Emulsion Modification of Unsealed Road Pavements

Transfund New Zealand Research Report No.195

Emulsion Modification of Unsealed Road Pavements

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Transfund New Zealand Research Report No. 195

ISBN 0-478-25053-3
ISSN 1174-0574

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Montgomery Watson 2001 Emulsion modification of unsealed road pavements, *Transfund New Zealand Research Report 195.* 42 pp.

Keywords: bitumen modification, lime, foam bitumen, unsealed roads, Central Otago, New Zealand.

An Important Note For The Reader

Contents

Executive Summary

The purpose of this research was to:

- Review recent South African experience of modifying unsealed pavements with bitumen
- Trial the use of bitumen modified pavement in typical unsealed roads in Central Otago New Zealand
- Determine if bitumen modification could offer most of the benefits of a sealed road without sealing, including reduced dust, maintenance and roughness costs

The research included a visit to South Africa in October 1998 to view and exchange information with South African engineers on the use of granular emulsion mixes (GEMS).

In November 1999 two unsealed roads in Central Otago were modified using lime and emulsion as a trial to determine if emulsion is an economic option for modifying unsealed roads. Controlled sections were established for comparison and road performance monitored over a winter and summer.

The emulsion modification of 600m of the flat Rockview Road and 500m of the hilly section of Conroys Road has significantly reduced dust and maintenance costs of these trial sections of road compared to the control sections. However, there was only a marginal reduction in roughness when compared to the control sections. Initial monitoring indicates that roughness will increase with time as the surface wears and that resurfacing will be required within a five year period.

The construction cost of emulsion modification was \$8.60 per m^2 which equates to 60% of local seal extension costs, costing approximately \$15.0 per m^2 .

We estimate that benefits beyond year five will not be significant and that surface wearing will require significant maintenance work including re-metalling. The initial trial observations indicate the surface of these roads will wear and deteriorate due to rain, snow and frosts if left unsealed.

In locations where there is a plentiful supply of good aggregate such as in Central Otago then seal extension using conventional unbound aggregate pavements will be less costly to construct and maintain than an emulsion modified pavement.

There is potential economic benefit from foam bitumen modification of pavements:

- In the recycling in situ of asphaltic pavements (RAP).
- Modification of low quality local aggregates where higher quality aggregates are remote
- Dust suppression.

Abstract

This report reviews South African experience of modifying aggregates with bitumen and a trial use of bitumen to modify two unsealed roads in the Central Otago District.

The test programme consisted of laboratory tests and NAASRA roughness counts and field observations.

Initial observations on the trials and control sections indicated that surface wear of the pavement will steadily increase the roughness of the road to a point within five years where additional maintenance work will be required to restore the surface and ride.

Modified aggregates resulted in reduced maintenance costs with a significant reduction in grading and dust.

These trials indicate that bitumen modification is generally less economic over the longer term than conventional seal extension particularly where aggregates are obtained at low cost.

Acknowledgement

The author is grateful for the assistance and financial support provided by the Central Otago District Council, and Transfund New Zealand, to conduct these trials.

1 Introduction

The purpose of this research was to review recent South African experience of modifying unsealed pavements with bitumen, and to trial the use of bitumen modified pavement in New Zealand. Central Otago was chosen as a trial area as it is subject to a range of climate and road user conditions.

The research included a visit to South Africa in October 1998 to view and exchange information with engineers on their use and experience of emulsion modified pavements. In particular, Mr Dave Collings of A.A. Lundon and Partners provided an overview of practice in South Africa.

In May 1999, as part of the project Dave Collings, and Mike Marshall, manger of Wirtgen Australia, visited New Zealand and gave three seminars in Christchurch, Wellington, and Hamilton on pavement recycling and the use of foam bitumen.

In November 1999 two unsealed roads in Central Otago were modified using lime and emulsion as a trial to determine if emulsion is an economic and practical option for modifying unsealed roads. Control sections were established for comparison and the road's performance monitored over a winter and summer.

2 Literature Review and South African Experience

2.1 Granular Emulsion Mixes (GEMS)

The original focus in South Africa was on Granular Emulsion Mixes for Roads (GEMS).

Sabita (1993) Manual 14 was compiled to set out mix design and structural testing procedures for GEMS. Where emulsion modification or stabilisation is applied to the following materials:

- Substandard materials normally those with high PI values
- Granular materials
- Recycled granular bases
- Recycled cement and lime treated bases
- And combinations of the above.

Sabita (1993) noted that GEMS were used in a wide range of applications including surfacing courses for low volume roads to bases for high volume freeways. These contain a wide range of material emulsion contents.

2.1.1 Kwa Zulu Natal Department of Transportation

The Kwa Zulu Natal Department of Transportation conducted a number of trials in early 1990s on the use of bitumen to modify roads to reduce their maintenance costs.

Their approach was principally from a need to reduce maintenance. A significant number of unsealed roads were becoming impassable due to heavy traffic particularly from the sugar cane industry. This traffic has very large loads causing severe corrugations, involving extensive additional heavy maintenance. Initial trials were based on an observational approach using basic equipment including agricultural discs for mixing emulsion and aggregates.

The intention was to retain a stable relatively smooth riding unsealed surface by modifying the pavement to reduce corrugations, dust and maintenance costs. There was no initial intention to have a sealed surface. However it became evident that sealing the surface of these roads was necessary to reduce wear of the road surface and subsequent maintenance. The local method of sealing consisted of a sand seal or a slurry seal.

During the author's visit to South Africa modification work was observed on the following Kwa Zulu Natal roads;

- District Road No 1621 Applebosch: emulsion treated weathered sandstone during construction November 1998
- Provincial Road No 423 near Nagle Dam: foam bitumen and emulsion treated weathered granite constructed in 1997
- Provincial Road No 504-0 near Shongweni interchange: foam bitumen treated weathered sandstone, constructed mid 1995

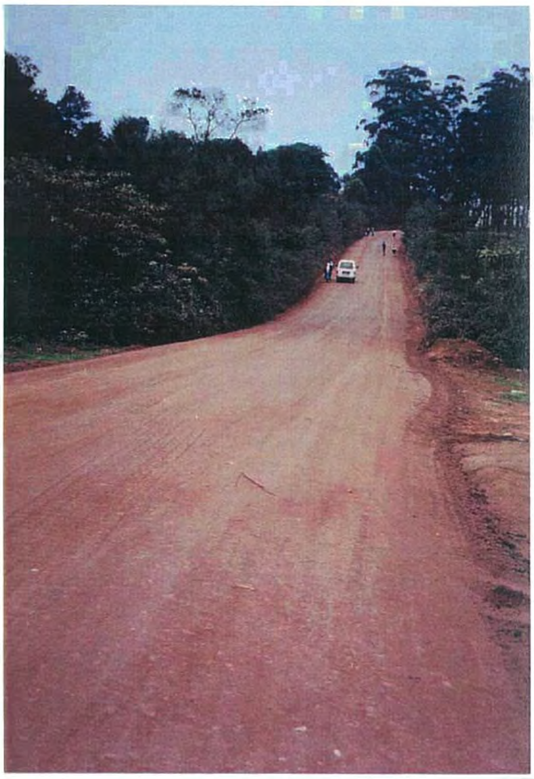
- Provincial Road No 324: recycled asphalt (RAP) foam bitumen, and a sealed and unsealed modified section, constructed 1997
- Provincial Road No P118: emulsion modified weathered sandstone constructed 1997.

The following figures show the use of agricultural equipment to mix emulsion into the sandstone pavement at D1621 Applesbosch. The road was modified using 8 litres per m^2 of 60% bitumen slow-set emulsion without lime or cement. While the CSIR (1997) recommended standard was for 1% cement to be added this was deleted due to insufficient funds.

Figure 2-1 Agricultural disc mixing of emulsion D1621

Following emulsion mixing the road was compacted with a vibrating roller, grid roller prior to grader trimming and pneumatic tyre roller to prepare for sealing. The final surface of the road had a smooth hard dense surface after 48 hours and was then ready for a slurry seal.

The roads P423, P504-0, P 324 and P118 that were modified during the period 1995-97 were observed in October 1998 and had generally performed well. However, there were sections where reseals were overdue and the underlying modified material was exposed. The exposed modified pavement had withstood the heavy traffic and approximately 1.5m of annual rainfall although there appeared to have been a loss of fines. The modified pavement had allowed the roading authority to maintain the road but sealed maintenance was falling behind that normally required to prevent deterioration. The results of the trials were documented by South Africa CSIR(1997).



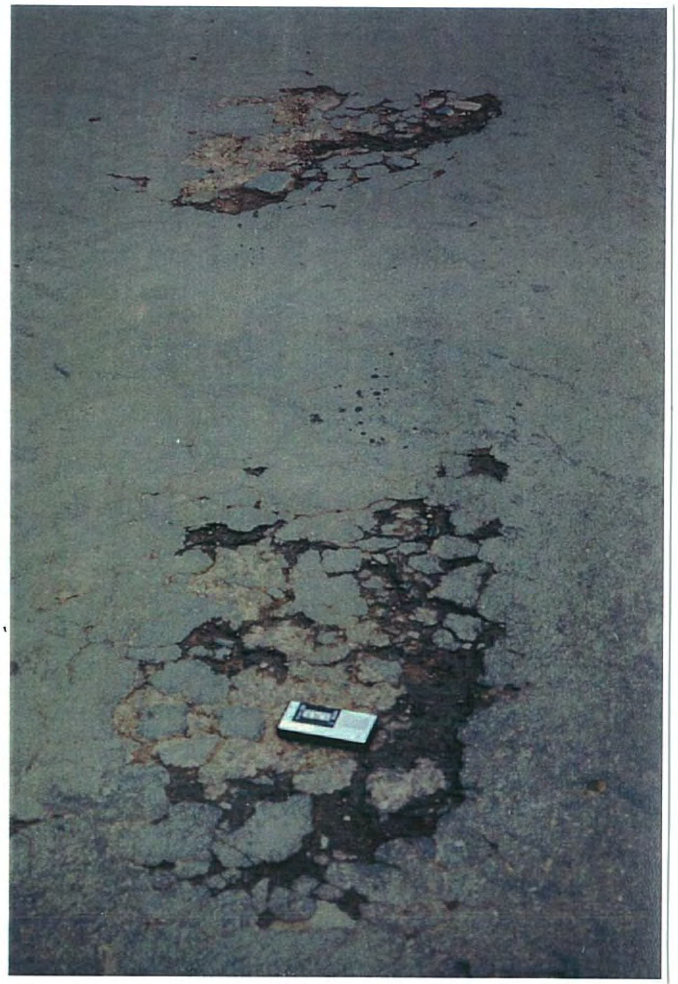


Figure 2-2 ***(left)*** **District Road D1621 after emulsion modification and surface preparation**

Figure 2-3 ***(right)*** **Provincial Road P118 showing deterioration after seal loss**

2.1.2 Foam Bitumen

The second stage of the South African research considered more advanced techniques particularly the use of foam bitumen. Foam bitumen is formed when a small quantity of water is injected into the bitumen stream, the bitumen expands to form a foam. In this state the foamed bitumen can be mixed with aggregate and the modified material has a ability to be stored prior to use. Foamed bitumen production can be incorporated into the heavy stabilisation equipment as evident by the Wirtgen machines.

CSIR (1997) reported on the performance of roads listed in section 2.2. The goal of their research was to provide guidance to engineers on mix design and structural design methods for foam bitumen. This research has been extended and the findings published by Wirtgen (1998) in their Cold Recycling Manual prepared by AA Loudon and Partners. This comprehensive manual on recycling pavements includes stabilising with cement, emulsion and foamed bitumen.

The key advantages of foam bitumen over emulsion according to Collings(1998) are:

- The cost of bitumen compared to emulsion in most counties is similar per litre
- The cost of transporting the additional water in emulsion adds to the costs
- The water in emulsion, typically 40% when added to the aggregate, adds further water that is potentially undesirable
- Emulsion may have a rapid set or too slow a set which makes construction difficult to control

The advantage of emulsion over bitumen is that low capital equipment may be used in spreading, mixing and modifying the pavement.

The main advantage cited by Collings(1998) for bitumen over lime and cement stabilisation is the flexibility of the pavement. This flexibility reduces the potential for cracking and slabbing of the pavement and avoids a rigid layer over a more flexible layer causing tension cracking, described by Collings(1998) as a "plane of glass on a bed".

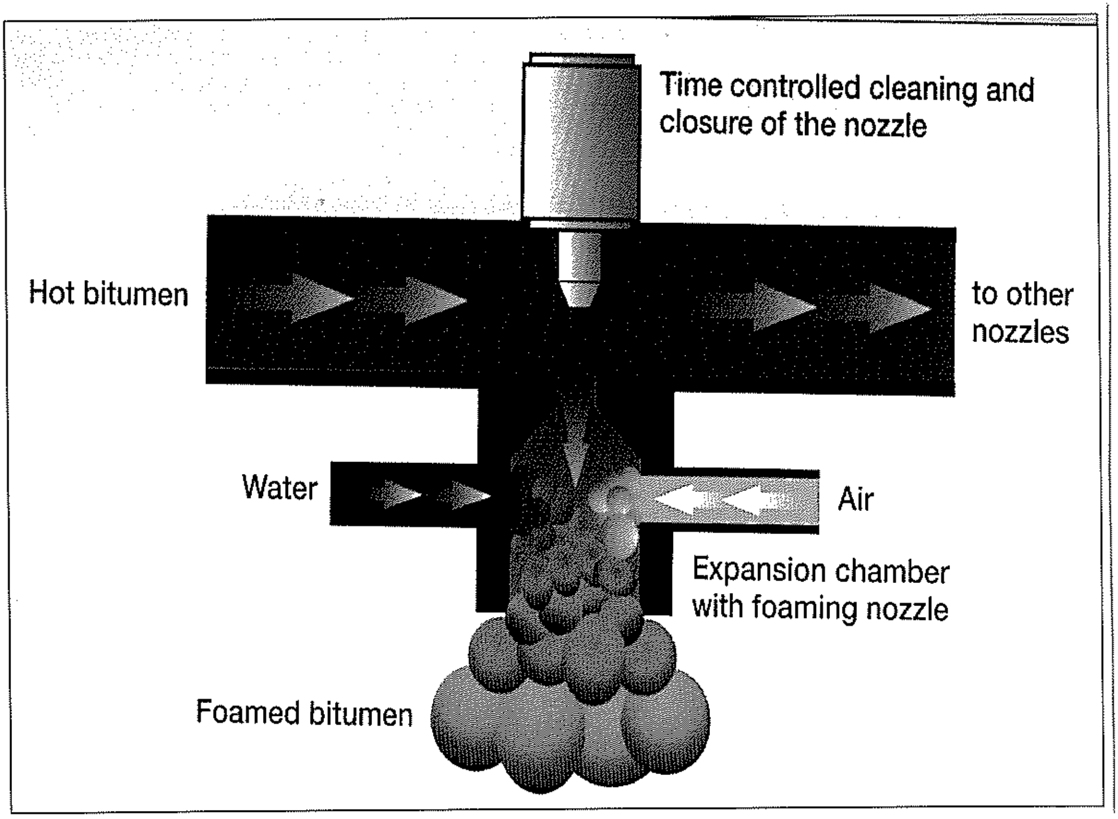


Figure 2-4 Foam bitumen chamber

The greater flexibility of bitumen reduces the pavement depth resulting in more economic design.

As an example Loudon (1998) gave three options for upgrading an unsealed road (Table 2.1)

Table 2-1 Cost comparison (Lundon) 1998 costs

Option	Description	Cost $US
Option 1	Crushed stone overlay 125mm	$9.25
Option 2	Overlay existing gravel with 125mm of natural gravel and stabilise with 3% cement	$6.85
Option 3 a	Recycle existing pavement with 5% bitumen emulsion and 1.5% cement to a depth of 100mm	$6.10
Option 3	Recycle with 3% foamed bitumen and 1.5% cement to a depth of 100mm	$5.34

Unfortunately, in New Zealand there is a significant cost difference between world rates for bitumen compared to other refinery products. Bitumen appears to be highly priced in New Zealand when compared to other petroleum products. This may be due to the refining system used in New Zealand.

Also aggregates in the South Island are comparatively plentiful and good quality and therefore modifying secondary materials is less likely to be attractive in New Zealand except in those areas where aggregates are not plentiful such as in parts of the North Island.

2.1.3 Surfacing

In all cases Colling(1998) recommends sealing the road surface for the following reasons;

- To provide water proofing
- To provide armouring to protect the softer pavement aggregates from crushing, deforming and the scuffing action of tyres

2.2 New Zealand

Bitumen binders have not been widely used to modify existing pavement in part due to the high cost of bitumen compared to other stabilising agents such as cement and lime.

Pidwersky(1998) described experience in New Zealand. The New Zealand experience was that foam bitumen had been attempted but that the Marsden Point refinery had apparently added anti foaming agents which made foaming difficult and the trials were largely unsuccessful. Also a foam bitumen unit was established to produce foam bitumen.

2.3 Australian

The Australian Stabilisation Industry have prepared the following; Model Specification for Insitu Stabilisation of local Government Roads using Bituminous Binders, version A, Auststab (1998).

Furthermore it is understood that the Queensland Department for Transport are planning to trial foam bitumen, Ramanujan et al. (1998).

3 Central Otago Trials

Two sections of road were selected for the trials and these were compared to controlled sections and other roads within the District.

3.1 Goal

The goal of the research was to determine if the South African experience of GEMS and bitumen modifications of unsealed aggregates could be feasibly and economically used to provide most of the benefits of an sealed road at significantly reduced cost compared to a sealed road.

It was not intended that these roads be sealed.

3.2 Background to Unsealed Roads in Central Otago

3.2.1 Climate of Central Otago

In Central Otago unsealed road aggregates are required to cater for two extremes.

Firstly, a summer continental climate with very low rainfall typical less than 30mm per month in summer and a high evaporation rate of 10-12mm per day. This requires a well graded material with at least 6% clay-silt content as measured on 0.075mm sieve.

Secondly, during the months of June to August there are greater than 20 days of frost each month. Typically this keeps the unsealed pavement frozen until the thaw during August/ September.

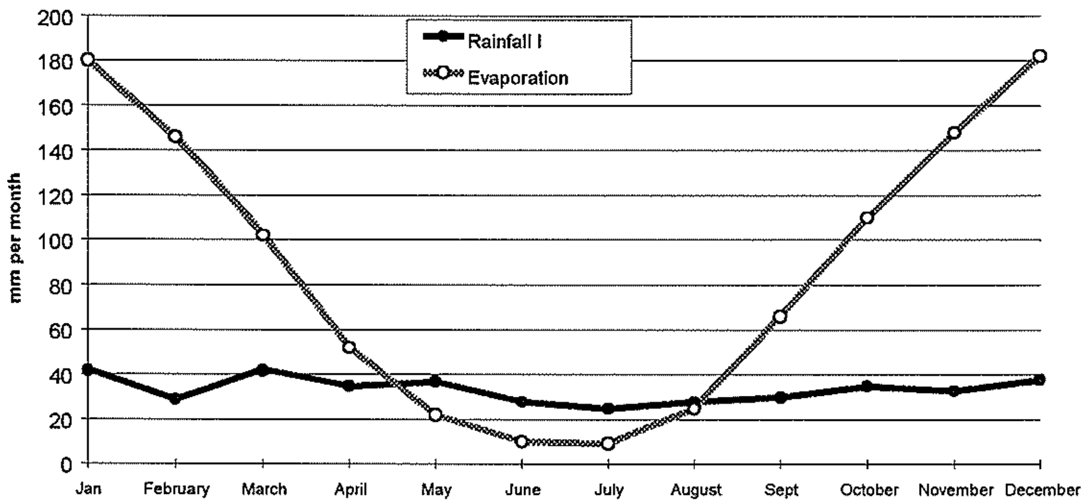
Aggregates with greater than 8-12% clay silt fractions during frost thaw create a soft saturated layer above a frozen impermeable layer. During this period the road can get very slippery, slushy and deform into greater than 300mm deep wheel ruts. Therefore past experience is that these aggregates are to be avoided or mechanically stabilised with sandy gravels by grader blending.

Thus the continental climate imposes severe restrictions on unsealed pavement aggregates.

3.3 Evaporation

Figure 3.1 graphs average pan evaporation per month and rainfall. The pan evaporation is the maximum potential evaporation that can occur during the month.

Figure 3-1 Moisture balance Central Otago



3.3.1 Local Aggregates

Central Otago is fortunate to have access to highly weathered river gravels that provide good quality aggregates at low cost. Historically these aggregates have been excavated and placed directly on the road by truck without compaction screening and crushing. In general these have provided very good unsealed roads.

Montgomery Watson (1998) reviewed Central Otago practice and concluded that pits with larger aggregate should receive the following:

- Rolling with 10 tonnes vibrating roller during final stages of construction to crush the larger stone and form smoother surface immediately following construction
- Follow-up rolling at year 1 and 2 if required
- Grader bit grooming of the surface to crush larger stone exposed by wearing and grading

The material used in the trials was from Roses Pit which consists of highly weathered alluvial aggregate. This material generally falls within the grading envelope recommended by Australian Road Research Board except at the upper end where there is some coarse aggregate that has been neither screened nor crushed.

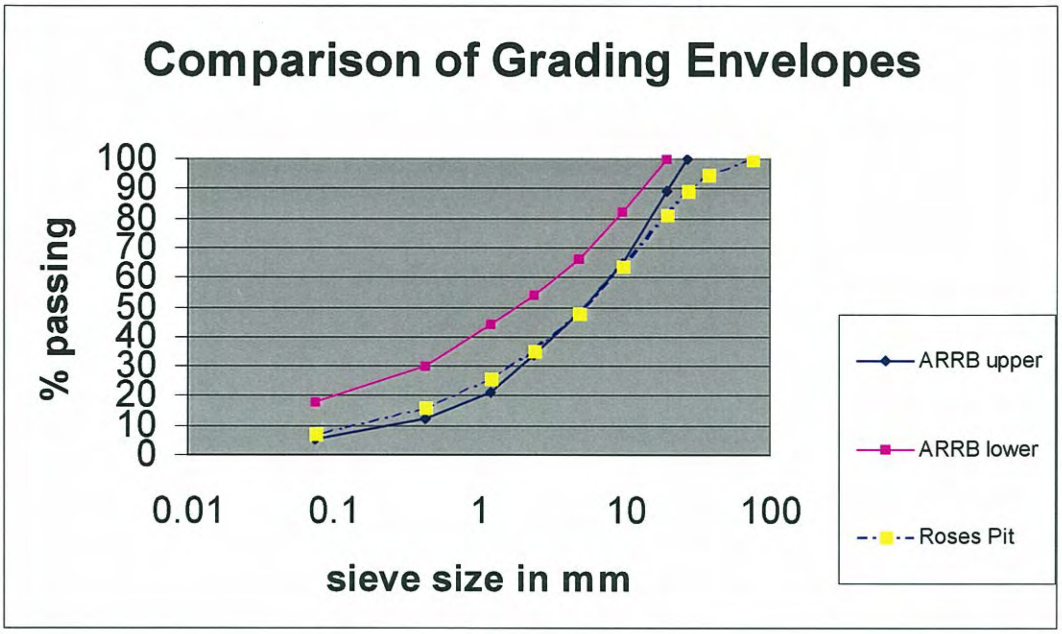


Figure 3-2 Local aggregate grading curves

3.4 Waikerikeri Valley Road Trials

In 1997 trials were established to review Central Otago District metalling practice and to explore potential refinements.

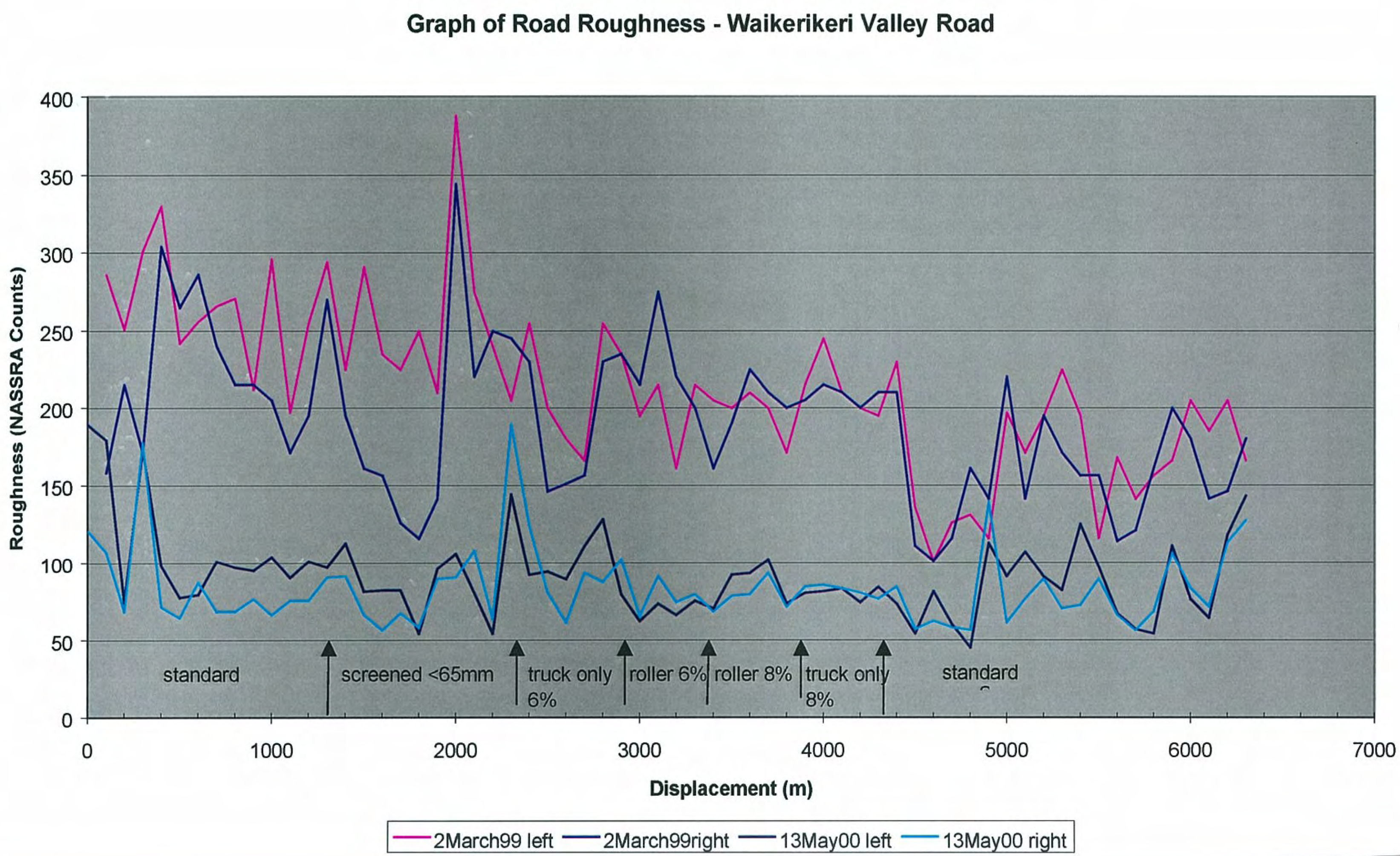
The Waikerikeri Valley Road was divided into sections and alternative techniques used during remetalling.

Alternative techniques were:

- **Standard**; no screening or crushing, aggregate applied in 100mm depth with only truck compaction
- **Screened**; screened aggregate to 65mm top size with truck compaction
- **Roller;** 10 tonne vibrating roller compaction during the final stages of remetalling to break up the larger aggregate and to provide a compaction surface without loose material.

Also 6% and 8% crossfalls were trialed with the above combinations.

Figure 3-3 Road Roughness Profile (Waikerikeri Valley)



It was concluded from that trial that the immediate benefit of rolling the road was to reduce the initial roughness and wear and tear on vehicles using the road. The screened section of road while smoother initially tended to corrugate more than the unscreened aggregate. The final section of road from displacement 4370m to the end initially behaved the best. This was attributed to the wet period of metalling and the greater initial compaction under wet conditions. There appeared to be no significant benefit from 8% cross fall compared to 6% crossfall due to the dry Central Otago climate.

Following the initial trials the full section of road from 0m to 4370m was compacted by a 10 tonnes vibrating roller. The road since that time is significantly smoother. After grading the road is generally rougher until the graded aggregate beds into the pavement.

That trial leads us to explore other options including the possibility of GEMS in Central Otago and the search for alternative methods that offer the benefits, but not the costs, of sealing.

3.5 Laboratory Tests for GEMS Trial

3.5.1 Soil parameters of Roses Pit

The aggregate was screened to exclude that greater than 19.0mm test sieve. Soil mechanics properties were as follows;

- liquid limit (LL) 26%
- plastic limit 14%
- plasticity index of 12
- maximum dry density of 2.29 t/m^3 using NZ Heavy Compaction test
- optimum water content 5.4%
- sand equivalent of this material was 20.

3.5.2 CBR test

The unmodified material had a soaked CBR of 110 at 2.5mm penetration confirmed that the material was inherently strong.

Two trial mixes were tested using cement and hydrated lime. Results are outlined in 3.5.3 and 3.5.4

3.5.3 Unconfined compressive strength using cement

Samples were cured at 25°C for one hour then 40°C for 72 hours and then cured at room temperature overnight, before testing to failure at a rate of compression of 0.76mm per minute. Table 3-4 (*next page*) summarises the test results for varying combinations of bitumen to optimise the mix design.

Table 3-4 Unconfined compressive strength

Failure mode	Modifier content	Strength mPa
Brittle	1% cement 2% emulsion	2.50
Brittle	1% cement 2.5% emulsion	3.05
Brittle	1% cement 3% emulsion	2.96
Slightly plastic brittle	1 % cement 3.5% emulsion	2.63
Slightly plastic brittle	1% cement 4% emulsion	2.35

The emulsion was 60% cationic slow-set 180/200 emulsion.

3.5.4 Indirect tensile strength using lime

Further testing was undertaken by the Contractor's laboratory using 60% 180/200 slow set emulsion. The sample blocks were prepared in Marshall moulds with 25 blows per side of the Marshall Hammer and then cured for 48 hours at 50C. Table 3-5 summarises the test results.

Table 3-5 Unconfined compressive strength

Emulsion level	6kg/m^2	8kg/m^2	10kg/m^2	None
Emulsifier used	QTS	QTS	QTS	QTS
Emulsifier	2.25%	2.25%	2.25%	2.25%
Lime added	1.00	1.00	1.00	1.00
Dry Strength (kPa) ITS	66.487	99.818	99.241	25.82

The emulsion level was based on depth of 112mm of stabilisation.

On this basis 8kg/m^2 of emulsion and 1% lime was elected as providing the strongest combination.

Two sections of road were selected for treatment based on the contractor's test results.

3.6 Equipment and Techniques

The equipment for the trial consisted of the following:

- 134 kW self powered "Rex Pulvimixer" rotary hoe
- emulsion tanker with a modified spray bar using internal pump to determine the rate of application
- lime distribution truck using chip roll spreader
- 10 tonne vibrating roller

The rate of application of emulsion was determined using the emulsion truck volume measurement system calibrated over a set speed of travel.

The sequence of construction consisted of the following:

- road was rotary hoed to 125mm,
- the 1% by weight of quicklime applied and slaked by water cart
- mixed by rotary hoe
- 8 kg of emulsion applied per square metre
- mixed using rotary hoe
- compacted with 4 passes of 10 tonne vibrating roller to achieve dense surface
- surface cut and trimmed by grader with follow up compaction to obtain a relatively smooth surface

The control sections were also constructed using the same technique except that no lime or emulsion was added.

Figure 3-6 Emulsion tanker with purpose built spray bar applying bitumen

Figure 3-7 Rex Rotary Hoe Mixing Emulsion

Figure 3-8 Compacted Bitumen Aggregate Mix Prior to Final Shaping

3.7 Rockview Road Flat Road Trial

This flat section of road carries 100 ADT count peaking at 300 vpd during fruit picking season. This road typically required grading at monthly intervals in winter and at 10 day intervals in summer when subject to peak traffic.

The principal problem with this road was the dust generation, corrugations and subsequent need for maintenance particularly grading.

The trial section consists of:

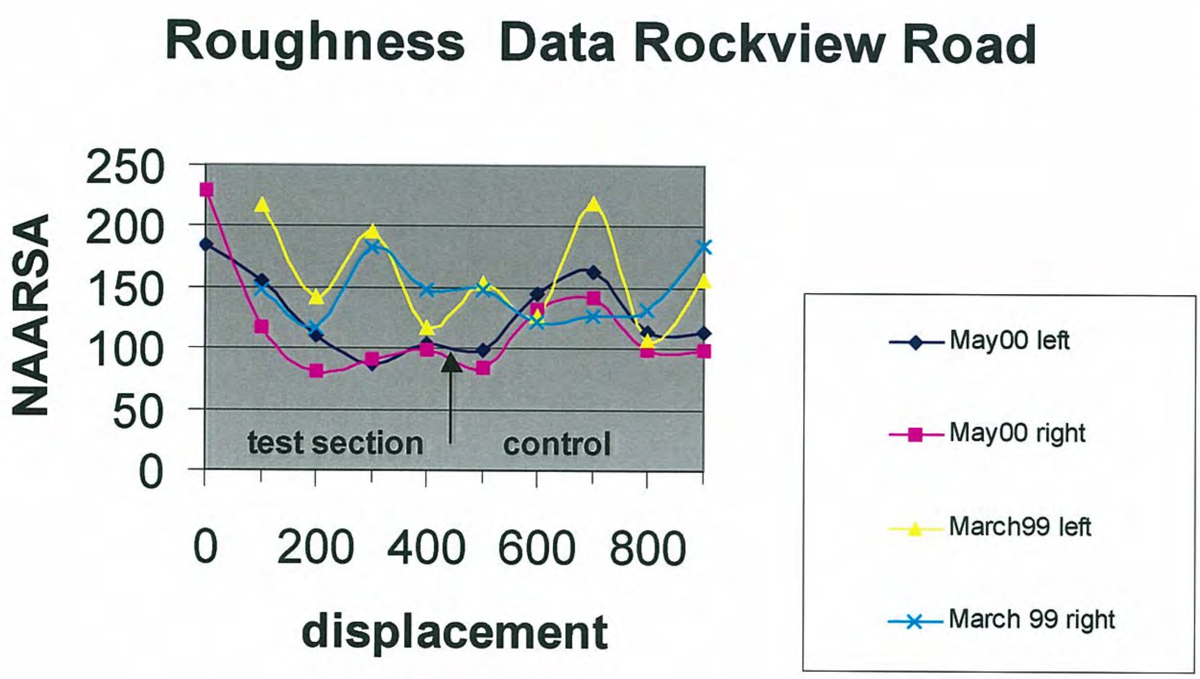
- a series of corners until 290m displacement
- followed by straight flat section of road from 290m to 600m
- from 600m to 900m the road was constructed as a control section.

3.8 Roughness Test Results

In general there was a reduction in roughness post modification. The trial section reduced from an average NAASRA count of 151 to 120 and the control section reduced from 154 to 121. Thus there was no significant reduction in roughness between the trial and control sections.

In the control section 600m to 900m there is generally less roughness after re-constituting. The mixing and compaction of the existing Roses Pit material would have crushed some the larger aggregate and reduced roughness.

Figure 3-9 Rockview Road roughness



3.8.1 Dust

Since the road was constructed in November 1999 the test section of road at Rockview road has preformed well against the control from a dust perspective. Using the Eaton et al. (1987) US Army Corp of Engineers method, the dust has been reduced from a low severity level to a very low severity when measured against the control section from 600 to 900 m. That is normal traffic produced negligible dust that does not obstruct visibility when a vehicle is driven at 40 km/h.

The control section however, had a low to moderate severity with moderately thick cloud that partially obstructed visibility but did not cause traffic to slow down. This was the major benefit of the modification with lime and emulsion.

3.8.2 Visual observations

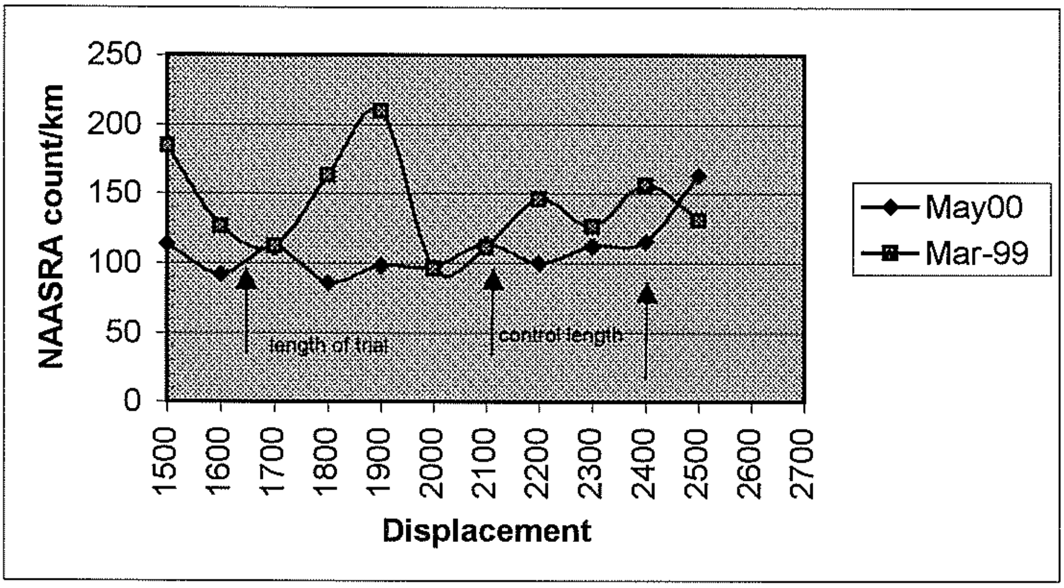
The lime/emulsion modified pavements have generally performed well. But one observation is that the surface of the road is prone to wearing from vehicle scuffing and breaking. Also, the flat spots that develop retain water and will pothole. The wearing of the surface exposes the larger aggregate in the underlying pavement to form a cobblestone effect of the larger aggregate: this is rougher, but is a stable surface.

The trial section has been graded but at a significantly reduced frequency. It would be desirable to seal the road surface to preserve the existing pavement rather than wait for the pavement to deteriorate.

3.9 Conroys Road Hill Section Trial

This hill section had a vertical gradient of 6-8% and averaged 100 vpd. The trial section 423m long commenced at displacement 1685m to 2108m and the control from 2108 to 2500m. This road has been prone to corrugations and unravelling of basecourse.

Figure 3-10 Conroys Road Hill section roughness



There was a significant reduction in the roughness between March 1999 and May 2000. The trial section reduced from 138 to 101 NAASRA counts and the control from 140 to 109. Therefore there was not a significant reduction in roughness between the trial and control section.

3.10 Observations

3.10.1 Dust

There was a significant reduction in dust at Conroys Road as observed at Rockview.

3.10.2 Surface observations

The lime/emulsion modified pavement has generally performed well but the surface of the road is prone to wearing from vehicle tyre scuffing and braking, as was observed at Rockview Road.

The trial section has since been graded but at a significantly reduced frequency. During the March 2000 period some 2000m^3 of rock was carted over the test section and there were some five minor pavement shear failures.

4 Economics and Costs

The capital cost to modify the 600m of Rockview Road section of road was as follows.

4.1 Unit rates of trial

- Plant and labour costs; $1.54/m^2
- Emulsion 8 litres per square or 7.3% by volume. Cost $6.54/m^2
- Hydrated Lime 0.8% by weight. Cost $0.51/m^2
- Total costs $8.59/m^2
- Cost of control section $0.73/m^2

4.2 Maintenance Savings

The estimated savings relate to six less grades per year especially over the summer period of higher traffic use. This is $510 per annum in grading costs at $85 per kilometre per grade.

The long term integrity of the road beyond year five can not be assured without sealing. This has a significant effect on the economics. Resurfacing of the road will probably be required within five years at considerable cost.

No maintenance saving beyond year five are envisaged at this stage of the trial.

4.3 Road User Savings

There has not been a significant saving in roughness costs.

However we estimate that motorist travel benefits will occur due to some 5 km/hr faster travel on the trial section especially after the road has been graded.

There is significantly less dust on the trial section compared to the control and this has benefited neighbouring vineyards and residences.

There is less loose aggregate and this has improved vehicle braking and road safety.

4.4 Trial Conclusions

The emulsion modification of Rockview Road and Conroys Road has significantly reduced dust and maintenance costs of these sections of road compared to the control sections. The roughness of the road surface will increase with tyre wear and climate and require remetalling within five years.

The construction cost of this modification at $8.60 per m^2 .

This compares to approximately $15.0 per m^2 for recent seal extension in the district consisting of 100mm of subbase and 100mm of M4 and grade 4 first coat seal.

The emulsion modification costs approximately 60% of a local seal extension but does not have the roughness benefits of seal extension.

To leave these roads as unsealed and subject to wear, rain and frosts to deteriorate is not economic. We estimate that benefits beyond year five will not be significant and that surface wearing will require significant maintenance work including re-metalling.

Where there is plentiful supply of good aggregate such as in Central Otago then conventional unbound aggregate pavements will be less costly to construct than this type of emulsion modified pavement.

New Zealand bitumen appears expensive compared to overseas unit rates and it is less economic to use bitumen in New Zealand.

Nevertheless there is potentially economic benefit from foam bitumen:

- In the recycling *in situ* of asphaltic pavements RAP.
- Modification of low local aggregates where higher quality aggregates are remote
- Dust suppression

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Appendices

Test reports

Table of contents *Wirtgen Cold Recycling Manual*, AA Loudon and Partners, Nov 1998

Central Testing Services Ltd
Kelman Street, P.O. Box 397, ALEXANDRA, Central Otago, NZ
Telephone (03) 448 7644, Fax (03) 448 8113, Email alan.julius@xtra.co.nz

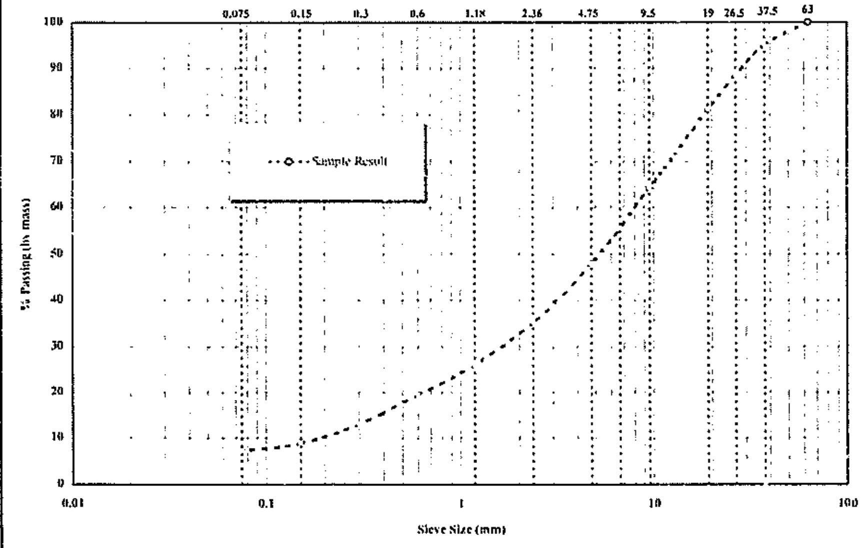
Reference No: 99/730
Date: 29 May 1999

TEST REPORT - BITUMEN EMULSION STABILISED PAVEMENT TRIALS

Client Details:	**Montgomery Watson Ltd, P.O. Box 124, Alexandra**	**Attention:**	**P. Jacobson**
Job Description:	**Bitumen Emulsion Stabilised Pavement Trials**		
Sample Description:	**SANDY GRAVEL with minor silt / clay (GW/GM)**	**Sample Source:**	**Roses Pit**
Date & Time Sampled:	**Unknown**	**Sampled By:**	**Roadex Contracting Staff**
Sample Method:	**Unknown**	**Date Received:**	**6-May-99**
Test Method:	**Particle Size Analysis - NZS 4407:1991, Test 3.8.1**		

PARTICLE SIZE ANALYSIS RESULTS

Sieve Size (mm)	% Passing (by mass)
63.0	100
37.5	95
26.5	89
19.0	81
13.2	72
9.50	64
4.75	48
2.36	35
1.18	26
0.60	19
0.30	13
0.15	9
0.075	7



Note: (i) The material received was in a natural state.
(ii) The percentage passing the finest sieve was obtained from difference.

Tested By: M.D. Taylor & A.P. Julius Date: 10 to 27-May-99

Data Transcriptions Checked By: [signature] Date: 29/5/99

Tests marked NOT IANZ REGD are outside the terms of the laboratory's scope of accreditation

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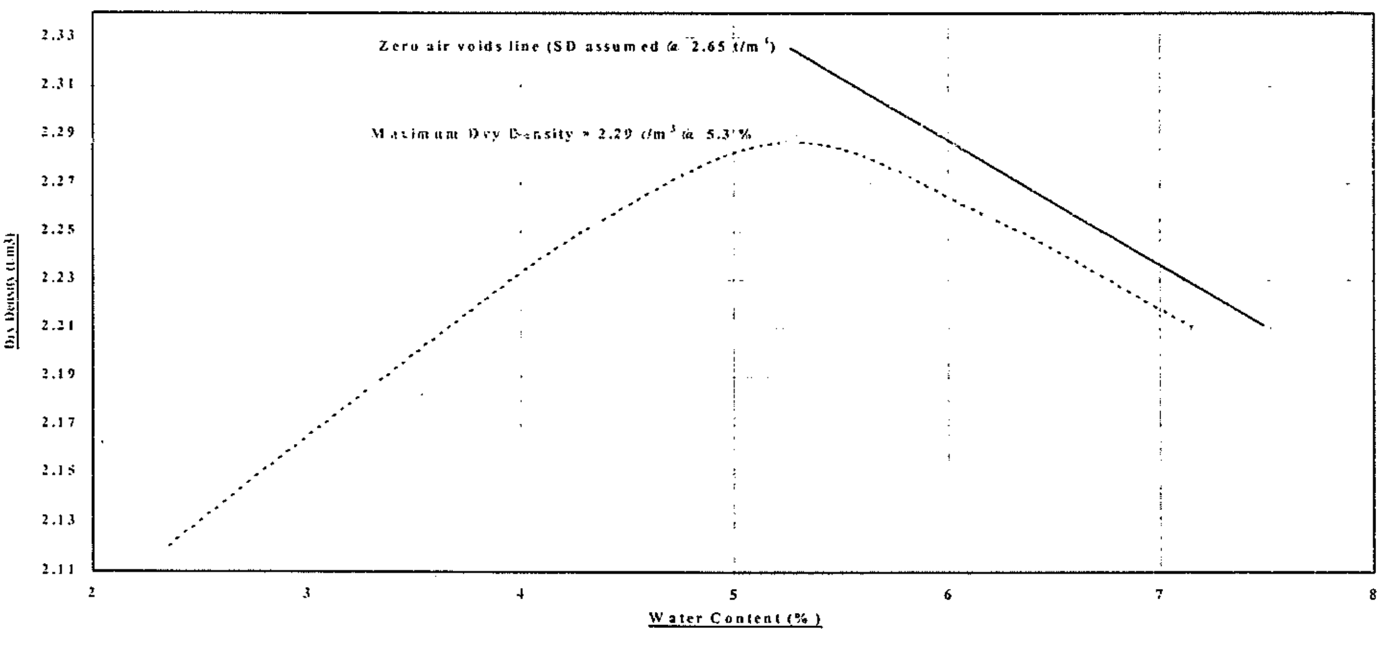
Central Testing Services Ltd
Kelman Street, P.O. Box 397, ALEXANDRA, Central Otago, NZ
Telephone (03) 448 7644, Fax (03) 448 8113, Email alan.julius@xtra.co.nz

Reference No: 99/730
Date: 29 May 1999

TEST REPORT - BITUMEN EMULSION STABILISED PAVEMENT TRIALS (cont.)

Client Details:	**Montgomery Watson Ltd, P.O. Box 124, Alexandra**	**Attention:**	**P. Jacobson**
Job Description:	**Bitumen Emulsion Stabilised Pavement Trials**		
Sample Description:	**SANDY GRAVEL with minor silt / clay (GW/GM)**	**Sample Source:**	**Roses Pit**
Date & Time Sampled:	**Unknown**	**Sampled By:**	**Roadex Contracting Staff**
Sample Method:	**Unknown**	**Date Received:**	**6-May-99**

NZ HEAVY COMPACTION RESULTS - NZS 4402:1986, Test 4.1.2			
Maximum Dry Density:	**2.29 t/m³**	**Optimum Water Content:**	**5.3 %**



Note: (i) The material received was in a natural state.
(ii) The sample tested was the fraction passing the 19.0mm test sieve.

Tested By: M.D. Taylor & A.P. Julius **Date:** 10 to 27-May-99

Data Transcriptions Checked By: [signature] **Date:** 29/5/99

Tests marked NOT IANZ REGD are outside the terms of the laboratory's scope of accreditation

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new zealand accredited laboratory

IANZ endorsement of this report applies to the sample as received.
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Sample Method:	**Unknown**	**Date Received:**	**6-May-99**

LABORATORY CBR RESULTS - NZS 4402:1986, Test 6.1.1	
Condition of Sample:	Soaked
Surcharge Mass: (kg)	4.0
Time Soaked:	5 days
Swell: (%)	0.0
Water Content as Compacted: (%)	5.0
Water Content Following Compaction: (%)	5.9
Dry Density As Compacted: (t/m^3)	2.29
CBR @ 2.5 mm	110
CBR @ 5.0 mm	120
Reported CBR Value:	120

PLASTICITY INDEX RESULTS - NZS 4402:1986, Tests 2.2, 2.3 & 2.4	
Liquid Limit (LL)	26
Plastic Limit (PL)	14
Plasticity Index (PI)	12

Note: (i) The material received was in a natural state.
(ii) The material tested in the CBR test was the fraction passing the 19.0mm test sieve and was compacted to NZ heavy compaction.
(iii) The rate of penetration was 1.14 mm / min.
(iv) The plasticity index test was carried out on material passing a 425 µm test sieve.

Tested By: M.D. Taylor & A.P. Julius Date: 10 to 27-May-99

Data Transcriptions Checked By: [signature] Date: 29/5/99

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TEST REPORT - BITUMEN EMULSION STABILISED PAVEMENT TRIALS (cont.)

Client Details:	**Montgomery Watson Ltd, P.O. Box 124, Alexandra**	**Attention:**	**P. Jacobson**
Job Description:	**Bitumen Emulsion Stabilised Pavement Trials**		
Sample Description:	**SANDY GRAVEL with minor silt / clay (GW/GM)**	**Sample Source:**	**Roses Pit**
Date & Time Sampled:	**Unknown**	**Sampled By:**	**Roadex Contracting Staff**
Sample Method:	**Unknown**	**Date Received:**	**6-May-99**

UNCONFINED COMPRESSIVE STRENGTH - NZS 4402:1986, Test 6.3.1 (NOT IANZ REGD)

Description	Type of Failure	Time to Failure (min)	Density (t/m³)	Unconfined Compressive Strength (MPa)
1% Cement / 2 % Emulsion:	Brittle	7.0	2.28	2.50
1% Cement / 2½ % Emulsion:	Brittle	6.5	2.30	3.05
1% Cement / 3 % Emulsion:	Brittle	7.0	2.30	2.96
1% Cement / 3½ % Emulsion:	Slightly Plastic / Brittle	6.3	2.28	2.63
1% Cement / 4 % Emulsion:	Slightly Plastic / Brittle	6.5	2.29	2.35

Note: (i) The material received was in a natural state.
(ii) The material tested was the fraction passing the 19.0mm test sieve and was compacted to NZ heavy compaction.
(iii) The rate of compression was 0.76 mm / min.
(iv) Milburn Pacific Cement and 60% Cationic Bitumen Emulsion were used.
(v) Samples were cured at 40 °C for 72 hours and then removed from the oven and cured at room temperature overnight. Prior to testing they were cured at 25 °C for one hour. This is in accordance with The Wirtgen Cold Recycling Manual - Appendix 2 - Section A2.2.4.

Tested By: **M.D. Taylor & A.P. Julius** **Date:** **10 to 27-May-99**

Data Transcriptions Checked By: [signature] **Date:** 29/5/99

Approved Signatory

[signature]

A.P. Julius
Laboratory Manager

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F.6 NO

Fulton Hogan Ltd
CIVIL ENGINEERING LABORATORY

PRIVATE BAG 1962, DUNEDIN, N.Z.
Fryatt Street, Dunedin, New Zealand
Fax: (03) 477-7664
TELEPHONE: (03) 477-6511

Laboratory Reference No: 690/1/99
Material: Pit Run
Original Source: Roses Pit
Sampled From: Pit Face
Sampled By: Peter Matheson
Date Sampled: 5/10/99
Client: Fulton Hogan Central
Job No: 1146-2-50

METHOD Water content and Sand Equivalent were completed on the sample as it was recieved.
Trials were completed using different levels of lime, cement and emulsion to determine what combination created the strongest result. Sample blocks were made up in the Marshall moulds, then compacted at 25 blows per side with the Marshall hammer. Samples were then cured in an oven for 48 hours at a temperature of 50°c
Samples were then strength tested with the Marshall flow apparatus to give the following results

RESULTS

	BLOCK NO.			
Emulsion Level (kg/m²)	6	8	10	None
Emulsifier Used	QTS	QTS	QTS	QTS
Emulsifier Added (%)	2.25	2.25	2.25	2.25
Lime Added (%)	1.00	1.00	1.00	1.00
Dry Strength(kPa)	66.487	99.818	99.241	25.82

SAND EQUIVALENT: 20
WATER CONTENT 6.3%

CONCLUSION: On the basis of the achieved results, they show that a combination of 8kg/m² of emulsion, and 1% of Lime when added to the aggregate as supplied would provide the strongest product.

G. Pellowe
Laboratory Technician

11 April 2000

Fulton Hogan Ltd
CIVIL ENGINEERING LABORATORY

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Emulsion Test Report

Lab Ref N⁰ : **3261/1/99**
Client : FH Bitumen
Emulsion Type : CQS-C
Original Source : FH Bitumen
Sampled From : Tank 5 Lots 1 & 2
Sampled By : Alan Cooper Date Sampled: 10/11/99 @ 0855 hrs
Sample Method : Unknown. Sample tested as received
Sample: Size: = 2.9 litres

Results

Test	Method	Result	Specification
Binder Content	BS 434 Pt 1 App F	61.9%	60 % min by mass
Residue on 710µm Sieve	BS434 Pt 1 App D	0.02%	0.05% max

Report issued 10 November, 1999

A.J. Horsfall
Laboratory Technician

Checked
Date 10/11/99

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