement/slag (70:30)<br>PR11L | 3%<br>2% |
| Old Corowa Rd<br><br>Four Corners Rd | Jerilderie | Hydrated lime<br>PR11L<br>Cement/slag (80:20) | 3%<br>2%<br>4% |
| Back Mimosa Rd | Temora | Hydrated lime<br>PR11L | 4%<br>2% |

[1] In several cases the pavement and subgrade materials were mixed in proportion to the proposed stabilisation depth.

Some key aspects of the laboratory mix design stage are:

- Need to extract a sufficient quantity of granular and subgrade material from the test pits to allow sufficient testing options with more than one binder. A guideline is to be produced to assist Shires and testing laboratories with a method to apply.
- Before carrying out a Lime Demand test on the pavement material review the category and PI of the material.
- If the depth of the pavement material is less than 150 mm it is recommended that testing is carried out using a linear proportion of pavement and subgrade materials based on depth. Should the PI of the pavement material exceed 20, review the possible binder content in light of the formation material and opportunities to use a granular overlay.
- Need to refine the decision making process for lime and polymer types in light of the post construction test results and performance after 12 months.

The laboratory protocols to establish the binder type and application rate will be reviewed during the evaluation of the performance measures at the trial sites.

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# 1 INTRODUCTION

AustStab members have been working with rural local government engineers in NSW to develop long term cost effective solutions to minimise dust generation, reduce demand on gravel pits and decrease the maintenance frequency of unsealed low volume roads. Prudent spending of limited road maintenance funding is paramount to Shires and beneficial to rate payers and the wider public users of these roads.

This report details the site investigation process and the development of a material mix design approach which aims to improve the long term performance of unsealed roads through insitu stabilisation of existing road material. It outlines the mix design, binder selection criteria and test protocols for each of the trial sites and should be read in conjunction with supplementary reports prepared during the performance data collection phase of the project.

This work was jointly funded by AusLink and AustStab. AustStab would also like to acknowledge the involvement and commitment of laboratory staff at Aitken Rowe Laboratories and Testrite.

# 2 TRIAL SITES

Ten initial sites were selected by AustStab in collaboration with Shire engineers from four different Shires in South West NSW (See Figure 1). The site inspections were completed in November 2007 and five potential sites were chosen for detailed investigation. A further site in Temora was investigated in June 2008 after the site investigation indicated that the pavement material may not be suitable for stabilisation.

The pavement material, topography, rainfall and existing performance of the site was taken into consideration in the selection of the trial sites. The sites have been chosen so that a range of materials and road topography could be tested against the mix design limits and field performance. The limits chosen have been empirically based on the experience of Shires and Contractors.

Table 1 and Figure 1 show the location of the proposed trial sites in South West NSW, west of the Great Dividing Range where climatic conditions over the performance monitoring period are likely to be consistent, rather than investigating sites spread over a wider climatic area of Australia. GPS has been used for the location of all sites and control sections; and the coordinates are to the WGA 84 format in decimal degrees.

**Table 1** Unsealed road sites to conduct trials (also refer to Figures 5 to 9).

| Road Name | Town | GPS Coordinates [A] at one end of the site | | Mean Annual Rainfall [B] |
|---|---|---|---|---|
| | | S | E | (mm) |
| Barber Rd | Griffith | 34.25314 | 145.8491 | 400 |
| Woodlands Rd | Wombat | 34.42101 | 148.2581 | 608 |
| Old Corowa Rd<br>Four Corners Rd | Jerilderie | 35.42889<br>34.86002 | 145.8409<br>145.7514 | 420 |
| Derricks Rd<br>Back Mimosa Rd | Temora | 34.42728<br>34.46140 | 147.4916<br>147.50713 | 521 |
| Notes:<br>A. GPS coordinates to WGA 84 format.<br>B. Annual rainfall records to nearest BoM weather station. | | | | |

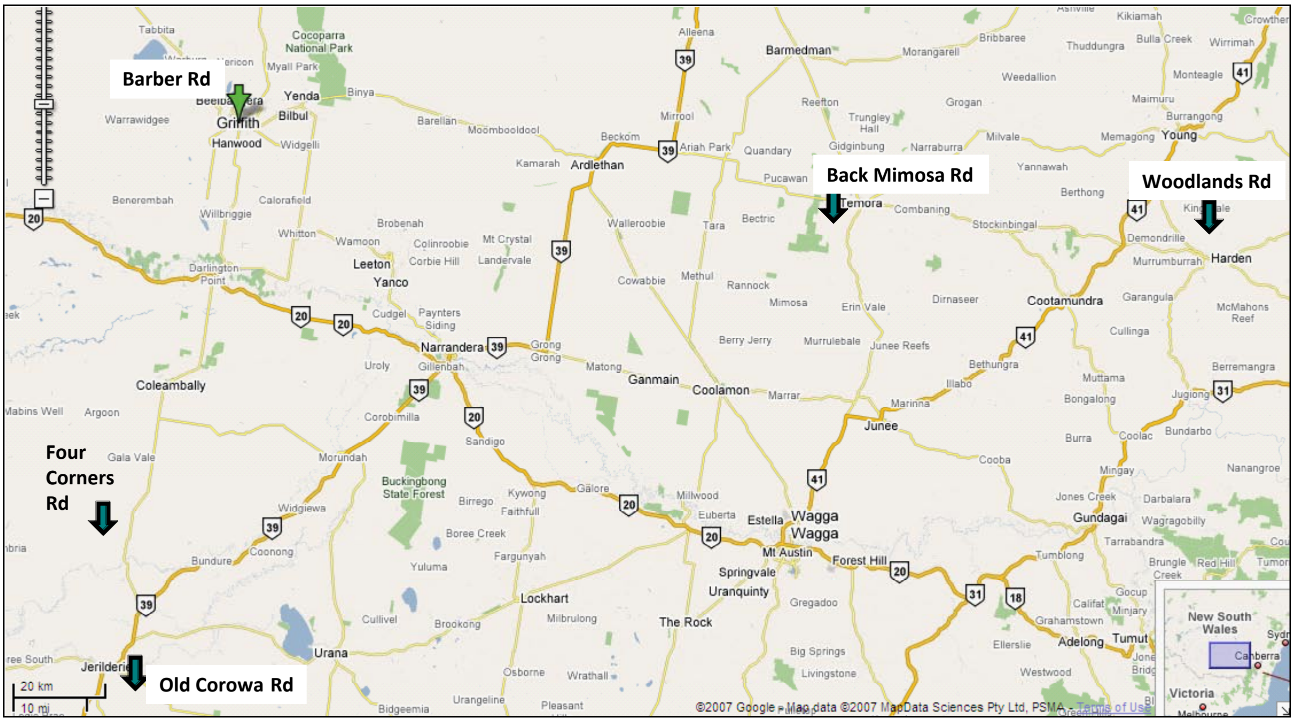


**Figure 1** Location of the final trial sites in the south west region of NSW.

# 3 SITE INVESTIGATION

## 3.1 General

Five initial sites were chosen for the determination of the existing pavement and subgrade materials and Aitken Rowe was selected for the geotechnical investigation at all sites. The following information was sought at each site:

- Description of the subgrade and pavement materials
- Depth of pavement material
- Insitu subgrade CBR to a depth up to 600 mm
- Particle size distribution (PSD) to AS 1289.3.6.1
- Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) to AS 1289.5.1.1
- Plasticity Index (PI) to AS 1289.3.3.1

As each trial site was between 1.0 to 1.25 km in length, a minimum of four pits were considered necessary to assess the variation of the materials along the trial section.

Sufficient material was also extracted from the pits to allow the following tests to be carried out:

- CBR of subgrade material to AS 1289.6.1.1
- Lime Demand of pavement material[2] to the Eades and Grim
- Unconfined compressive strength test

The Lime Demand and UCS testing during the mix design phase were carried out by Testrite and reported in Section 4.

The following sections provide an overview of each trial site.

[2] In several cases the pavement and subgrade materials were mixed in proportion to the proposed stabilisation depth.

## 3.2 Griffith Shire

This Shire is in an important agricultural region of NSW called the SW Riverland. During harvest season, there are considerable traffic increases on both sealed and unsealed roads. The roads initially selected for further inspections were Barber and McNamara Roads, west of Griffith. However upon inspection, it was agreed to start the trial in Barber Road and incorporate the intersection of McNamara Road and a short section of this road (see Figure 2).

The key features of this site were:

- An approximate traffic volume of 30 vehicles per day.
- Unsealed road width of about 8 m with resheeting practice in the region set at 6 m width.
- A relatively flat site.
- Table drains well maintained.
- A section of the road is adjacent to an irrigation channel
- Water was not an issue at this site with standpipe access within 10km.

**Figure 2** View of potential trial site on Barber Road, Griffith (NSW).

Sample material taken from Barber Road was tested and the results are summarised in Table 2 and as follows:

- Much of the existing pavement material consisted of a sandy gravel clay with low plasticity with 80% of the material passing the 19.0 mm sieve, 53% of the material passing the 2.36 mm sieve, 37% passing the 0.425 mm sieve and 17 % passing the 0.075 mm sieve.
- The pavement material was 100 to 140 mm in thickness and therefore up to 50 mm of subgrade material will be required in the stabilisation process. For preliminary testing, it will be assumed that 105 mm (70%) and 45 mm of pavement and subgrade material respectively will be stabilised in the mix design.
- The LL and PI material at pit B1 was 18 and 2respectively. Also, the OMC and MDD of the material was 8.5% and 2.17 t/m$^3$ respectively.

**Table 2** The basic parameters of the pavement and subgrade materials from four test pits at the Barber Road site.

| Details | Pit designation | | | |
|---|---|---|---|---|
| | B1 | B2 | B3 | B4 |
| Chainage (m) | 250 | 500 | 750 | 1000 |
| Offset [A] from road centreline (m) | 1.0 L | 2.0 R | 0.5 R | 2.0 L |
| Pavement layer depth (mm) | 140 | 110 | 100 | 140 |
| Pavement material description by group symbol | GM | GM | CL | CL |
| Description of top of subgrade material | CI-CH 140 - 440 | CI-CH 110 - 430 | CI-CH 140 - 440 | CI-CH 140 – 430 |
| DCP of top of subgrade (%) | 25 | 35 | 33 | 49 |
| 4 day soaked CBR (%)[B] | 10 | - | - | - |
| NOTES: A. Either left (L) or right (R) offsets. B. Subgrade testing at only Site B1. Sample prepared at 95% relative standard compaction. | | | | |

## 3.3 Harden Shire

Harden Shire has a large network of unsealed roads for low volume road traffic. The Shire engineer choose Garryowen, Fairview and Woodlands Roads near the town of Wombat for initial inspections (see Figure 3). Upon further visual investigation of the sites, Woodlands Road was selected as the preferred site because of the intersection and moderate longitudinal grades. The key features of this site were:

- Approximately 30-40 vehicles per day (cars and school buses).
- A section of this road was recently resheeted and would form an adequate control section.
- Trial would commence at the intersection of Gladstone Road.
- Typical width of current unsealed road is 7.7m.
- Table drains well maintained.
- Water was not an issue at this site with standpipe access at Wombat township.

**Figure 3** Views of trial site on Woodlands Road, Wombat (NSW).

Sample material taken from Woodlands Road was tested and the results are summarised in Table 4 and as follows:

- Much of the existing pavement material consisted of a silty sandy gravel with moderate plasticity with 85% of the material passing the 19.0 mm sieve, 53% of the material passing the 2.36 mm sieve, 38% passing the 0.425 mm sieve and 23 % passing the 0.075 mm sieve.
- The pavement material was 100 to 180 mm in thickness and therefore up to 50 mm of subgrade material will be required in the stabilisation process. For preliminary testing, it will be assumed

that 100 mm (67%) and 50 mm of pavement and subgrade material respectively will be stabilised in the mix design.
- The LL and PI material at pit B2 was 27 and 13 respectively. Also, the OMC and MDD of the material was 9.0% and 2.03 t/m$^3$ respectively.

**Table 3** The basic parameters of the pavement and subgrade materials from four test pits at the Woodlands Road site.

| Details | Pit designation | | | |
|---|---|---|---|---|
| | B1 | B2 | B3 | B4 |
| Chainage (m) | 250 | 500 | 750 | 1000 |
| Offset [A] from road centreline (m) | 0.5 R | 2.0 R | 2.5 L | 1.5 R |
| Pavement layer depth (mm) | 180 | 100 | 150 | 150 |
| Pavement material description by group symbol | GP | GP | CL | SC |
| Description of top of subgrade material | CI-CH 180 - 400 | CI 100 - 400 | CI-CH 150 - 400 | CI 150 – 300 SC 300 - 400 |
| DCP of top of subgrade (%) | 55 | 49 | 36 | > 100 |
| 4 day soaked CBR (%)[B] | | 10 | - | - |
| NOTES: A. Either left (L) or right (R) offsets.<br>B. Subgrade testing at only Site B2. Sample prepared at 95% relative standard compaction. | | | | |

## 3.4 Jerilderie Shire

The Shire engineer recommended both Old Corowa and Four Corner Roads as potential sites as they had quite different pavement material types and topography (see Figures 4 and 5). Testing was carried out on both sites to choose one site for the trial.

Sample material taken from Old Corowa Road was tested and the results are summarised in Table 4 and as follows:

- Much of the existing pavement material consisted of a sandy gravel clay with low plasticity with 100% of the material passing the 19.0 mm sieve, 95% of the material passing the 2.36 mm sieve, 58% passing the 0.425 mm sieve and 20 % passing the 0.075 mm sieve.
- The pavement material was 100 to 120 mm in thickness and therefore some 50 mm of subgrade material will be required in the stabilisation process. For preliminary testing, it will be assumed that 100 mm (67%) and 50 mm of pavement and subgrade material respectively will be stabilised in the mix design.
- The LL and PI material at pit B3 was 23 and 9 respectively. Also, the OMC and MDD of the material was 9.5% and 2.01 t/m$^3$ respectively.

Sample material taken from Four Corners Road was tested and the results are summarised in Table 5 and as follows:

- Much of the existing pavement material consisted of a sandy gravel clay with low plasticity with 93% of the material passing the 19.0 mm sieve, 90% of the material passing the 2.36 mm sieve, 63% passing the 0.425 mm sieve and 11 % passing the 0.075 mm sieve.
- The pavement material was 100 to 120 mm in thickness and therefore some 50 mm of subgrade material will be required in the stabilisation process. For preliminary testing, it will be assumed

that 100 mm (67%) and 50 mm of pavement and subgrade material respectively will be stabilised in the mix design.

- The LL and PI material at pit B3 was 17 and 2 respectively. Also, the OMC and MDD of the material was 10.0% and 1.87 t/m$^3$ respectively.

**Figure 4** View of trial site on Old Corowa Road, Jerilderie (NSW).

**Figure 5** View of trial site on Four Corners Road Jerilderie (NSW).

**Table 4** The basic parameters of the pavement and subgrade materials from three test pits at the Old Corowa Road site.

| Details | Pit designation | | | |
|---|---|---|---|---|
| | B1 | B2 | B3 | - |
| Chainage (m) | 125 | 375 | 625 | |
| Offset [A] from road centreline (m) | 1.0 L | 2.0 R | 2.0 L | |
| Pavement layer depth (mm) | 100 | 100 | 120 | |
| Pavement material description by group symbol | CL | CL | GM | |
| Description of top of subgrade material | CI-CH<br>100 – 400 | CL<br>100 – 170<br>CI-CH<br>170 – 230<br>CL-CI<br>230 - 410 | CI-CH<br>150 - 400 | |
| DCP of top of subgrade (%) | > 100 | 53 | 55 | |
| 4 day soaked CBR (%)[B] | 7 | | - | - |
| NOTES: A. Either left (L) or right (R) offsets.<br>B. Subgrade testing at only Site B1. Sample prepared at 95% relative standard compaction. | | | | |

**Table 5** The basic parameters of the pavement and subgrade materials from two test pits at the Four Corners Road site.

| Details | Pit designation | | | |
|---|---|---|---|---|
| | B1 | B2 | - | - |
| Chainage (m) | 125 | 400 | | |
| Offset [A] from road centreline (m) | 2.0 L | 2.0 R | | |
| Pavement layer depth (mm) | 100 | 40 | | |
| Pavement material description by group symbol | CL | CL | | |
| Description of top of subgrade material | SC<br>100 - 460 | SC<br>40 - 410 | | |
| DCP of top of subgrade (%) | 59 | 81 | | |
| 4 day soaked CBR (%)[B] | 20 | | | - |
| NOTES: A. Either left (L) or right (R) offsets.<br>B. Subgrade testing at only Site B1. Sample prepared at 95% relative standard compaction. | | | | |

## 3.5 Temora Shire

The Shire engineer suggested Derricks Road as an appropriate trial site (see Figure 6). This site was found to be relatively flat and straight with poor side drainage. Testing was carried out in December and the results are summarised in Table 6.

**Figure 6** View of trial site on Derricks Road, Temora (NSW).

Sample material taken from Derricks Road was tested and the results are summarised in Table 6 and as follows:

- Half the length of the trial site consisted of a silty sandy gravel with low plasticity with 89% of the material passing the 19.0 mm sieve, 57% of the material passing the 2.36 mm sieve, 42% passing the 0.425 mm sieve and 24 % passing the 0.075 mm sieve. The other half consisted of gravelly sandy clay.
- The pavement material was 80 to 150 mm in thickness and therefore up to 70 mm of subgrade material will be required in the stabilisation process. For preliminary testing, it will be assumed that 105 mm (70%) and 45 mm of pavement and subgrade material respectively will be stabilised in the mix design.
- The LL and PI material at pit B1 was 21 and 6 respectively. Also, the OMC and MDD of the material was 8.0% and 2.07 $t/m^3$ respectively.

**Table 6** The basic parameters of the pavement and subgrade materials from four test pits at the Derricks Road site.

| Details | Pit designation | | | |
|---|---|---|---|---|
| | **B1** | **B2** | **B3** | **B4** |
| Chainage (m) | 250 | 500 | 750 | 1000 |
| Offset [A] from road centreline (m) | 1.5 R | 0.0 | 1.0 L | 1.0 R |
| Pavement layer depth (mm) | 80 | 80 | 150 | 150 |
| Pavement material description by group symbol | GP | GP | CI | CI |
| Description of top of subgrade material | CL<br>80 – 150<br>CI<br>150 - 400 | CI<br>80 - 400 | CL-CI<br>150 – 400 | CI<br>150 – 400 |
| DCP of top of subgrade (%) | > 100 | > 100 | > 100 | > 100 |
| 4 day soaked CBR (%)[B] | | | 16 | - |
| NOTES: A. Either left (L) or right (R) offsets.<br>B. Subgrade testing at only Site B3. Sample prepared at 95% relative standard compaction. | | | | |

Subsequent to the laboratory testing of materials for Derricks Road, the use of lime seemed to not fit the mix design limits, and another site was sought with the Shire engineer. The next site to be investigated was Back Mimosa Road just south of the township (see Figure 7). Sample material taken from Back Mimosa Road was tested and the results are summarised in Table 7 and as follows:

- Much of the existing pavement material consisted of a fine to coarse grained gravel with low plasticity.
- The pavement material was 70 to 170 mm in thickness and therefore some 80 mm of subgrade material may be required in the stabilisation process. For preliminary testing, it will be assumed that 105 mm (70%) and 45 mm of pavement and subgrade material respectively will be stabilised in the mix design.
- The LL and PI material at various test pits are detailed in Tables 8 and 9 for the pavement and subgrade material respectively. Also, the OMC and MDD of the materials are detailed in Tables 8 and 9.

**Figure 7** View of trial site on Back Mimosa Road, Temora (NSW).

**Table 7** The basic parameters of the pavement and subgrade materials from four test pits at the Back Mimosa Road site.

| Details | Pit designation | | | |
|---|---|---|---|---|
| | **B1** | **B2** | **B3** | **B4** |
| Chainage (m) | 0.8 | 500 | 800 | 1100 |
| Offset [A] from road centreline (m) | 1.0 L | 0.0 | 0.0 | 0.0 |
| Pavement layer depth (mm) | 80 | 70 | 170 | 160 |
| Pavement material description by group symbol | | | | |
| Description of top of subgrade material | ML<br>80 – 200 | CL-CI<br>700 - 200 | -<br>170 - 240 | -<br>160 – 240 |
| DCP of top of subgrade (%) | 55 | 55 | 55 | 55 |
| 4 day soaked CBR (%)[B] | - | - | - | 4 |
| NOTES: A. Either left (L) or right (R) offsets.<br>B. Subgrade testing at only Site B4. Sample prepared at 95% relative standard compaction. | | | | |

**Table 8** The PSD, LL and PI of the pavement materials from four test pits at the Back Mimosa Road site.

| Details | Pit designation | | | |
|---|---|---|---|---|
| | **B1** | **B2** | **B3** | **B4** |
| Chainage (m) | 0.8 | 500 | 800 | 1100 |
| Particle Size Distribution: % passing the | | | | |
| - 19.0 mm | 91 | 83 | 60 | 75 |
| - 2.36 mm | 52 | 39 | 27 | 28 |
| - 0.425 mm | 32 | 28 | 18 | 20 |
| - 0.075 mm | 15 | 15 | 12 | 11 |
| Max. Dry Density (t/m3) | 2.02 | 2.08 | 2.05 | 2.02 |
| Optimum Moisture Content (%) | 8.3 | 8.0 | 9.1 | 9.5 |
| Liquid Limit (%) | 22 | 25 | 23 | 24 |
| Plasticity Index (%) | 6 | 10 | 5 | 8 |
| Insitu moisture content | 2.2 | 1.9 | 1.8 | - |

**Table 9** The PSD, LL and PI of the subgrade materials from four test pits at the Back Mimosa Road site.

| Details | Pit designation | |
|---|---|---|
| | **SG1** | **SG2** |
| Chainage (m) | 0.8 | 500 |
| Particle Size Distribution: % passing the | | |
| - 19.0 mm | 100 | 93 |
| - 2.36 mm | 95 | 55 |
| - 0.425 mm | 87 | 43 |
| - 0.075 mm | 71 | 26 |
| Max. Dry Density (t/m3) | 1.94 | 2.00 |
| Optimum Moisture Content (%) | 11.3 | 8.9 |
| Liquid Limit (%) | 17 | 22 |
| Plasticity Index (%) | 3 | 5 |
| Insitu moisture content | 2.0 | 2.2 |

# 4 INTERIM MIX DESIGN

## 4.1 General

The limited funding and low traffic volume of unsealed roads provides little incentive for Shires to carry out site investigations into the material properties of the pavement and formation (subgrade). For this research project, the minimum laboratory testing was carried out with the extracted materials.

As the goal of the research project was to form a lightly bound material after stabilisation, the definition of modified and bound materials published by Austroads (see Table 10) was adopted for this project. Stabilisation binders used in roadworks are manufactured to either specific Australian Standards or the relevant road authority specifications. The following Austroads approach to categorise binder types in common usage in Australia was used:

- Lime (AS 1672.1)
- Cement (AS 3972)
- Bitumen (AS 2008 for hot bitumen for foaming and AS 2341 for emulsions)
- Slag (AS 3582.2)
- Fly ash (AS 3582.1)

It is noted that there are no recognised standards for chemicals binders. More information about binder types is detailed in Appendix A.

Dust suppressants were not used in this study due to their limited life and requirement to apply again on a regular basis. In addition, many proprietary products exist today that are hard to identify (Andrews, 2001 & Andrews, 2007) and it would have been an expensive exercise to test numerous dust suppressants and develop separate protocols for each suppressant type.

**Table 10** The difference between bound, modified and granular materials stabilised with a binder (Austroads, 2006).

| Category of stabilisation | Indicative laboratory strength after stabilisation | Common binders adopted | Anticipated performance attributes |
|---|---|---|---|
| Subgrade | CBR[1] > 5%<br>(subgrades and formations) | Addition of lime<br>Addition of chemical binders | Vertical deformation<br>Shear failure<br>Seasonal heave & shrinkage |
| Granular | 40% < CBR[1] < +100%<br>(subbase and basecourse) | Blending other granular materials which are classified as binders in the context of this Guide. | Flexible pavement subject to shear failure within pavement layers and/or subgrade deformation |
| Modified | 0.7 MPa < UCS[2] < 1.5 MPa<br>(basecourse) | Addition of small quantities of cementitious binders<br>Addition of lime<br>Addition of chemical binders | Flexible pavement subject to shear failure within pavement layers and/or subgrade deformation.<br>Can also be subject to erosion by water penetration through cracks.<br>Increased volumetric stability |
| Bound | UCS[2] > 1.5 MPa<br>(basecourse) | Addition of higher quantities of cementitious binder<br>Addition of a combination of cementitious and bituminous binders | Bound pavement subject to tensile fatigue cracking and transverse shrinkage cracking.<br>Low binder contents may be subjected to erosion through pumping through cracks |
| Notes: 1. Four day soaked CBR. 2.Values determined from test specimens stabilised with GP cement and prepared using standard compactive effort, normal curing for a minimum 28 days and 4 hour soak conditioning. | | | |

With limited funding for the project, it was decided at the start of the project to target lime for the unsealed roads. If Shire engineers want to assess the use of other binders however, it is recommended that the guidelines in Table 11 are used where the usual range of the suitability of various binders is based on the percentage of material passing the 0.425 mm sieve and the plasticity index (PI) of the pavement material. The weighted plasticity index (WPI) is equal to the percent passing 0.425 mm multiplied by the Plasticity Index (PI). This provides a guide for more detailed studies with particular materials and particular stabilising binders.

**Table 11** Guide to selecting a binder with limited site material data (Austroads, 2006).

| Particle Size | MORE THAN 25% PASSING 0.425mm | | | LESS THAN 25% PASSING 0.425mm | | |
|---|---|---|---|---|---|---|
| Plasticity Index | PI ≤ 10 | 10 < PI <20 | PI ≥ 20 | PI ≤ 6<br>WPI ≤ 60 | PI ≤ 10 | PI > 10 |
| Binder Type | | | | | | |
| Cement and Cementitious Blends* | Usually suitable | Doubtful or Supplementary binder required | Usually not Suitable | Usually suitable | Usually suitable | Usually suitable |
| Lime | Doubtful or Supplementary binder required | Usually suitable | Usually suitable | Usually not Suitable | Doubtful or Supplementary binder required | Usually suitable |
| Bitumen | Doubtful or Supplementary binder required | Doubtful or Supplementary binder required | Usually not Suitable | Usually suitable | Usually suitable | Usually not Suitable |
| Bitumen/ Cement Blends | Usually suitable | Doubtful or Supplementary binder required | Usually not Suitable | Usually suitable | Usually suitable | Doubtful or Supplementary binder required |
| Granular | Usually suitable | Usually not Suitable | Usually not Suitable | Usually suitable | Usually suitable | Doubtful or Supplementary binder required |
| Polymers | Usually suitable | Usually suitable | Usually not Suitable | Usually suitable | Usually suitable | Usually not Suitable |
| Miscellaneous Chemicals** | Usually not Suitable | Usually suitable | Usually suitable | Usually not Suitable | Doubtful or Supplementary binder required | Usually suitable |

Key: Usually suitable (solid) · Doubtful or Supplementary binder required (hatched) · Usually not Suitable (blank)

NOTES:

* The use of some chemical binders as a supplementary addition can extend the effectiveness of cementitious binders in finer soils and higher plasticities

** Should be taken as a broad guideline only. Refer to trade literature for further information.

The primary binder chosen for this research project is lime. Lime is widely used in Australia to improve subgrade support, dry clays, and improve capping layers. It is also used for the treatment of acid sulfate soils (AustStab, 2006).

As noted in Table 12 the Weighted Plasticity Index is usually a simple method to distinguish between the application of lime, cement or other binders, and Table 12 list the WPI and recommended binder for each trial site using the guidelines from Table 11. The outcome from Tables 11 and 12 indicate that most of the sites are more favourable for the use of a cementitious binder with the base material only in the stabilisation process. However, as the other sections in this report has indicated, the potential for subgrade material to be incorporated into the stabilisation process would in most cases increase the PI[3] and change the potential for lime to be a more appropriate binder.

[3] The initial site investigations did not establish the PI of the subgrade material and therefore, no further calculations could be carried out using the possible PI of the combined pavement and subgrade materials.

**Table 12** Using the PI and PSD to establish preliminary binder choice.

| Site | PI | % passing 0.425mm | WPI | Remarks |
|---|---|---|---|---|
| Barber Rd, Griffith | 2 | 37 | 74 | Cementitious |
| Woodlands Rd, Wombat | 13 | 38 | 494 | Lime |
| Old Corowa Rd, Jerilderie | 9 | 58 | 522 | Cementitious |
| Four Corners Rd, Jerilderie | 2 | 63 | 126 | Cementitious |
| Derricks Rd, Temora | 6 | 42 | 252 | Cementitious |
| Back Mimosa Rd, Temora | 6 | 32 (B1) | 192 | Cementitious |
| | 5 | 19 (B3) | 95 | Cementitious |

AustStab was also asked to test an insoluble synthetic polymer in the trial. More details about these binders are covered in Appendix A of this report.

Lime is suited to subgrade and pavement materials with a medium to high clay content. As some soils in Australia tend to be more of a sandy clay, cementitious binders[4] are more likely to be effective than lime. Some sites were not suited to lime stabilisation during this project as analysis of the soil extracted from the trial sites indicated that a cementitious binder could provide better long term results. However, AustStab is keen to use those binders that have a propensity to perform well based on extensive experience.

## 4.2 Binder selection and application rate protocols

### *4.2.1 General*

No material has been published on the material mix design procedure for the use of lime, cement and synthetic polymers for the stabilisation of unsealed roads. The proposed mix design has been based on experience from practitioners and it is similar to the approach adopted for the stabilisation of pavement materials for sealed roads.

Standard soil testing protocols such as soil classification, particle size distribution and plasticity index were carried out on sample material from each site to determine the capacity of the material to react with lime, synthetic polymer or a cementitious blend.

The following sections outline the test protocols adopted for the laboratory mix design program and recommendations for further investigation.

### *4.2.2 Lime*

The common tests carried out for lime stabilisation for roads are:

- Determination of the Available Lime Index (ALI) of the lime[5]
- Lime demand test
- Determination of CBR for subgrade materials
- Unconfined compressive strength (UCS) for pavement materials
- Capillary rise and swell potential where wet subgrades and/or sensitive soils are evident

The sources of quicklime supplied to NSW road construction sites have a typical available lime index exceeding 80%. Although lime will generally be sourced from NSW due to the lower cartage costs, if it is

[4] Cementitious binders are those binders that consist of cement, slag, fly ash and lime in various ratios to form a cemented material after mixing, compaction and curing.
[5] ALI normally supplied by lime manufacturer.

sourced from other regions with an ALI lower than 80%, linear adjustments will be made to the application rate. For example if quicklime is supplied with an ALI of 65%, the application rate established in the laboratory studies will be increased by 85/65 or 1.31.

The lime demand test is a commonly used test in Australia to provide guidance on the minimum lime content to ensure long term chemical bonding of the lime with the clay particles. This test was used to establish the lower limit of the lime application rate and the result was used in conjunction with the 28-day UCS results.

There are no current guidelines for the minimum UCS for the application of lime stabilisation on unsealed roads. Austroads documents note that a bound pavement forms when the UCS at 28-days curing is greater than 1.5 MPa and this will form the initial lower limit to the lime content (Austroads, 2006).

Work by Little (Little, 1995) indicates that lime in clay gains strength over time. The UCS at 6 months will therefore be determined at each site to gauge the ratio of short and long term strength for the stabilised pavement materials. The long term strength results are reported in the document titled *The performance of the insitu stabilisation of unsealed road trials using lime, cement and polymers binders – Interim Report A* (due to be published in 2009).

Experience indicates that the minimum lime content may not be sufficient for all sections of unsealed roads and where high shear forces from turning traffic exists. At sites with turning traffic, the lime application rate will therefore be increased by 2% or double the minimum content depending on the UCS results. The recommended application rate for intersections, steep longitudinal grades or curved alignments will be reviewed after short and long-term performance evaluation.

Capillary rise and swell testing will not be carried out on these sites as much of the material stabilised with clay immediately reduces the effect of capillary rise. With no known published limits, the testing could therefore not be used to make a decision on the design application rate.

### *4.2.3 Synthetic polymers*

Similar to lime stabilisation, the standard basic soil parameters, such as MDD, OMC, grading and PI, were determined on the pavement material. Figure 8 shows the selection and application rate (by mass) of insoluble dry powdered synthetic polymer (IDPSP) under specific pavement conditions (AustStab, 2007). This pavement material selection diagram may not be applicable to all IDPSPs and further information should be sought from the binder supplier based on laboratory and performance data. The binders designated in Figure 8 are as follows:

- PR100 – Polymix with no other supplementary binder
- PR11L – Equal proportions of Polymix and hydrated lime[6] pneumatically blended
- PR21L –Polymix and hydrated lime (67:33) pneumatically blended

IDPSP binders do not typically bind the subgrade or pavement materials after mixing and compaction, and do not create a bound material. Therefore, after the binder is selected using PI values taken from the site investigation and taking into consideration possible blending of the pavement and subgrade material, it is recommended that a capillary rise test is carried out comparing the moisture rise of the untreated material against the treated material. It is generally accepted that this treated material will perform well if the capillary rise is within the limits detailed in Figure 8.

[6] Hydrated lime used for blending must have a minimum Available Lime Index of 85%.

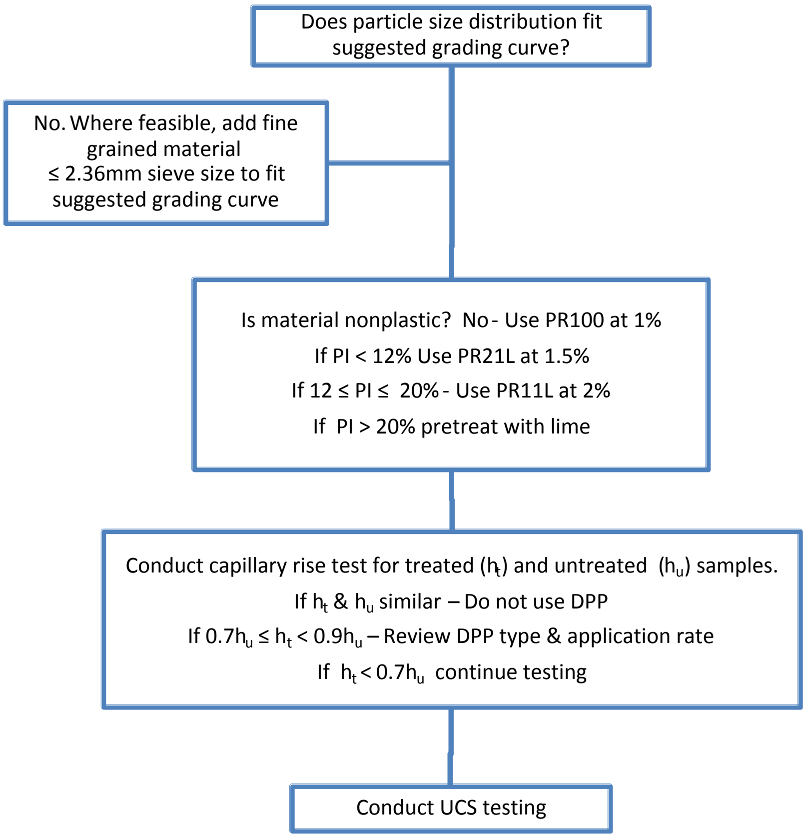


**Figure 8** Determination of IDPSP binders (such as Polyroad) for granular pavement materials.

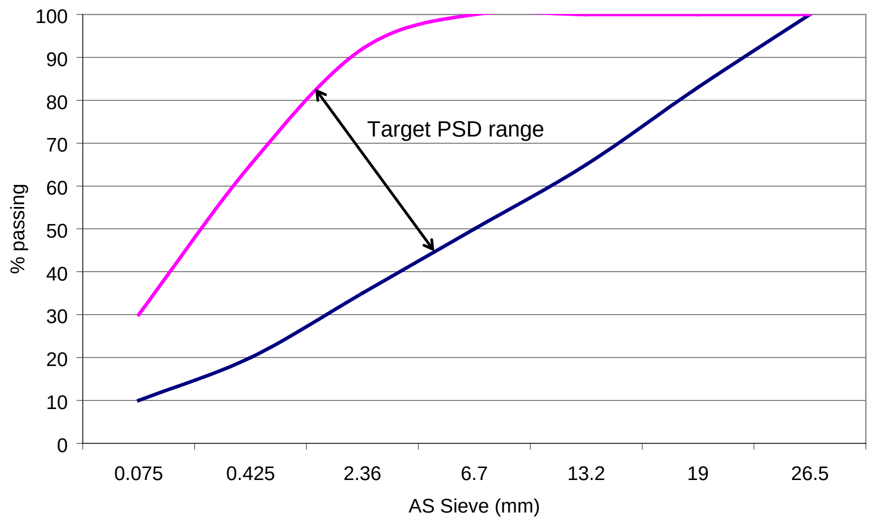


**Figure 9** Suggested particle size distribution range for IDPSP binders (Lacey, 2006).

The final stage in the mix design with these polymer binders is to check that the UCS value is less than 0.75 MPa to ensure the material remains unbound. However during the preparation of the samples for capillary rise, an experienced technician should be able to determine if the material is unbound and therefore, the testing would not proceed. During construction, sampling of the mixed material could be taken back to the laboratory to prepare UCS samples for subsequent capillary rise and UCS testing if local experience is limited.

### *4.2.4 Cementitious*

UCS testing has been the foundation for the determination of the application rate for cement stabilised materials for many years. The minimum design application rate will be the cement content that provides for a minimum 1.5 MPa UCS at 28-days curing period. As noted in Table 11, cementitious binders will not achieve the necessary strength if the material being treated has a high PI and clay content.

## 4.3 Test methods

### *4.3.1 General*

The Australian standards test methods for investigating soil properties were adopted for all materials received from these trial sites.

As noted in the report, the minimum stabilisation depth for the stabilisation of unsealed roads with a binder has been set at 150 mm. Where the existing granular pavement material is less than 150 mm in thickness, the testing protocol required the use of the formation material, if the PI of this material was less than 20. In all cases, the PI of the formation material was less than 20 and the material for testing was used in linear combination by dry mass.

### *4.3.2 Compaction and curing*

The mixing of lime or other binders should not commence until the depth and PI of the pavement and formation material is known. As noted previously, the binder content should be mixed with the proposed combination of formation and pavement materials.

The lime and cemented materials were compacted using 100% standard compactive effort and cured under standard laboratory curing periods for 28-days. This is considered a satisfactory approach given the low volume of traffic these roads are expected to carry and the limited funding to support higher reliability.

All polymer treated samples were also compacted using 100% standard compactive effort and cured for 7 days at laboratory table curing conditions. The mass of the sample after compaction and at 5, 6 and 7 days was measured and curing was considered completed when the change in daily mass was less than 10 gm.

### *4.3.3 Lime Demand Test*

The Eades and Grimm test was used to establish the lime demand for the various materials proposed for stabilisation.

### *4.3.4 Unconfined compressive strength test*

The RTA Test Method T131 was used for the UCS testing with a 4-hour soak prior to testing. Whilst RTA Test Method T131 was used for the unconfined compressive strength test during the research project, using AS 1141.54 with the following requirements would produce similar testing conditions:

- Samples are compacted to Standard Compactive effort
- Curing is carried out at 23˚C for 28 days
- Samples are soaked for four hour prior to testing

These unsealed roads are subject to moisture during rainfall even with a sufficient camber and therefore a 4 day soak was considered necessary. For unsealed roads subject to average annual rainfall exceeding 800ml, a longer soaking period should be considered.

### *4.3.5 Capillary rise test*

All capillary rise testing was carried out to AS1141.53 with samples untreated and treated with the polymer binder (see Figure 10). The average height of the water rise will be measured at about 12 hour intervals and the test will cease after 3 days or at which time the water has risen to the top of both samples.

Capillary rise testing was only carried out for the material stabilised with the polymer. It is an optional test when lime or cementitious binders are used as there is no guidance on how to establish suitable limits of capillary rise and it is common to compare the rise of untreated and treated material.


**Figure 10** Untreated (left photo) and treated samples after the capillary rise test.

## 4.4 Test results

### 4.4.1 General

Five sites were chosen in conjunction with the Shire engineers for detailed site investigation. The following section provides the test results after the samples were prepared and tested at each of the proposed sites.

The Lime Demand test was carried at the start of the laboratory mix design program to give and indication if the minimum or default hydrated lime content of 3% would be sufficient for long term stabilisation.

Table 13 lists the pH readings at different lime application rates for four of the trial sites. The test results are indicative of pavement materials with a low clay content and therefore, the default lime content of 3% will be used in the initial UCS testing for each of the sites.

**Table 13** Lime demand test results for several of the trial sites.

| % hydrated lime | Location | | | |
|---|---|---|---|---|
| | Barber Rd | Woodlands Rd | Old Corowa | Derricks Rd |
| | pH reading | | | |
| 2 | 12.39 | 12.51 | 12.42 | 12.39 |
| 3 | 12.48 | 12.58 | 12.53 | 12.51 |
| 4 | 12.51 | 12.60 | 12.55 | 12.54 |
| 5 | 12.52 | 12.62 | 12.56 | 12.55 |
| 6 | 12.54 | 12.63 | 12.57 | 12.57 |

### 4.4.2 Griffith Shire

Due to the depth of the existing pavement material it was determined that the pavement material to be stabilised consisted of 70% (B1) of the brown gravelly silty clay with 30% (SG1) of red brown sandy silty clay with some gravel. The ratio of mixing was based on a percentage by mass of material collected at insitu moisture content.

Table 14 shows the UCS test results for Barber Road and it indicates that 3% hydrated lime would meet the design criteria for UCS strength of the material. The 28-day UCS values for this site were 1.1 and 1.2 MPa which was below the minimum criteria of 1.5 MPa.

**Table 14** The UCS results for samples from taken from Barber Road, Griffith using hydrated lime.

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | B1/A | B1/B | B1/C | B1/D |
| Dry density ($t/m^3$) | 2.03 | 2.05 | 2.02 | 2.03 |
| Moisture content as moulded (%) | 10.7 | 10.7 | 10.3 | 10.3 |
| Binder rate (%) | 3.0 | 3.0 | 3.0 | 3.0 |
| UCS (MPa) | 1.15 | 1.1 | 1.2 | 1.15 |

PR21L at 1.5% application rate was chosen for Barber Road and the capillary rise was to the top of the untreated and treated samples within one day (see Table 15). It was decided that a polymer trial would not be warranted on this site with the existing pavement materials.

**Table 15** The capillary rise test results for samples taken from Barber Road, Griffith and treated with 1.5% PR21L polymer binder.

| | 1 (not treated) | 2 (polymer) |
|---|---|---|
| Start date and time: 17.03.08 11:15 | | |
| Rise at 17.03.08 15:30 | 100 | 75 |
| Rise at 18.03.08 6:00 | 115 | 115 |
| Rise at 18.03.08 16:45 | 115 | 115 |
| Capillary rise after 72 hours | 100 | 100 |
| Water absorption of specimen (%) | 12 | 12 |
| Notes: Polymer treated sample air cured to equilibrium moisture at 14 days. | | |

### 4.4.3 Harden Shire

Testing was carried out on pavement and subgrade material from Woodlands Road, Wombat using lime and polymer binder. Testing was carried out by Testrite on the 19th March 2008 with the UCS test results for the hydrated lime at application rates of 3% and 5%. The test results in Table 16 shows that the lime was not providing significant strength increase with the pavement material for this site. It was determined that a cementitious binder would more than likely work with this material and a cement/slag binder was chosen for further testing.

**Table 16** The UCS results for samples taken from Woodlands Road, Wombat using hydrated lime.

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | **B4/A** | **B4/B** | **B4/C** | **B4/D** |
| Dry density ($t/m^3$) | 2.07 | 2.06 | 2.04 | 2.04 |
| Binder rate (%) | 3 | 3 | 5 | 5 |
| UCS (MPa) | 0.25 | 0.25 | 0.35 | 0.45 |

The second round of testing was carried out by Testrite on 6th May 2008 with the UCS test results for the cement and slag binder at 2.0 MPa for an application rate of 3%. No further testing was required and it was recommended that the minimum application rate be 3% of cement/slag (80:20) blend. However new information was received after testing and a cement blend with 30% of slag was chosen. No further testing was carried out prior to construction but post construction testing was done to confirm that strength was achieved for the stabilised insitu material using the slightly different cementitious binder.

**Table 17** The UCS results for samples taken from Woodlands Road, Wombat using cement/slag (80:20) blend.

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | **B4/A** | **B4/B** | **B4/C** | **B4/D** |
| Dry density ($t/m^3$) | 2.11 | 2.11 | 2.11 | 2.10 |
| Binder rate (%) | 3 | 3 | 5 | 5 |
| UCS (MPa) | 2.1 | 1.9 | 2.7 | 2.85 |

Based on the PI of the material, PR11L at 2% application rate was chosen for this site. Capillary rise testing was carried out for the untreated and treaded samples (see Table 18) and water had risen to the top in 2 days and 20 mm above the water reservoir after 3 days respectively. These results indicated that PR11L should perform satisfactorily in the trial.

**Table 18** The capillary rise results in mm for samples taken from Woodlands Road, Wombat and treated with 2% PR11L polymer binder.

| | **1 (not treated)** | **2 (polymer)** |
|---|---|---|
| Start date and time: 17.03.08 11:15 | | |
| Rise at 17.03.08 15:30 | 40 | 20 |
| Rise at 18.03.08 6:00 | 75 | 20 |
| Rise at 18.03.08 16:45 | 90 | 20 |
| Rise at 19.03.08 6:45 | 115 | 20 |
| Rise at 19.03.08 16:00 | 115 | 20 |
| Rise at 20.03.08 6:00 | 115 | 20 |
| Rise at 20.03.08 15:00 | 115 | 20 |
| Capillary rise after 72 hours | 100 | 17 |
| Water absorption of specimen (%) | 10 | 2 |
| Notes: Polymer treated sample air cured to equilibrium moisture at 14 days. | | |

### 4.4.4 Jerilderie Shire

Testing was carried out on pavement material from Old Corowa and Four Corner Roads using lime, cementitious and polymer binders.

Due to the depth of the existing pavement material Old Corowa Road it was determined that the pavement material to be stabilised consisted of 67% (B2) of the yellow/brown silty clay sand with 33% (SG2) of yellow/grey gravelly sand & dark grey plastic clay lumps. The ratio of mixing was based on a percentage by mass of material collected at insitu moisture content. The geometric combined PI and material passing the 0.425 mm sieve for the blended pavement material was 14% and 64% respectively.

Table 19 shows the 28-day UCS test results for Old Corowa Road and for this site the UCS was 0.8 MPa which was below the minimum criteria of 1.5 MPa. However given the variability of the pavement depth and the increase in strength from the lime reaction over time, a 3% application rate of lime was suitable for this trial site and subsequent testing may indicate that the 1.5 MPa limit may be reduced to a lover value based on the outcomes from the performance test results.

**Table 19** The UCS results for samples from taken from Old Corowa Road, Jerilderie using hydrated lime.

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | B2/A | B2/B | B2/C | B2/D |
| Dry density (t/m$^3$) | 1.92 | 1.92 | 1.92 | 1.90 |
| Binder rate (%) | 3.0 | 3.0 | 5.0 | 5.0 |
| UCS (MPa) | 0.75 | 0.85 | 0.70 | 0.90 |

Based on the PI of the material, PR11L at 2% application rate and PR21L at 1.5% application rate were chosen for this site. Capillary rise testing was carried out for the untreated and treaded samples (see Table 20) and water had risen to the top within 2 hours for the untreated sample and with 2 days for the PR21L treated material. However, the PR11L treated material showed that moisture did not rise within the test period. These results indicated that PR11L should perform satisfactorily in the trial.

**Table 20** The capillary rise results in mm for samples taken from Old Corowa Road, Jerilderie and treated with 2% PR11L (A) and 1.5% PR21L (B) polymer binder.

| | Sample Designation | | |
|---|---|---|---|
| | 1 (not treated) | 2 (Polymer A) | 3 (Polymer B) |
| Start date and time: 21.04.08 6:00 | | | |
| Rise at 21.04.08 :15 | 115 | 10 | 40 |
| Rise at 21.04.08 14:00 | 115 | 10 | 60 |
| Rise at 22.04.08 6:00 | 115 | 30 | 90 |
| Rise at 22.04.08 13:00 | 115 | 30 | 105 |
| Rise at 23.04.08 6:00 | 115 | 30 | 115 |
| Rise at 23.04.08 16:00 | 115 | 30 | 115 |
| Rise at 24.04.08 7:00 | 115 | 30 | 115 |
| Capillary rise after 72 hours | 100 | 26 | 100 |
| Water absorption of specimen (%) | 14 | 5 | 6 |
| Notes: Polymer treated sample air cured to equilibrium moisture at 14 days. | | | |

The depth of the existing pavement material Four Corners Road was similar to Old Corowa Road, and it was determined that the pavement material to be stabilised consisted of 67% (B2) of the orange/brown gravelly silty clayey sand with 33% (SG1) of orange/brown silty sand. The ratio of mixing was based on a percentage by mass of material collected at insitu moisture content. The geometric combined PI and material passing the 0.425 mm sieve for the blended pavement material was 1% and 68% respectively. A cementitious binder would be more suitable than lime for a somewhat non-plastic material.

Table 21 shows the 28-day UCS test results for Four Corners Road and for this site the UCS was 1.5 and 3.0 MPa for binder application rates of 3 and 5% respectively, which was at the minimum criteria of 1.5 MPa.

**Table 21** The UCS results for samples from taken from Four Corners Road, Jerilderie using cement/slag blend (80:20).

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | **B2/A** | **B2/B** | **B2/C** | **B2/D** |
| Dry density (t/m$^3$) | 1.91 | 1.90 | 1.92 | 1.92 |
| Binder rate (%) | 3.0 | 3.0 | 5.0 | 5.0 |
| UCS (MPa) | 1.55 | 1.50 | 2.85 | 3.15 |

### 4.4.5 Temora Shire

Testing was carried out on pavement material from Derricks Roads using lime and polymer binders. The UCS and capillary rise test results are shown in Table 22. The data indicated that the lime at application rates of 3 and 5% did not meeting the minimum strength criteria of 1.5 MPa.

For the capillary rise test required for the polymer binder, PR21L at an application rate of 1.5% was chosen for testing. It was found that the capillary rise was at and near the top of the sample within 3 days for the treated and untreated samples respectively, indicating that the polymer was unsuitable for the pavement material at this site (see Table 22).

After review of the UCS and capillary rise laboratory results and discussion with the Shire engineer, it was agreed to select another site for an unsealed road trial in Temora.

**Table 22** The UCS results for samples from taken from Derricks Road, Temora using hydrated lime.

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | **B3/A** | **B3/B** | **B3/C** | **B3/D** |
| Dry density (t/m$^3$) | 1.99 | 1.99 | 1.95 | 1.94 |
| Binder rate (%) | 3 | 3 | 5 | 5 |
| UCS (MPa) | 0.40 | 0.35 | 0.35 | 0.35 |

**Table 23** The capillary rise results in mm for samples taken from Derricks Road, Temora and treated with 1.5% PR21L polymer binder.

| | **1 (not treated)** | **2 (polymer)** |
|---|---|---|
| Start date and time: 17.03.08 11:15 | | |
| Rise at 17.03.08 15:30 | 57 | 35 |
| Rise at 18.03.08 6:00 | 90 | 60 |
| Rise at 18.03.08 16:45 | 95 | 70 |
| Rise at 19.03.08 6:45 | 110 | 75 |
| Rise at 19.03.08 16:00 | 112 | 85 |
| Rise at 20.03.08 6:00 | 115 | 95 |
| Rise at 20.03.08 15:00 | 115 | 100 |
| Capillary rise after 72 hours | 100 | 87 |
| Water absorption of specimen (%) | 12 | 9 |
| Notes: Polymer treated sample air cured to equilibrium moisture at 14 days. | | |

Back Mimosa Road was identified by the Shire engineer as another potential site for the project and Tables 24 and 25 list the UCS testing results. The UCS results using hydrated lime did not reach the minimum value. Of all the trial sites none of the sites have been prepared below the lower bound of minimum strength and this site provides an opportunity for looking at early distress of the treated pavement. In addition, this site may also beneficial to trial stabilisation at 150 mm and 200 mm depths leading to some indication whether that depth may be a factor in performance in roads that may be subject to flooding.

**Table 24** The UCS results for samples taken from TP2 at Back Mimosa Road, Temora using hydrated lime.

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | TP2B(a) | TP2B(a) | TP2C(a) | TP2C(b) |
| Dry density (t/m$^3$) | 1.98 | 1.99 | 1.95 | 1.95 |
| Binder rate (%) | 3 | 3 | 5 | 5 |
| UCS (MPa) | 0.23 | 0.27 | 0.28 | 0.29 |

**Table 25** The UCS results for samples taken from TP3 at Back Mimosa Road, Temora using hydrated lime.

| Property | Sample Designation | | | |
|---|---|---|---|---|
| | TP3B(a) | TP3B(b) | TP3C(a) | TP3C(b) |
| Dry density (t/m$^3$) | 2.02 | 2.02 | 2.01 | 2.01 |
| Binder rate (%) | 5 | 5 | 5 | 5 |
| UCS (MPa) | 0.30 | 0.28 | 0.33 | 0.33 |

Similar to Derricks Road the capillary rise test was carried out on pavement material for Back Mimosa Road but using a polymer binder with a higher lime content, that is PR11L. The test results are shown in Table 26 and indicated that the polymer binder was not appropriate for this pavement material. However, since only two out of three sites had been chosen for the polymer, this would be the last possible site and therefore, appropriate to assess the lower bound.

**Table 26** The capillary rise results in mm for samples taken from Back Mimosa Road, Temora and treated with 2% PR11L polymer binder.

| | 1 (not treated) | 2 (polymer) |
|---|---|---|
| Start date and time: 8.07.08 8:30 | | |
| Rise at 8.07.08 16:30 | 75 | 60 |
| Rise at 9.07.08 8:00 | 100 | 90 |
| Rise at 9.07.08 17:00 | 105 | 100 |
| Rise at 10.07.08 8:00 | 115 | 105 |
| Rise at 11.07.08 8:00 | 115 | 115 |
| Capillary rise after 72 hours | 100 | 100 |
| Water absorption of specimen (%) | 9 | 6 |
| Notes: Polymer treated sample air cured to equilibrium moisture at 7 days. | | |

## 4.5 Refinements for test protocols

The test program adopted in early 2008 indicated that Lime Demand test was a good indicator for the minimum lime content. However, all of the test sites had more granular materials than clay with lower than expected Plasticity Index (PI) leading to trialling the nominal lime content of 3% in the UCS test program. It is recommended that if the PI of the granular material is less than 10 and the depth of the pavement layer from the test pit is less than 100 mm, a Lime Demand test should be carried out on the combined formation and pavement materials.

The project consistently used 28-days as the standard curing procedure for strength testing. Further investigation is required to potentially develop a short term (ie 7 days) accelerated curing procedure for lime stabilised materials.

# 5 BINDER APPLICATION SUMMARY

Table 27 outlines the binder types and application rates chosen for the construction of the trial sites. It is noted that the proportion of binder is by mass of the sample and not volume.

Where hydrated lime has been specified, quicklime had been used on site.

**Table 27** Binder type and application rate selected for the unsealed road sites.

| Road Name | Town | Binder type | Application rate |
|---|---|---|---|
| Barber Rd | Griffith | Hydrated lime | 3% |
| Woodlands Rd | Wombat | Cement/slag (70:30)<br>PR11L | 3%<br>2% |
| Old Corowa Rd<br><br>Four Corners Rd | Jerilderie | Hydrated lime<br>PR11L<br>Cement/slag (80:20) | 3%<br>2%<br>4% |
| Back Mimosa Rd | Temora | Hydrated lime<br>PR11L | 4%<br>2% |

# 6 CONCLUSIONS

The limited funding and low traffic volumes experienced on many unsealed Australian roads provides real challenges to road owners seeking to lift the performance of these roads and make them accessible all year round. This report has outlined the background to the mix design and the laboratory protocols to establish the binder type and application rate for lime or polymer binders.

Five potential sites in four Shires in South West NSW were chosen for detailed site investigation and laboratory testing of materials extracted from the site. An analysis of the test data from the laboratory program provided sufficient information to select the most appropriate site and binder application rates for construction works (refer to Table 27).

Some key aspects of the laboratory mix design stage are:

- Need to extract a sufficient quantity of granular and subgrade material from the test pits to allow sufficient testing options with more than one binder. A guideline is to be produced to assist Shires and testing laboratories with a method to apply.
- Before carrying out a Lime Demand test on the pavement material review the category and PI of the material.
- If the depth of the pavement material is less than 150 mm it is recommended that testing is carried out using a linear proportion of pavement and subgrade materials based on depth. Should the PI of the pavement material exceed 20, review the possible binder content in light of the formation material and opportunities to use a granular overlay.

- Need to refine the decision making process for lime and polymer types in light of the post construction test results and performance after 12 months.

The aim of the laboratory test program is to understand the materials that will be stabilised and to make informed decisions on the appropriate binder type and application rate for the site. Sufficient time should be given to allowing further testing if the initial results are below the guidelines of the test protocols. Testing costs are significantly less than construction costs and practitioners will gain experience with their pavement and formation materials over time, and ease of access to all test results in the Shire will be critical to the successful application of this unsealed road treatment.

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# Appendix A Road Stabilisation Binders for Unsealed Low Volume Roads

## A.1 General

Australia is fortunate to have a range of binders available for use in road stabilisation and for unsealed roads some binders are cost prohibitive (ie bitumen) due to the lower volume traffic and their high initial costs. This appendix details the binders used for this research project.

## A.2 Lime

The word 'lime' is a generic term used to describe either quicklime or hydrated lime as listed in Table A1 (but not limestone or agricultural lime). Quicklime manufactured in Australia is processed through a fluid bed, rotary or vertical shaft kilns. Lime slurry is rarely used for road construction due to the higher construction costs.

**Table A1** The properties of lime used for soil stabilisation [Austroads, 2006].

| | Hydrated lime | Quicklime |
|---|---|---|
| Composition | $Ca(OH)_2$ | CaO |
| Form | Fine powder | Granular |
| Equiv. $Ca(OH)_2$ | 1.00 | 1.32 |
| Bulk density ($t/m^3$) | 0.45 to 0.56 | 0.9 to 1.3 |

Hydrated lime in the presence of water sets up an alkaline environment (pH>7) in which the lime will react with any Pozzolans (materials containing reactive silica and alumina) that are present in the pavement material or subgrade. This chemical process is at work in road stabilisation projects where clays provide the siliceous and aluminous components of the soil. Small quantities of organic material are likely to reduce the effectiveness of this chemical reaction.

The lime's reaction with the soil is two-fold. It firstly agglomerates fine clay particles into coarse, friable particles by a base exchange with the calcium cation (of the lime) displacing sodium or hydrogen ions with a subsequent 'dewatering' of the clay. Secondly, the lime raises the pH to above 12, which encourages chemical reactions that lead to the formation of calcium silicates and aluminates.

These calcium complexes initially form as a gel which coats and binds soil particles as the chemical processes move toward the crystallisation (cementitious) stage as they form hydrates. The rate of crystallisation is temperature dependent and may take many months to reach completion. This in turn correlates to a steady strength gain that can be tracked and measured using the CBR test for subgrade materials and the Unconfined Compressive Strength (UCS) test for pavement materials.

The hydrate complexes are cementitious products, similar in composition to those found in cement paste, and are the end results of physio-chemical reactions with clayey soil minerals (or other Pozzolans such as fly ash) that dramatically reduce the plasticity of the soil, increase its workability and improve its compaction characteristics.

Lime stabilisation has a significant effect on the engineering properties of the clay material. Some of these properties are detailed in Table A2 which helps the understanding of design considerations.

Lime is widely available from all States and Territories in Australia as listed:

- NSW & ACT – Maralun, Galong, Charbon and Attunga
- Queensland – Tamaree, Woodstock, Marmer, Rockhampton & Gladstone
- Victoria - Lilydale and Traralgon
- South Australia - Angaston
- Northern Territory - Mataranka

- Western Australia - Dongara & Munster
- Tasmania - Mole Creek

**Table A2** General properties of lime stabilised soils. (AustStab, 2006)

| Property | Description |
|---|---|
| Plasticity | The plasticity index decreases, as much as four times in some circumstances. This is due to the liquid limit decreasing and the plastic limit increasing. |
| Moisture density relationship | The result of immediate reactions between lime and the clay soil is a substantial change in the moisture density relationship. The moisture density changes reflect the new nature of the soil and are evidence of the physical property changes occurring in the soil upon lime treatment. |
| Swell potential | Soil swell potential and swelling pressures are normally significantly reduced by lime treatment. |
| Drying | Lime (particularly quicklime) aids the immediate drying of wet clay soils. This allows compaction to proceed more quickly. |
| Strength properties | Both the Unconfined Compressive Strength (UCS) and CBR increase considerably with the addition of lime. These values can be further increased by a follow up treatment of cement after the initial lime treatment. Experience has shown increases of CBR's from 3 up to 20 with lime only treatment and as high as CBR 50 with a follow up cement treatment. This gain in strength is often used in the design of pavements in order to reduce the depth of pavement material required. |
| Water resistance | The lime stabilised layer forms a water resistant barrier by impeding penetration of moisture from above and below. Thus, the layer becomes a working platform shedding water and allowing construction to proceed unaffected by weather. Experience in Victoria is that a second treatment with cement is required to achieve long-term waterproofing of the clay-stabilised layer unless the stabilised layer is covered by another pavement layer as quickly as possible. |

## A.3 Cementitious materials

Cement and cement blended binders have bee used extensively in Australia for over may years and for this project cement and slag blends were chosen. In other unsealed roads, the use of slag and lime, and fly ash and lime maybe applicable.

## A.4 Synthetic polymers

The categories of the mainstream chemical binders used in unsealed roads and their reaction with subgrade soils and pavement materials may be categorised as follows:

- Synthetic polymers
- Natural polymers
- Ionic compounds
- Salt

In addition, many proprietary products exist today that are merely dust suppressants and have very limited life (Andrews, 2001 & Andrews, 2007).

Synthetic polymers may be grouped into water soluble and water insoluble, and most synthetic polymers in Australia are sold in a dry powdered format.

*Insoluble dry powdered synthetic polymer (IDPSP)*
A water insoluble dry powdered synthetic polymer is a manufactured material that is thermally bound to a very fine carrier such as fly ash, and should not be confused with dust suppressants. The fine powdered product, when mixed with hydrated lime, has the effect of flocculating and coating clay particles within the pavement material. The fly ash, which is encapsulated by the polymer, is effectively inert and does not react chemically in the stabilisation process. Its only function is to facilitate the distribution of the polymer throughout the pavement material. This polymer is used only in the powdered format and remains in a powder form during the pavement material mixing process.

Most water insoluble synthetic polymers act to preserve the dry strength of pavement materials by creating a hydrophobic soil matrix reducing permeability and minimising water absorption into the clayey fines.

Three IDPSP blends are commercially available and are spread at a rate typically 1% to 2% by dry mass of pavement material (Austroads, 2003, AustStab, 2007, Geopave, 2003 and Rodway, 2001):

- The synthetic polymer thermally bonded to a fine powder carrier (ie fly ash)
- A blend of 2:1 synthetic polymer-coated fly ash/ hydrated lime for medium plasticity materials (< 12);
- A blend of 1:1 synthetic polymer-coated fly ash/ hydrated lime for higher plasticity materials (12 < PI < 20).

*Synthetic Soluble polymers*
These products are manufactured in granulated or liquid form and added to the compaction water to form the polymer chain which is an acrylimide or urethane copolymer. These products encapsulate soil particles with a thin film of polymer and upon drying create bonding and water insolubility is achieved. This binder type was not used in the project.

[END]