MTRD REPORT NO. 97/PA/056

SURFACE LONGEVITY TREATMENTS FOR UNSEALED ROADS

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Transport System - Pavements Technology Development Programme

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FOR
UNSEALED ROADS

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PROJECT MT 97/PA/056

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Pavebond, Reynolds Soil Technologies, BP Bitumen, CMG Holdings as product suppliers to the project.

This project was undertaken by Transport SA Materials Technology Section in conjunction with the Northern & Western Region as part of the Transport System-Pavements Technology Development Programme.

EXECUTIVE SUMMARY

Objectives

To quantify the physical performance of various unsealed road surface treatments, life cycle costs and road user perceptions of road condition, measure of improvement and deterioration with time.

Background

The unsealed road network contains significant freight and tourist transportation routes which incur an annual maintenance expenditure in excess of $10 million as well as consuming large quantities of natural resources.

By comparison to sealed roads, unsealed road performance is typified by:

- Low traffic volumes but vital transport routes
- High operating costs in routine maintenance grading and re-sheeting.
- Restricted access in times of heavy rain.
- High accident risk.
- High environmental and heritage impact of material borrow pits.

Within Transport SA, these issues have been addressed with the introduction of “wet maintenance” techniques that provide improved surface characteristics. This technique has been achieved through with significant investment in support infrastructure to provide a source of water.

As an addition to wet maintenance, there are a large variety of chemical stabilisers on the market which could potentially further enhance the quality of the unsealed surface.

Methodology

- ♦ To establish a trial section on road number 16021 (Copley - Balcanoona) in which a variety of products can be incorporated.
- ♦ The products proposed are Roadbond EN-1, Reynolds RT12 & RT20, Bitumen Emulsion and Dustex.
- ♦ Devise laboratory tests to provide quantitative assessment for product selection.
- ♦ Regional maintenance to re-sheet a 6km trial section using local borrow material. In conjunction with product suppliers stabilise the re-sheeting material using only the existing equipment used by the maintenance gang.
- ♦ Establish a monitoring program incorporating an environmental impact assessment to quantitatively access roughness, dust generation, surface texture, rutting, erosion and shape loss. Monitoring to be conducted over 1,3,6,12,& 24 months.
- ♦ Adapt Unsealed Road Maintenance System (URMS) to the trial section to describe pavement condition rating over 1,3,6,12 & 24 months.
- ♦ Undertake cost benefit analysis of the various treatments compared to current process of wet maintenance (refer 97/PA/057).
- ♦ Technology transfer through presentation to Regional Staff, Local Governments of Eyre Peninsula, Yorke Peninsula, Murray Bridge.

- If appropriate, provide recommendations for implementation of the technology to maximise the benefits offered to the network.

Conclusions

The trial has revealed the following quantitative data :

- 10% - 20% decrease in roughness
- 0% - 50% reduction in permeability
- 0% - 10% increase in stiffness
- 10% - 30% reduction in rutting
- 20% - 50% reduction in loose surface material
- 20% - 50% decrease in maintenance
- 10% - 50% increase in sheeting life
- minus10% - 20% decrease in road operating costs
- a general recognition by road users of improvement over conventional sections
- Pavement behavioural patterns enabling targeted maintenance intervention to optimise surface condition.

Benefits

Monitoring of the Copley trial sections over a two year period has indicated that immediate benefits are realised from chemical stabilisation and are sustained over a 12 to 18 month period before maintenance intervention is required. In addition, continued monitoring is developing a behavioural model of an unsealed road which will lead to identification of timely maintenance intervention optimising the riding condition of the pavement.

A simple evaluation test has been devised to provide a visual indication of the benefits a particular product may have when used in conjunction with a particular soil type.

Recommendations for incorporation of the products include:

- Heavy wear areas: Corners, intersections, slopes
- High impact areas: Grid approach & departures
- Access difficulties: Swamps, creeks
- Poor material areas: No natural gravels available
- Sealed widening: Shoulders into pavement
- Secondary additive: General stabilisation of poor materials

Implementation

In conjunction with two other Technology Development Projects, two seminars were held at Port Augusta for Transport SA staff and external stakeholders. In addition recommendations have been made to incorporate the products into management of the unsealed road network.

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1. INTRODUCTION

1.1 South Australian Unsealed Roads Transport System

Transport SA has responsibility for the management of some 10,100 kilometres of unsealed roads comprising a vast network across the far north and west of the state and the eastern pastoral area. The roads in the outback of South Australia are vital links for local communities and provide access to the region for important economic activities such as mining, pastoral activities and tourism [1].

Within the unsealed network there are a number of principal routes, which serve as major transport links carrying a significant proportion of commercial trucks and road trains eg:

- Strezlecki track servicing the Moomba gas field
- Birdsville track servicing the western Queensland stock route
- Copley Balcanoona servicing tourism and proposed Beverley mining development

In other circumstances, the traffic on these routes could perhaps justify bituminous sealing, but is economically prohibited by:

- Long distances requiring major funding and road construction activity
- Availability of road making materials appropriate to bituminous surfaced roads
- Extreme environmental operating conditions implying high operating costs through maintenance and resealing.

As a result, for the foreseeable future such transport routes will remain unsealed.

1.2 Performance Improvement

By comparison to sealed roads, unsealed road performance is typified by:

- Low traffic volumes but vital transport routes
- High operating costs in routine maintenance grading and re-sheeting.
- Restricted access in times of heavy rain.
- High accident risk.
- High environmental and heritage impact of material borrow pits.

Within Transport SA, these issues have been addressed with the introduction of "wet maintenance" techniques that provide improved surface characteristics. This technique has been achieved through significant investment in providing support infrastructure to make a source of water available.

As an addition to wet maintenance, there are a large variety of chemical stabilisers on the market which could potentially further enhance the quality of the unsealed surface.

In a strategic sense therefore, wet maintenance with or without chemical stabilisation has the potential to improve the use and management of the unsealed road network by providing:

- Improved skidding and braking safety with less loose gravel on the road.
- Improved road safety with increased visibility through less dust.
- Less stone damage to vehicles eg. broken windscreens.
- Less routine maintenance grading resulting in lower operating costs.
- Increased periods between re-sheeting resulting in conservation of natural materials.
- Reduced environment and heritage impact due to less material extraction.
- Reduced impact of loose material on roadside habitat.
- More timely application of maintenance intervention to suit the behavioural pattern of the unsealed surface.

This project was therefore established to quantify the physical performance of various unsealed road surface treatments and their behavioural attributes. In addition, life cycle costs of various road management strategies and customer perceptions of road condition were determined.

2. UNSEALED ROADS – FIELD TECHNOLOGY

2.1 Construction & Dry Maintenance

The structure of an unsealed road is generally comprised of a 100mm - 150mm thick wearing course (basecourse), maybe a similar thickness subbase overlying a raised subgrade formation. The pavement materials used are naturally occurring gravels extracted from local pits or quarries generally processed by grid rolling Figure 1.

Figure 1 Grid roller & vibratory roller for dry crushing & compaction

In the past, because of the scarcity of water, pavement materials were placed and compacted dry resulting in gravelly surfaces which deteriorate quickly under traffic and erode and scour with rain.

Subsequent surface wearing characteristics eg. corrugations, pot holes, scouring, loose material necessitate maintenance intervention via routine grading approximately four times per year. Additional concentrated maintenance effort is also required in periods of heavy rain or flooding when road closures are not uncommon and damage to unsealed roads can be extensive

The typical "normal life" for major unsealed road is around 8 to 12 years before the sheeting material is worn away and the sub base or subgrade exposed. At this stage surface deterioration increases rapidly until a new sheeting layer is placed.

New materials are obtained following geological material search and complex environmental, heritage and quarrying approval systems. This process is becoming increasingly more difficult and protracted due to environmental and heritage issues as well as depleting suitable sources. Therefore any process which increases the re-sheeting intervention time impacts significantly on road operating costs and environmental acceptance.

2.2 Wet Maintenance

Since about 1994, Transport SA Northern & Western Region have progressively introduced wet maintenance practices to major unsealed transport and tourist routes. This has been achieved by investing in infrastructure eg. bores, pumps and storage ponds to provide a local construction water supply. In addition, a significant increase in plant and equipment is necessary as well as associated increases in the gang labour force.

The specific resources, plant and equipment for both dry and wet maintenance are detailed in Section 7.2 associated with life cycle costing.

The introduction of wet maintenance on the unsealed roads network recognised that a better quality riding surface coupled with potentially longer maintenance intervention periods could be achieved through:

- Higher compacted densities being achieved to lower permeability and decrease erosion and surface softening.
- Fine material being mobilised by dilation during compaction leaving a tight surface with improved gravel retention.

Two forms of wet maintenance are adopted viz:

- ♦ Intervention grading where material is simply graded back over the pavement from the sides, watered, reshaped and compacted. This maintenance is process is invoked between major wet maintenance interventions as needed.
- ♦ Major intervention maintenance where the pavement is ripped, watered and grader mixed, shaped and compacted.

The sheeting process involves carting and applying water over the loose placed and spread sheeting material followed by grader mixing by windrowing from one side to the other.

Shaping, compacting and final trimming follow prior to surface tightness being developed by slurrying and compacting with a multi tyred roller. Figures 4 – 6 illustrate typical construction activities.

Figure 2 Bore water storage dam

Figure 3 Water tank in tipper and tank trailer

Figure 4 Multi tyred roller & wet maintenance

Figure 5 Typical "Dry & Wet" Maintenance Surfaces

Since its introduction, wet maintenance surfaces have proved to last up to 12 months before any maintenance is required whereas dry maintenance required intervention grading every 2 to three months.

Because of the significant investment in support infrastructure, plant and resource requirements, the Region requested as part of this project that a cost benefit life cycle costing be undertaken to establish future strategies.

3. CHEMICAL STABILISATION

3.1 Applicability of Chemical Stabilisation

Chemical stabilisers come in either liquid or powder forms ideally suited for incorporation with wet maintenance because they are simply added to the compaction water. Additionally, unlike traditional stabilisers (eg. cement, lime and bitumen) where approximately 48 tonnes per kilometre is required (2%) chemical stabilisers are ideally suited in remote areas because they only use approximately 180 litres per kilometre. Consequently, significant savings in transportation and storage costs are made.

Over the whole range of chemical stabilising products, they are most applicable to materials with significant fines contents and moderate plasticities, which are the same material requirements for unsealed surfaces.

As natural dispersants, they mobilise the fine fractions within the material and provide bonding characteristics by gluing or ionic exchange. In addition, most have an oily base that acts as a waterproofing medium.

In an unsealed road surface situation these products have the potential to both bind the fine material together to lock in aggregate and suppress dust as well as provide waterproofing to the pavement surface.

3.2 Chemical Stabilisation Products

There are many brand names of chemical stabilisation products in the market, each of which falls into one of six generic categories [2] viz:

1. *Salts:* hygroscopic and deliquescent chlorides eg. Sodium, Magnesium, Calcium chlorides. Act by absorbing water before liquidating.
2. *Organic:* derived from sulphonating processes eg. Sodium, calcium, ammonium lignin sulphonates from wood pulping or fruit industries (D-Limonene). Act as clay dispersants and cohesive bonding agents.
3. *Petroleum based:* derived from waste oils and bituminous products eg. Recycled oils, bitumen emulsions. Act as cohesive bonding agents.
4. *Electro Chemical:* sulphonated pertroleums and enzymes. Specifically manufactured as highly ionic. Act as cohesive bonding agents through electro chemical polarisation of clay particles.
5. *Microbiological:* specially formulated and act by applying microbes to clay fractions, developing polymeric cohesive bonding agents.
6. 6.*Polymers:* PVC or PVA based products specially formulated to act as cohesive bonding agents.

An inventory (alphabetical) of chemical stabilisation products currently available is shown in Table 1. This list is not exhaustive and no attempt to categorise products into the above generic groupings has been undertaken because of the confidential nature of some formulations.

Table 1 Chemical Stabilisation Products & Suppliers (at May 1999)

Product Name	Agent or Manufacturer
Bitumen Emulsion *	BP Bitumen, Kororoit Creek Rd, Altona North, Victoria, 3025
Claycrete	The Hampshire Group Pty Ltd, 8 Cohn St, Carlisle WA 6101
Dustex *	Emeco, 510 Great Eastern Highway, Redcliffe, WA, 6104
Endurazyme	World Enzymes Australia Pty Ltd, 49 Cutler Rd, Jandakot, WA, 6164
Magchlor	Penrice Soda Products, Magazine Rd, Dry Creek, SA, 5094
Dustmag **Paczyme**	Rainstorm Dust Control Pty Ltd, PO Box 190, Nuriootpa SA 5355
Reynolds RT 12 * **Reynolds RT 20** *	Reynolds Soil Technologies, PO Box 155, Fullarton, SA 5063
Road Tech 2000 **	Acron Pty Ltd, 364 Brookfield Rd, Kenmore Hills, QLD, 4069
Roadbond EN-1 *	Pavebond Pty Ltd, 26 Duncan Rd, Dry Creek, SA, 5094
Roadbond SS 2-3-5 **	International Soil Science (Australia) Pty Ltd, PO Box 7734, Bundall Qld 4217
Warajay DWB100T **Warajay DWB106P**	Warajay Civil & Mining Services, PO Box 173, Redcliffe, Qld 4020
Weslig 120 **Stabilig**	Wesco Technologies Australia Pty Ltd, PO Box 16 Lochinvar NSW 2321
Polyroad	Polymix Industries Pty Ltd, PO Box 1584 Wodonga Vic 3689

Product names may be subject to patent

* *Products incorporated into the trial at time of construction in January 1998*

** *Products added at a later date at other locations on the Copley – Balcanoona road.*

4. ESTABLISHING THE FIELD TRIAL SITE

4.1 Selection of Products and Trial Site Layout

The trial site was incorporated into programmed re-sheeting approximately 90 kilometres of RN 16021 [Copley – Balcanoona] as part of the *Flinders Ranges Tourist Road Strategy*.

The main trial section began from the outskirts of Copley proceeding eastwards

Products were selected on the basis of availability, commercial interest and potential to provide a long-term solution (ie some salt products are only temporary treatments). Five products were initially incorporated into the trial section.

Over time, other product suppliers showed interest in the trial and inclusion of two additional products were accepted on a *no product cost* basis. Whilst not possible to directly relate performance to the main trial section, the two additional products were incorporated at different locations for indicative comparison.

One kilometre long product trial sections were constructed interspersed with shorter untreated sections (wet maintenance) acting as controls as detailed in Table 2.

Table 2 Trial Section Layout

Trial Section	Chainage metres	Length	Treatment
	00 - 200		Excluded from trial
1	200 - 388	388	Wet maintenance
2	388 - 1523	1135	Roadbond EN - 1
3	1526 - 2331	805	Reynolds RT 12
4	2331 - 2906	575	Wet maintenance
5	2906 - 3725	819	Reynolds RT 20
6	3725 - 4018	293	Wet maintenance
7	4018 - 5164	1146	2% Bitumen Emulsion
8	5164 - 6164	1000	Dustex

4.2 Modifications To Wet Maintenance

Re-sheeting unsealed roads in the far north of South Australia using wet maintenance is a well-established technique undertaken with considerable expertise by the TSA Gammon Ranges Road Maintenance Group. In addition, the availability of the Copley Balcanoona project as a large project made selection of the trial site simple.

One of the constraints to introducing chemical stabilisation into unsealed road construction and maintenance practices was that the process should not introduce additional plant eg. rotary mixer and spreader tanker traditionally used for powder binder stabilisation. Therefore chemical stabiliser products were selected such that they could be added directly into the water tanker and mixed by grader.

The dosage rates and associated product only costs per kilometre are shown in Table 3

Table 3 Stabiliser Product Details and Costs

Product	Container Size	Usage Rate	Cost & quantity per Kilometre
Roadbond EN-1	20 litres	1 litre per 6.5 m^3	$4 280 & 185litres
Reynolds RT 12	200 litres	1 litre per 5 m^3	$4 200 & 240 litres
Reynolds RT 20	200 litres	1 litre per 6 m^3	$1 606 & 200 litres
Bitumen Emulsion	200 litres	1 litre per 6 m^3	$4 000 & 200 litres
Dustex	25 kg bags	1 tonne per 133.5 m^3	$10 337 & 9 tonnes

The three liquid products viz: Roadbond EN-1, Reynolds RT 12 and RT 20, in concentrated form are extremely acidic and special precautions are necessary when handling them.

With all chemicals handling, a breathing mask, gloves and apron are mandatory protection from spillage.

Roadbond EN-1 supplied in 20 litre containers can be lifted and poured into the tanker.

Both the Reynolds products and bitumen emulsion are supplied in 200 litre containers necessitating mechanical means of adding to the tanker. Initially a plastic hand pump was purchased but because of the static head and viscous nature of the liquids it did not have the capacity to discharge directly into the tanker. As a result, the products were siphoned into the Roadbond EN-1 containers and manually handled.

The Dustex product, being a powder requires a recirculating pump fitted to the tanker to mix the product prior to spreading. However, because of its gelatinous nature when wetted, thorough mixing is required.

Working with the bitumen emulsion it was necessary to first bring the material close to optimum moisture content in order to prevent it from "breaking" too early.

4.3 Sheeting Material

The trial sites were constructed in 500 metres of full width pavement lengths, which relates to a typical daily completion length under wet maintenance. Product application rates as recommended by the suppliers were therefore calculated on this basis.

In practice the daily completion length can vary dependent upon haulage distances (pavement material and water) and the quantity of water required (ie related to OMC and insitu moisture content).

For the Copley project approximately 80 000 litres of water and 1500 tonnes of sheeting material was required for each 500 metre section.

Sheeting material comprised weathered shale, which was raised from the *borrow* pit by ripping and stockpiling Figure 6

Figure 6 Stockpiled material in Copley Pit.

Laboratory characteristics of the pit material are shown in Figure 7

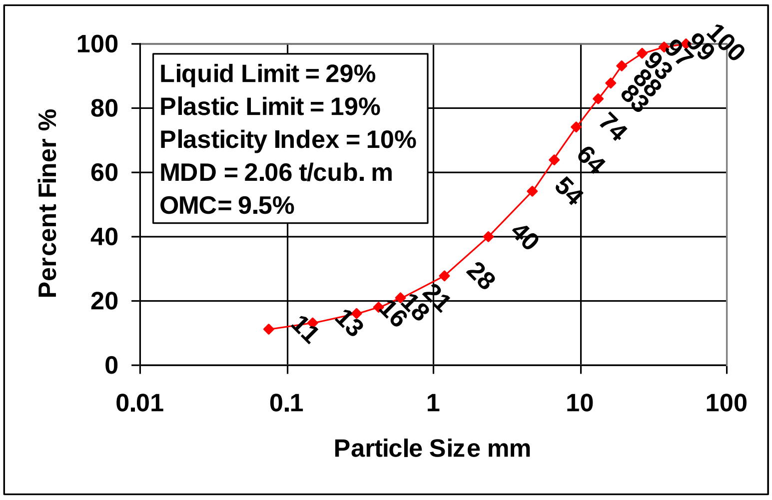


Figure 7 Laboratory Classification

In terms of the suitability of the material for chemical stabilisation, product literature generally refers to a minimum plasticity index of 10 and a minimum fines fraction (finer than 0.425mm) of 20%. The Copley material therefore rates as "borderline" as the plasticity index is at the minimum and the percent fines below that recommended.

4.4 Laboratory Assessment of Chemical Stabilisers

Traditionally strength tests like the CBR test have been used to evaluate the effectiveness of adding a chemical stabiliser. However, often these results do not relate to field conditions (particularly soaked CBR) and give little indication of product effectiveness.

Accordingly, a laboratory "drip test" was devised to provide a simple procedure to give some indication of product effectiveness with a particular soil. The test was made deliberately simple and uses commonly available equipment in order that it can be used by local authorities with limited laboratory resources and expertise.

Details of the test and a typical result are illustrated below:

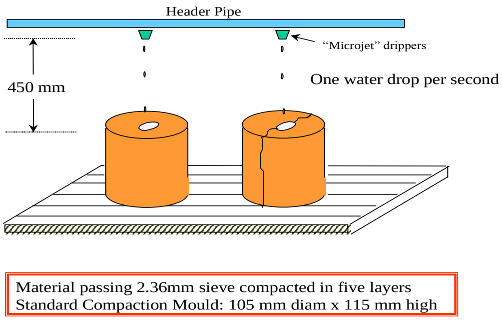


Figure 8 "Drip Test" Evaluation of Stabiliser

Figure 9 Untreated Specimen after 12 hours

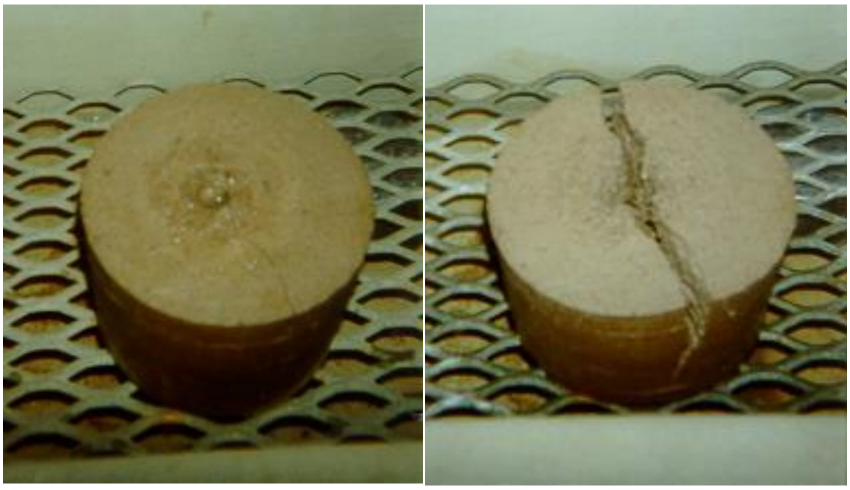


Figure 10 Treated Specimen after 24 hours & 8 days

This simple test is strongly recommended where chemical stabilisation is being considered prior to purchasing any product. In addition, the test does provide a rapid process by which the most suited product can be selected.

It is further recommended that the test procedure be further developed with a view to submitting to AUSTSTAB for consideration and inclusion in their guides to stabilisation.

5. PERFORMANCE EVALUATION

5.1 Performance Monitoring

The performance of the trial sections were assessed in a number of ways viz:

a) *Structural condition* from Falling Weight Deflectometer (FWD) data.

b) *Riding condition* from Two-Laser Profilometer (2LP) surface roughness measurements.

c) *Surface deterioration* from measurements of loose material in wheel paths.

d) *Surface wear* from measurements of wheel path rutting

e) *Visual condition* from Unsealed Roads Management System.

f) *Road user perceptions* of Safety (vehicle control), Visibility (dustiness) and Condition (roughness).

This report details the first 15 months performance in order to provide some early information on cost benefits of wet maintenance and identify product enhancement to cost benefits.

5.1.1 Climatic Conditions During the Trial

Rainfall being the most significant performance factor affecting the surface performance was obtained from the Bureau of Meteorology for the period Jan 1998 through May 1999. The total rainfall for 1998 was 196mm and for 1999 was 80mm up until May (just prior to maintenance intervention). The distribution of rainfall is illustrated in Figure 11.

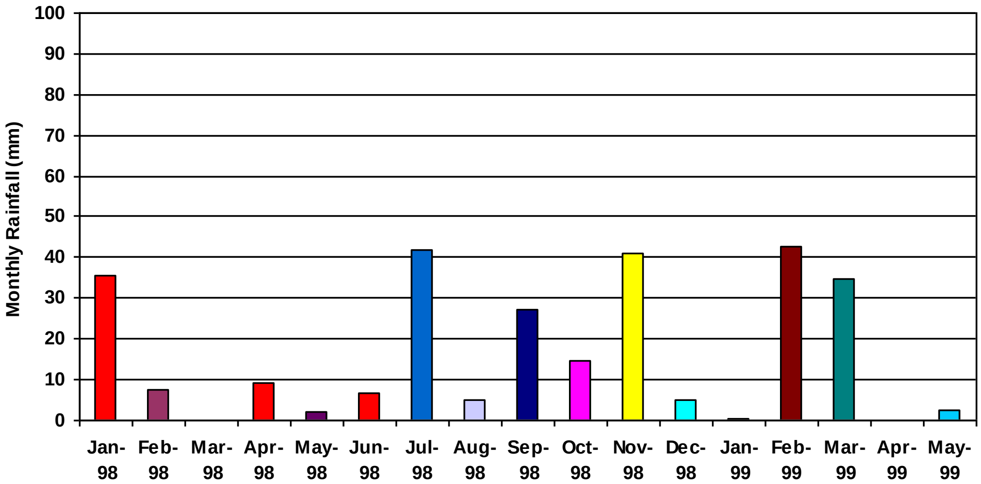


Figure 11 Monthly Rainfall Jan ’98 to May ‘99

5.1.2 Traffic Volumes

A traffic counting device was installed on the stock grid at the end of Section 2 and beginning of Section 3 in June 1998. These devices are simply a geophone attached to the grid which registers a single event when sensing vibration.

The composition of traffic on the Copley road is mainly local traffic to Nepabunna, TSA construction traffic into Copley and tourist traffic through to Arkaroola and the Flinders/Gammon Ranges. Heavy commercial vehicles are few. The average daily vehicle count (both directions) are shown below Figure 12:

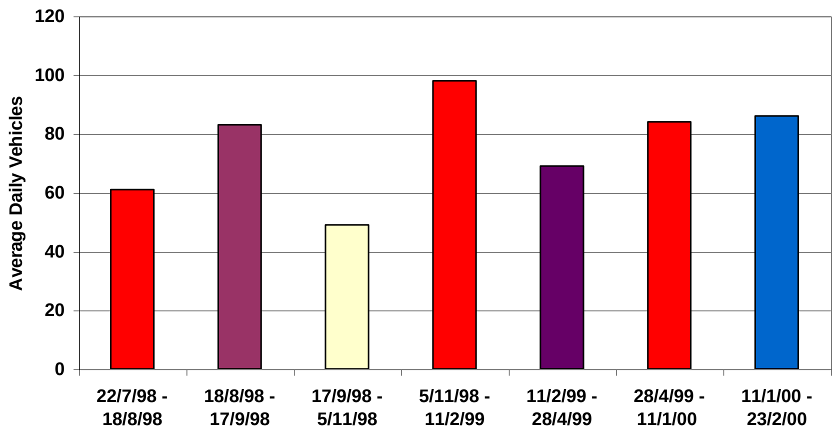


Figure 12 Average Daily Traffic Counts (Both Directions)

5.1.3 Structural Condition [Deflection & Stiffness]

Chemical stabilisation product literature frequently refers to increased strengths being one of the attributes of using the product. Generally, the increase is in terms of improved CBR but it is generally not clear whether the increase reflects different moisture contents and/or increased densities of test specimens. Excepting Roadbond EN-1 used on the Eyre Highway by TSA, no other product has been evaluated in the field using traditional pavement deflection or insitu strength techniques ie Benkelmann Beam, Lacroix Deflectograph, Dynatest Falling Weight Deflectometer, Clegg Hammer or Dynamic Cone (CBR) etc.

It was therefore considered an ideal opportunity to investigate the insitu structural characteristics of the product sections using the Falling Weight Deflectometer (FWD). The testing was undertaken in late June 1998 (6 months after construction) to allow some time for the chemicals to take effect and the surface was still intact.

The average maximum deflection for each trial section is shown in Figure 13. These deflections reflect those of a typical granular pavement indicating that (per chance) adequate pavement thickness exists in relation to subgrade stiffness.

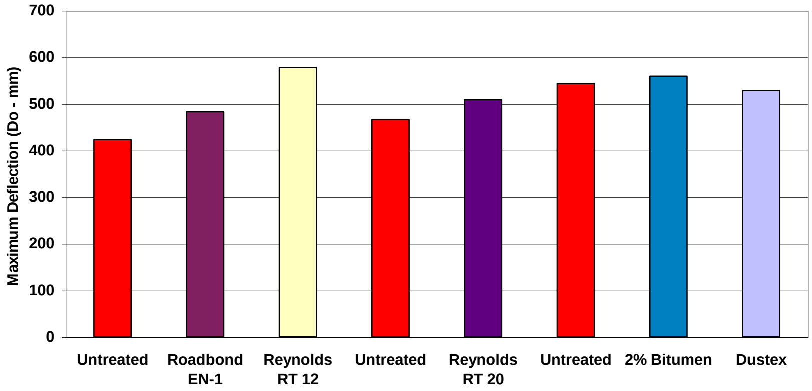


Figure 13 Average Maximum Deflections for each section

The corresponding curvature functions are shown in Figure 14

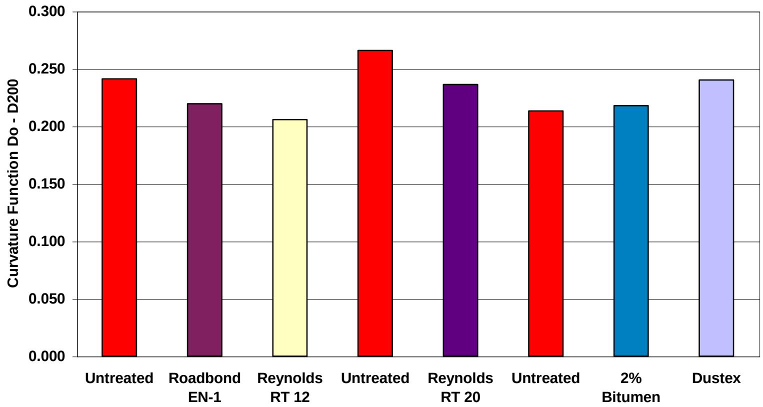


Figure 14 Average Curvature for each section

From both of the above pavement attributes it is concluded that no increase in pavement strength has been achieved with any of the products. This is in total contrast to the many laboratory evaluations indicating significant increases in CBR etc.

As a further indication, back analysis of FWD deflection bowls was undertaken to indicate the characteristic pavement stiffness (Resilient Modulus) for each trial section. The back analysis Dynatest proprietary software ELMOD was used. The results are shown in Figure 15.

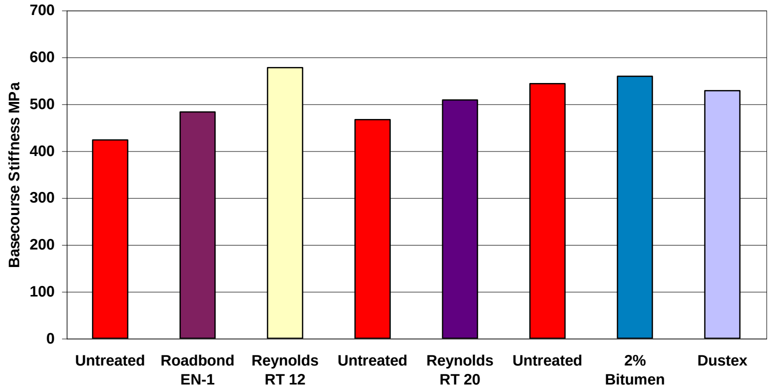


Figure 15 Pavement Stiffness [Resilient Modulus] from FWD back-calculation

Whilst some improvement in stiffness may be interpreted from Figure 15, the differences are marginal in relation to the accuracy of the back analysis. More likely, for the Copley material, because of the large stone size and overall coarse grading, inter–stone contacts rather than soil matrix stability (provided from the products) will dominate CBR or pavement stiffness.

The pavement stiffness results above are therefore unlikely to represent any benefit in terms of longer pavement life (subgrade rutting) or thinner pavement layers offered by the stabiliser products since these only react on the fine soil matrix. However, the waterproofing and partial cohesive properties offered by the products will contribute to these strengths being maintained to some degree during rainy periods.

5.1.4 Riding Condition [Roughness]

The *as constructed* riding condition of the pavement was quantified from determining surface roughness using the Two-Laser Profilometer.

The purpose of this testing was to repeat the testing at intervals with a view to

- *Defining a maintenance intervention condition*
- *Defining an unacceptable road user condition*
- *Giving some indication of time dependent deterioration*

The initial results of average surface roughness for each section is shown in Figure 16

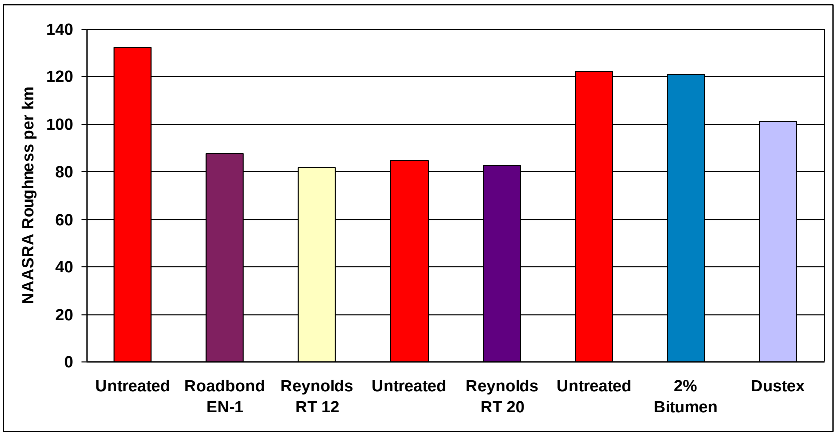


Figure 16 Two Laser Profilometer NAASRA Roughness Counts

Clearly, the Roadbond EN-1, and Reynolds RT 12, RT 20 products that are effective through ionic exchange, suggests that a smoother surface is achieved. These products noticeably activated the fine silt/clay fractions when slurried with the multi tyred roller. In contrast the Bitumen and Dustex that are effective through adhesion, resulted in rougher surfaces due to initial hardening (*cementing*) prior to slurrying.

It is also noted that the untreated section No.4 also produced low roughness probably from the material containing more fines, as the effect of slurrying is dependent upon fines content through dilation.

Updated information will be provided as an addendum.

5.1.5 Surface Deterioration [Loose Surface Material]

Measuring the amount of loose material generated from trafficking monitored surface deterioration. It was considered that this represented a quantitative measure of the relative abilities of products to "stabilise" the fine material matrix holding the gravel in place. Deterioration subsequently occurs as fine material is loosened (ie dust) under traffic followed by loosening of gravel.

A simple test was developed involving a frame sectioning off one square metre of pavement from which all loose material was removed by soft brushing and vacuuming as shown in Figure 17.

Figure 17 Removal of loose material from surface

Sites were selected in the outer wheel path with each test being undertaken in the same vicinity to reduce the influences of material variations and wind. The material recovered was subsequently fractioned on a 0.425mm sieve to indicate a measure of “Dust” and “Gravel”

Within each section one site in each wheel path was selected and results averaged. Care was taken in selecting sites so as to avoid bends, wash ways, grid proximity etc. The frame was placed centrally over the *defined* wheel path taking care not bias results by intruding into the outer rill.

Inspection and testing was undertaken approximately quarterly with one unscheduled visit following heavy rain (42mm on 12th February 1999).

The progressive results for each trial section are shown visually in Figure 18, Figure 19 and graphically in Figure 20.

Figure 18 Loose Material Day 450 (April '99) Sections 1 – 4

Figure 19 Loose Material Day 450 (April ’99) Sections 5 - 8

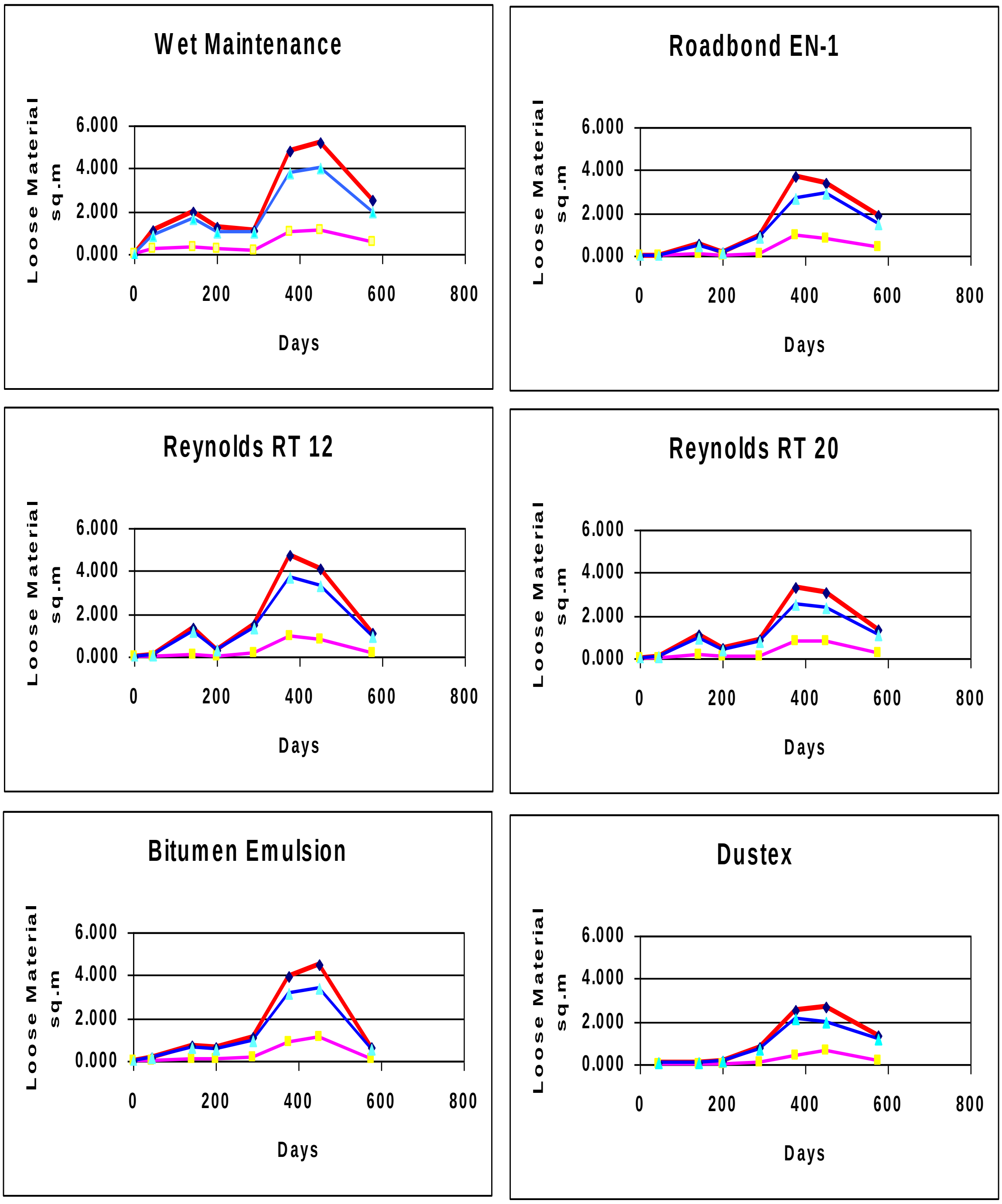


Figure 20 Total Loose Material & Gravel – Dust Fractions

The above results indicate that for the first 10 months (approx. 300 days) trafficking all sections displayed little deterioration in generation of loose *dust* and *gravel*. Immediate and higher deterioration was recorded in the untreated *wet maintenance* sections reflecting the binding properties of the products on the soil matrix. However, from November 1998 rapid deterioration of the pavement was observed in all sections with the treated sections performing marginally better than the untreated sections.

The relative performance of each trial section is further illustrated in Figure 21 (dust) and Figure 22 where the cumulative area beneath the graphs (kg/m^2 x total days) from Figure 20 have been determined.

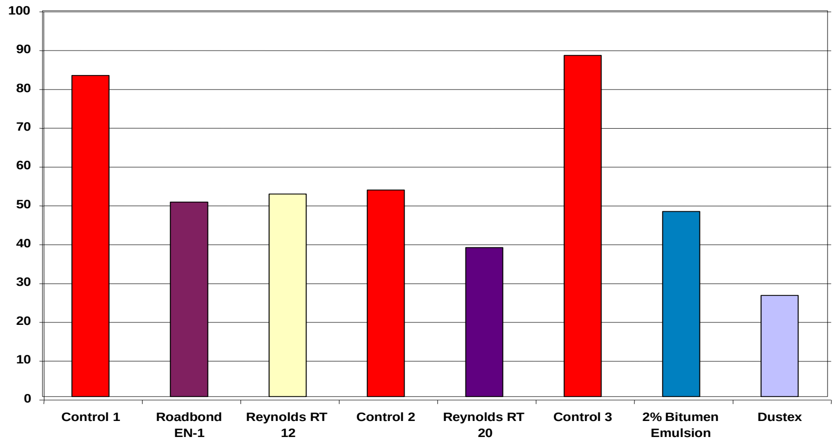


Figure 21 Cumulative "dust" 1 Feb "98 to 28 April '99

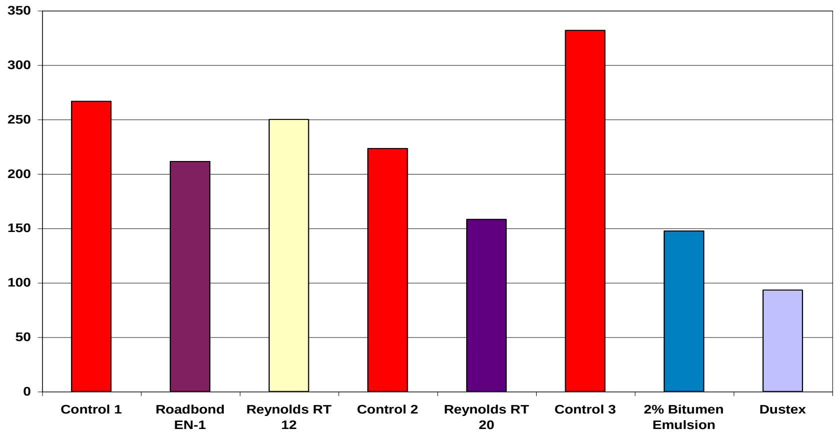


Figure 22 Cumulative "gravel" 1 Feb '98 to 28 April '99

5.1.6 Surface Wear [Rutting]

Rut depths were measured after 15 months trafficking (April '99) using a 2 metre straight edge with the maximum depth being recorded ie Figure 23

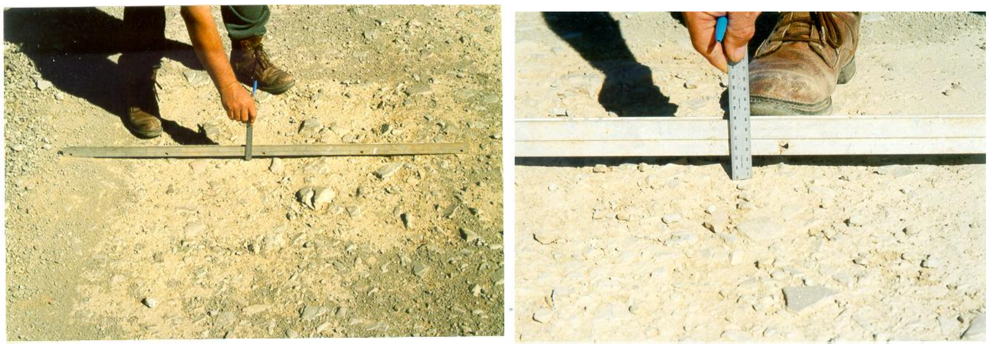


Figure 23 Maximum Rut Depth Measurement

Six locations for measurement of rut depth in both wheel paths was undertaken within each trial section. At each location a series of measurements were taken to determine the maximum value as illustrated in Figure 24.

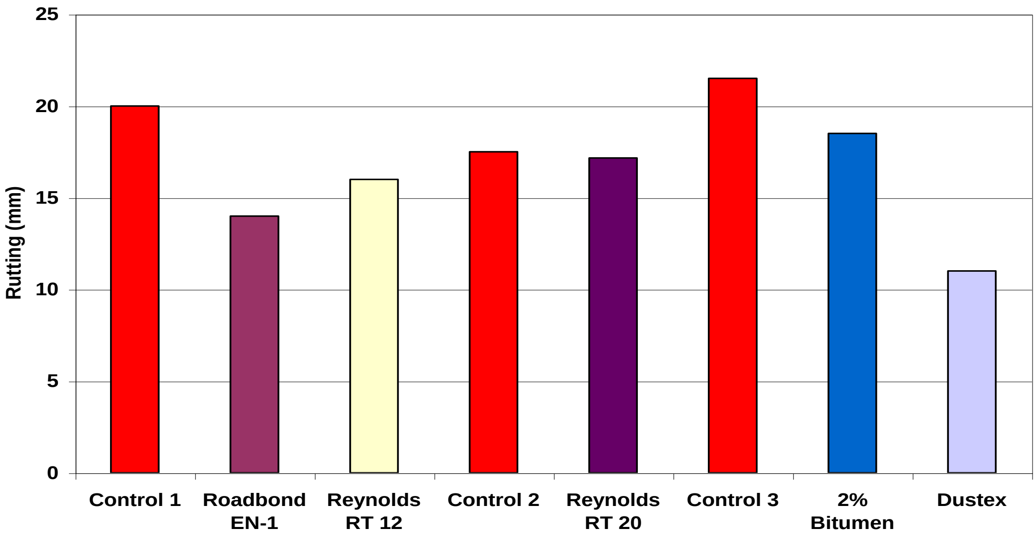


Figure 24 Maximum Rut Depth after 15 months

5.1.7 Visual Surface Condition

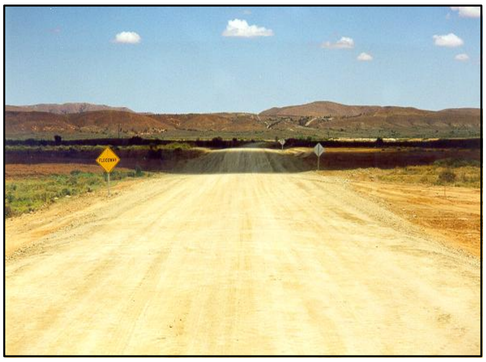
An attempt to use the Unsealed Roads Management System (URMS) was used on a *micro* scale to quantify the road condition with time. This locally developed system is detailed in Appendix 'A'.

It was found that the rating system was far too general to depict significant changes in the wearing condition of the road. Under the URMS categories the following observations were made:

Table 4 URMS Ratings

Corrugations	Rating 1. No corrugations evident throughout stabilised sections. Some corrugations noted in unstabilised sections Rating 3.
Ravelling	Rating at start 1, on completion 2 some loose stones of varying degrees.
Wet ruts	Rating 1 (Not applicable)
Bulldust holes	Rating 1 (Not applicable)
Coarse texture	Rating 1, reverted to 2 at completion of trial due to presence of loose gravel.

The progressive conditions of the road surface over the two year monitoring period (to date) are depicted below



Day 1: 8 Feb 1998

Day 142 : 22 July 1998

Day 200: 18 August 1998

Day 450: 29 April 1999

1 September 1999
Wet maintenance July 1999

15 January 2000

Figure 25 Surface Conditions Jan 98 through Jan 00

The July '98 condition followed light rain and it can be seen that some re-working of the surface occurs under normal trafficking. Subsequently the August '98 condition shows the first indications of pot holes as a result of the earlier rain.

The condition depicted in April '99 is essentially the terminal condition at which maintenance intervention is required. The amount of loose gravel combined with rut depths was considered to render the surface hazardous and a wet maintenance intervention was undertaken in July '99.

During the monitoring period, the majority of deterioration occurred during the summer months ie. November to April.

As an addition to the URMS rating system, the determination of the total amount of loose material on the surface, combined with rut depth is considered to be a good quantitative indicator of maintenance intervention viz:

- ***Maximum mass of loose material per square metre*** ***> 3kgms/m^2***
- ***Maximum rut depth*** ***< 15mm.***

5.1.8 Road User Perceptions:

In addition to quantitative and engineering evaluation, it was considered advantageous to seek general opinions from road users over the life of the trials. Consequently, in consultation with the TSA Publicity Officer Andrea Luks and Project Coordinator Gaye Carr, a road condition public survey was designed followed by a publicity campaign.

Publicising the survey was achieved by presenting information sessions to the children and teachers at the Leigh Creek and Hawker schools as well as the Copley Progress Association.

Specially designed response forms (Appendix 2) were located at a number of retail outlets, the Copley tourist park and amenities area as well as on the side of the road at the start and completion of the trial sections. Signs were erected clearly indicating the start and finish of each section.

The survey asked participants to rate each road section on a scale of 1 – 7 for road condition (roughness, corrugations, pot holes), visibility (dustiness) and safety (stones on surface, slipperiness).

Of the 380 or so replies received over 15 months (April '98 to July '99) the majority were surprisingly astute, constructive and praiseworthy in comment and expressed gratitude at the opportunity to comment.

A small percentage however sought comment on other issues including fixing up roads in other parts of the State or bitumen being requested all the way to Nepabunna (ATSIC) or the Arkaroola road needs "fixing" (Tourists).

A breakdown of where travellers came from was:

- Adelaide & suburbs 26%
- Rural South Australia 17%
- Interstate 46%
- Overseas .01%
- Unidentified 9%

The survey form is shown below:

OUTBACK ROAD SURFACE TRIALS

As part of ongoing efforts to improve outback driving conditions, Transport SA has selected an eight kilometre section of the Copley to Arkaroola road to trial new road surface treatments.

Located to the east of Copley, this piece of road is being used to test several surface treatments that are designed to improve the safety, visibility and condition (corrugation) of outback roads. Your impressions of road conditions on each section of the trial roadway will be important in assessing and comparing the success of the various treatments being tested.

By filling in and returning the attached survey form you can contribute to the continuing improvement of outback roads and, in the process, enhance motorist safety.

Transport SA is working to improve outback road conditions such as those pictured at the trial site east of Copley in June 1997.

Completed survey forms can be placed in special boxes at:

• A signposted drop off point at either end of the 8km trial section •
• Any retail outlet or the information bay in Copley •
• Hawker Mobil Service Station •
• Arkaroola Tourist Motel •
• Leigh Creek Foodland •
• Leigh Creek Canteen •

Enquiries:

Mr Bob Andrews, Supervising Materials Engineer (08) 8260 0244

TRANSPORT SA

Government of South Australia

On a scale of 1 (very good) to 7 (terrible) how do you rate the effectiveness of the current road surface treatments being tested on the Copley to Arkaroola road? (Please circle your number choices)

	SAFETY	VISIBILITY (related to dust)	CONDITION (corrugation)
	VERY GOOD — POOR	VERY GOOD — POOR	VERY GOOD — POOR
Section 1	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Section 2	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Section 3	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Section 4	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Section 5	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Section 6	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Section 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Section 8	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

Feel free to comment further: ....

....

....

....

Name .... Date ....

Address ....

....

Many thanks for your help with this important road surface trial.

KATRON 2935

Figure 26 Customer Response Form

Whilst the number of replies was relatively small, the publicity program is considered to have served its purpose in:

- Providing some indication of road user perception to the point where towards the terminal surface condition complimentary remarks were rapidly replaced by derogatory ones (intervention levels).
- Matching public perceptions to scientific and engineering assessments.
- Public relations for Transport SA in the remote communities, in particular the school visits which were well received and appreciated as they are a rare occurrence.

From the replies a simple weighting system was applied multiplied by the number assessments over the period April '98 to September '99. Pavement condition shown in Table 5 was assessed as a measure of surface roughness (ie corrugations).

Table 5 Pavement Condition Public Perceptions

RATING 1 Best	RATING 2 Better	RATING 3 Good	RATING 4 OK	RATING 5 Poor	RATING 6 Poorer	RATING 7 Worst	POINTS TOTALS	RANKING ORDER	Product
4	3	2	1	-2	-3	-4			Weighting
76	45	92	51	-124	-174	-200	-234	**8**	Untreated
176	174	164	57	-66	-51	-44	410	**4**	Roadbond
140	237	150	63	-64	-36	-20	470	**1**	Reynolds RT12
104	132	168	84	-70	-63	-24	331	**5**	Untreated
184	219	128	61	-60	-51	-24	457	**2**	Reynolds RT20
72	81	116	70	-134	-96	-76	33	**6**	Untreated
64	90	80	63	-120	-162	-168	-153	**7**	Bitumen
236	234	132	32	-60	-78	-60	436	**3**	Dustex

It is noted that Section 7 was rated poorly by the public but performed equally as well as most other products. It is considered that this is most probably associated with the high roughness developed at the time of construction. In all other cases the treated sections rated higher.

Pavement safety was related to the amount of loose material on the surface in terms of slipperiness. Results for this are shown in Table 6. Again section 7 rated low with the other treated sections out ranking untreated sections.

Table 6 Pavement Safety Public Perceptions

RATING 1 Best	RATING 2 Better	RATING 3 Good	RATING 4 OK	RATING 5 Poor	RATING 6 Poorer	RATING 7 Worst	POINTS TOTALS	RANKING ORDER	Product
120	156	128	71	-60	-78	-80	257	**6**	Untreated
200	282	132	56	-40	-27	-32	571	**2**	Roadbond
172	294	116	71	-46	-12	-16	579	**1**	Reynolds RT12
112	231	148	65	-62	-39	-16	439	**5**	Untreated
180	291	126	53	-34	-39	-20	557	**3**	Reynolds RT20
72	123	158	62	-108	-60	-44	203	**8**	Untreated
88	159	158	62	-84	-72	-72	239	**7**	Bitumen
256	294	96	37	-48	-57	-48	530	**4**	Dustex

The measure of visibility related to the amount of dust raised by traffic as detailed in Table 7.

As dust suppressants, the treated sections rated more effective.

Table 7 Pavement Dust Public Perceptions

RATING 1 Best	RATING 2 Better	RATING 3 Good	RATING 4 OK	RATING 5 Poor	RATING 6 Poorer	RATING 7 Worst	POINTS TOTALS	RANKING ORDER	Product
196	195	110	47	-44	-54	-48	402	**7**	Untreated
268	279	110	34	-36	-12	-24	619	**2**	Roadbond
224	225	122	52	-38	-9	-32	544	**4**	Reynolds RT12
184	201	120	63	-56	-18	-32	462	**6**	Untreated
280	222	122	42	-40	-15	-28	583	**3**	Reynolds RT20
160	150	102	61	-74	-45	-60	294	**8**	Untreated
216	225	122	43	-50	-27	-56	473	**5**	Bitumen
384	243	110	26	-26	-24	-24	689	**1**	Dustex

6. PERFORMANCE MODELS

Work undertaken by Paige Green [1989][4] developed relationships between sheeting material performance and intrinsic classification parameters viz:

Shrinkage Product: $S_P = L_S.P_{0.425}$ *[L_s = Linear shrinkage, $P_{0.425}$ = Percent passing 0.425mm]*

Grading Coefficient $G_c = \dfrac{(P_{26.5} - P_{2.0}).P_{4.75}}{100}$ *[$P_{26.5}$, $P_{4.75}$, $P_{2.0}$ = Percent passing sieve sizes]*

The relationship between these two parameters and unsealed surface performance is illustrated in Figure 27

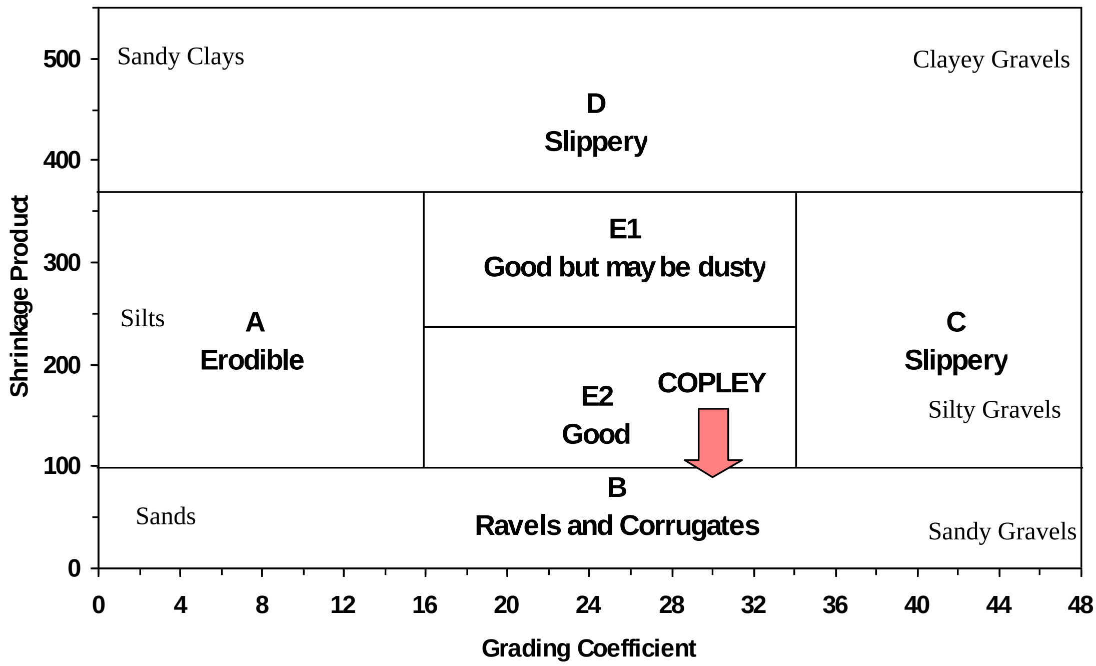


Figure 27 Unsealed Surface Performance Related to Grading & Plasticity

For the Copley material, S_P = 90 and G_C = 31 ie. zone B, indicating that the material is relatively good but with some potential for ravelling and corrugating.

International studies of the performance of unsealed roads have led to a number of development models in particular relating to World Bank considerations in developing countries. These models considered inter relationships between construction, maintenance and vehicle operating costs. These studies were initiated by the Transport and Road Research Laboratory (UK) TRRL in association with the Kenyan Ministry of Transportation and Communications (MOTC) [6].

In this study the following were considered:

- Gravel loss as an impact on re sheeting intervention
- Surface looseness as an impact on vehicle operating costs (VOC)
- Surface roughness as an impact on VOC and maintenance intervention
- Rut depth as an impact on maintenance and re sheeting intervention
- Journey times as a measure of road condition
- Traffic volumes (both ways) as a measure of pavement wear
- Climate as an impact on surface dust and erosion characteristics
- Geometry (slope and camber) in terms of an indicator of erosion

[It is noted in the above that road safety costs are not included in the studies.]

6.1.1 Untreated Sheeting Life Estimate Based on Material Properties

In the Kenyan studies, gravel loss was measured from optical surveys with the following relationship being developed for particular materials:

Gravel Loss: $$G = f\left(\frac{T_A^{2}}{T_A^{2}+50}\right)\left(4.2+0.092T_A+3.5R_L^{2}+1.88VC\right)$$

G_L = annual gravel loss in millimetres

T_A = annual traffic in both directions in vehicle thousands (Copley = 25 000vpa)

R_L = annual rainfall in metres (Copley = 0.2 m)

VC = percent gradient (Copley = flat)

f = material constant viz; laterite (0.94), quartzite (1.1), Volcanic(0.7), coral(1.5) essentially relating to stone hardness. (Copley = 1.0)

Using this relationship for the Copley material, the annual gravel loss is:

1.0(0.926)(4.2+2.3+0.14+0.0) = 6.1 mm per annum.

Considering a sheeting life being the point at which half the thickness is lost (75mm) this rate of attrition suggest that a sheeting life of 12 years can be expected.

In terms of loose surface material, considering that all minus 0.425mm material is blown away, a 6.1mm loss of sheeting material equates to about 10kgms per square metre of loose gravel being on the surface.

6.1.2 Sheeting Life Estimates Based on Wheel Path Rutting

To provide an estimate of relative re-sheeting intervals for the various stabiliser products, the estimated re-sheeting interval from the untreated section (12 years) has been factored by the proportionate measured rut depths of each section relative to that of the untreated section viz;

$$Stabilised\ Re\text{-}Sheeting\ Interval = Untreated\ re\text{-}sheeting\ interval\ x\ \frac{Rut\ depth\ of\ untreated\ section}{Rut\ depth\ of\ stabilised\ section}$$

The *relative* re-sheeting intervals using the rut depth model are shown in Table 8 below.

- ***NOTE: The values illustrated are not to be taken literally as confirmed outcomes from the trial but are estimates only for use in the financial analysis reported in 7.2.2***

Table 8 Estimated Sheeting Life from Annual Rut Depths

Treatment	Average Rut Depth (mm)	Factor	Relative Re-sheeting interval (years)
Wet Maintenance	20	1.00	12
Roadbond EN-1	14	1.43	17
Reynolds RT12	16	1.25	15
Reynolds RT20	17	1.18	14
Bitumen Emulsion	19	1.05	12
Dustex	13	1.54	18

In consideration of the above it is recognised that maintenance interventions will return material to the pavement and therefore the *absolute* re-sheeting interval would be expected to be greater. However, the *relative* differences are most likely to remain in the same proportions.

6.1.3 Sheeting Life Estimates from Loose Material

As a secondary estimate of sheeting life, the cumulative amount of loose material taken from the surface could be considered as "lost" material. Therefore relative estimates of sheeting lives for each treatment can be obtained using the same factorising process as for rutting viz:

$$Stabilised\ Re\text{-}Sheeting\ Interval = Untreated\ re\text{-}sheeting\ interval\ x\ \frac{Loose\ material\ on\ untreated\ section}{Loose\ material\ on\ stabilised\ section}$$

Table 9 Estimated Sheeting Life from Cumulative Loose Material

Treatment	Cumulative Loose Material (kg/m^2)	Factor	Relative Re-sheeting interval (years)
Wet Maintenance	15.4	1.0	12
Roadbond EN-1	8.8	1.8	22 (increase of 5yrs)
Reynolds RT12	12.0	1.3	16 (increase of 1 yr)
Reynolds RT20	9.0	1.7	20 (increase of 6 yrs)
Bitumen Emulsion	11.2	1.4	17 (increase of 5 yrs)
Dustex	7.6	2.0	24 (increase of 6 years)

In considering the sheeting life estimates from measurements of loose material as "lost" material, it is recognised that whilst the fine fractions ie dust, are most probably totally lost when loose, a significant proportion of the gravel fractions are retained on the surface but displaced to the edges of the wheel paths. This is particularly evident on the untreated sections depicted in Figure 18 and Figure 19.

In addition, rainfall events between surface measurements will also remove loose surface material and therefore it is obvious that they cannot capture the total amount of loose material lost from the surface. Therefore these values will overestimate sheeting life. The comparisons made in Table 9 support this where it is noted that the sheeting life estimates are increased by around 5 years (with the exception of RT12). However it will be noted that the relative differences between treatments remain very similar for the two methodologies.

In consideration of the above it is considered that the sheeting life estimates based upon rutting are more reliable in that they provide a direct measurement of material loss.

6.1.4 Maintenance Intervention Levels

The combined measurement of rut depth and loose surface material can provide a quantitative method for determining a most appropriate maintenance intervention time. From the periodic measurements of loose material (Figure 20) the point of "maximum deterioration" can be determined and defines the point at which maintenance intervention is necessary.

With continued monitoring, a behavioural pattern can emerge as illustrated in Figure 28 where very little surface deterioration occurs in the winter months and light rains allow the daily traffic to actually rejuvenate the surface. It is suggested that this type of monitoring as part of a pavement management program could result in a optimal surface conditions which take into account the benefits of climatic conditions.

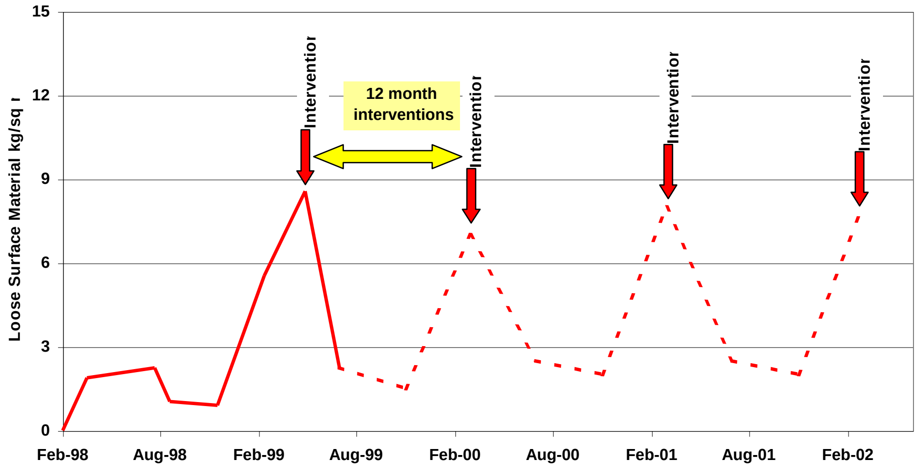


Figure 28 Maintenance Intervention Model based on Loose Surface Material

7. LIFE CYCLE COSTS FOR ASSET MANAGEMENT STRATEGIES

7.1 Operational Costs

The *per kilometre costs* for re-sheeting are summarised in Table 10

Table 10 Re-Sheeting Costs Per Kilometre

Activity	Assumptions	Parameters	Wet Construction $ per km
INITIAL CONSTRUCTION			
Materials Search & Approvals	One pit per 10 kms	$5000 per pit	$500
Raise, process, shape & compact	Construct 500 metres per day	600 cub m	$24,500
Bore & Dam Construction	Serves 40 km/bore	$25,000 each	$750
Pump Operating Costs	$50 litres fuel + pump	$60 per day	$60
Water Carting	Per km	120 000 litres	$2,000
Stabiliser addition	Product cost per km	$1600 - $10 000	
Initial Sheeting Cost	Total cost per km		$27,810

The cost of incorporating a stabilising agent in wet maintenance is assumed to simply be the added cost of the product. However the added cost of disposing the containers or transportation costs if the containers are returned and recycled have not been included in the analysis.

The costs for routine dry maintenance are shown in Table 11. This data was provided by Transport SA to ARRB Transport Research as part of a contract report SA [8].

Table 11 Unit and Cost per Km for “Dry Maintenance”

Equipment & Resources	**Hourly Rates**	**Annual Cost**
Loader 4wd bucket capacity 0.8 to 1.29 m^3	S18.72	$41,615
Grader 100 to 109 kw	$32.78	$72,870
Roller drawn combination. Ballasted mass 10 to 15 tonnes	$3.65	$8,114
Alternator set skid mounted <20 kva	$2.65	$5,891
Truck tipper single cab 6x4, 13 tonne	$30.11	$66,935
Trailer a.t.m. >4.5 tonne payload up to 16 tonnes	$3.80	$8,447
Trailer, fuel tanker, 4.5 kl	$1.90	$4,224
Caravan patrol 2 berth/ablution/kitchen	$9.49	$21,096
Total Plant Cost		$229,192
Average Labour Cost: 2 men @ $91 700 pa each		$183,400
Average Materials Cost eg. culverts, signs, delineation		$139,000
TOTAL Annual COST of Dry Maintenance operations crew		$551,592
DRY MAINTENANCE COST per Km (2304 kms total length per year)*		**$239.41**

Length determined from 12km per day over 12 periods of 16 days production per year viz: 12x16x12 = 2304 kms

The costs associated with wet maintenance grading are similarly tabulated in Table 12

Table 12 Unit and Cost per Km for "Wet Maintenance"

Equipment & Resources	Hourly Rates	Annual Cost
Water tank skid 12kl x 2	$1.75	$7,798
Loader 4wd bucket capacity 0.8 to 1.29 m^3	$18.72	$41,615
Grader 100 to 109 kw	$32.78	$72,861
Roller drawn combination. Ballasted mass 10 to 15 tonnes	$3.65	$8,116
Alternator set skid mounted <20 kva x 2	$2.65	$11,786
Pump 100mm truck mountable	$1.90	$4,219
Utility large 4wd 301-500	$6.88	$15,303
Truck tipper single cab 6x4 13 tonnes	$30.11	$66,925
Truck, water cart 12 kl to 15 kl	$2.33	$5,186
Trailer a.t.m > 4.5 tonne, payload up to 16 tonnes x 3	$3.80	$25,309
Trailer a.t.m > 4.5 tonne, payload up to 25 tonnes	$5.84	$12,985
Trailer, fuel tanker, 4.5kl	$1.90	$4,220
Trailer mounted pump 100mm	$1.90	$4,219
Caravan patrol 2 berth/ablution/kitchen	$9.45	$21,092
Total Plant Cost		$301,637
Average Labour Cost: 2 men @ $91,700 each		$183,400
Average Materials Cost eg. culverts, signs, delineation		$139,400
TOTAL Annual COST of Wet Maintenance operations crew		$624,440
WET MAINTENANCE COST per Km (288 kms total length per year)		**$2168.19**

Length determined from 1.5 kms per day over 12 periods of 16 days production per year viz: 12X16X1.5 = 288 kms

In summary the unit costs for life cycle costing are assumed to be:

- *Re-sheeting* — *$28,000 (plus cost of stabilising agent)*
- *Dry maintenance per intervention* — *$240 per kilometre*
- *Wet maintenance per intervention* — *$2,170 per kilometre*

7.2 Life Cycle Cost Analyses

To evaluate the relative cost effectiveness of the various products maintenance management strategies the RTA-NSW Life Cycle Costing System [7] has been used.

This analysis is based upon *Net Present Worth* (NPW) and *Equivalent Annual Cash Flow* (EACF) defined by the following formulae:

$$NPW = \sum \$C_n \left[\frac{1}{(1+r)^n} \right] \quad \text{and} \quad EACF = NPW \left[\frac{r(1+r)^N}{(1+r)^N - 1} \right]$$

where:

$\$C_n$ *Treatment cost in year "n"*

r *Discount rate of future expenditure (taken as 6% which includes net effects of inflation*

n *Number of years projected into the future*

N *Life of the strategy*

In the analyses, road user costs in terms of delay costs due to network closures and higher vehicle operating costs related to surface roughness etc have not been included in the analyses. However, whilst this assumption is considered reasonable in view of the low traffic volumes on the Copley-Balcanoona road, it may not be the case for important freight routes eg. Strezlecki Track which supplies the Moomba gas fields.

Three operational strategies have been considered based upon the sheeting lives determined from rutting in each section viz:

- Annual wet maintenance ie maintaining current practice
- 18 month wet maintenance where no further product is added
- 24 month 25% of normal dilution rate of product is added as stabilised wet maintenance

The construction and operating costs of each of the strategies in accordance with product costs is summarised in Table 13

Table 13 Operting Costs for Life Cycle Cost Analyses

Product	Construction	Annual Wet Maintenance per km	18 Month Wet Maintenance Annual Cost per km	2 Year Stabilised Maintenance Per intervention per km
Wet Maintenance	$28,000	$2,170	N/A	N/A
Roadbond EN-1	$32,280	$2,170	$1,455	$3,240
Reynolds RT12	$32,200	$2,170	$1,455	$3,220
Reynolds RT20	$29,606	$2,170	$1,455	$2,570
2% Bitumen	$32,000	$2,170	$1,455	$3,170
Dustex	$38,337	$2,170	$1,455	$4,755

A typical construction & maintenance strategy is illustrated in Figure 29

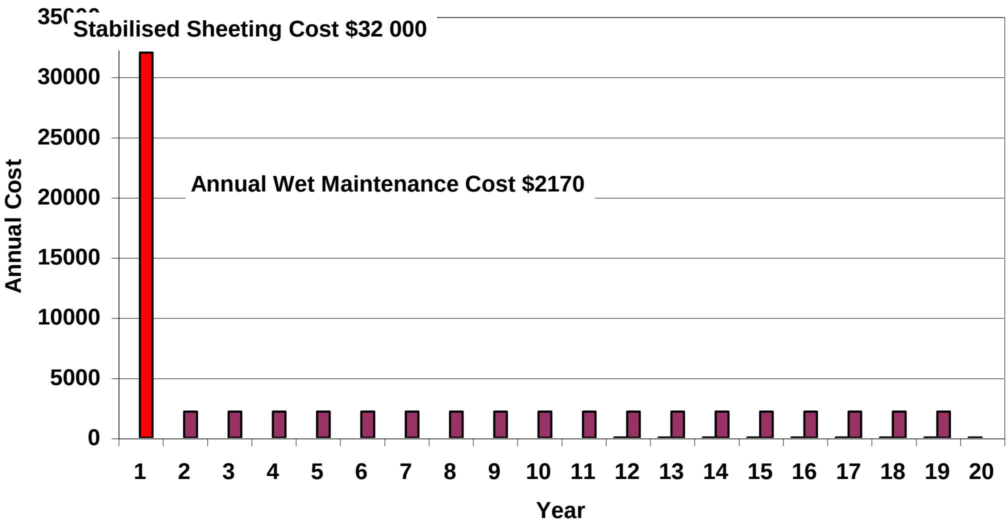


Figure 29 Typical Life Cycle Cost Strategy

7.2.1 Wet & Dry Maintenance Comparison

Northern and Western Region dry maintenance practice is to undertake quarterly patrol grading and it is expected that a typical sheeting life of 8 years is common. Wet maintenance practice is to wet patrol grade and re-compact the surface on an annual basis. For this treatment, a sheeting life of 12 years is assumed as discussed in Section 6.1.1 above.

Table 14 Wet- Dry Maintenance Comparisons

Re-sheeting & Maintenance Strategy	Equivalent Annual Cash Flow (6% discount rate)
Quarterly dry maintenance and re-sheet every 8th year	$5 118
No stabiliser, annual wet maintenance and re-sheet every 12th year	$5 217

These analyses indicates that there is very little difference between the cost of wet and dry maintenance operations and the margin would become even smaller should the re-sheeting intervention period for wet maintenance be greater than 12 years.

7.2.2 Relative Product Comparisons – Extended Sheeting Life

To assess the potential cost benefits of each product, the product cost has been added on to the sheeting costs but no additional costs associated with handling and container disposal considered.

For this financial analysis, the estimates of sheeting life determined from the rutting measurements are considered to be the most appropriate since they are a direct measurement of surface wear directly attributable to traffic.

Table 15 Product Comparisons Extended Sheeting Lives

Treatment with Annual Wet maintenance	Estimated Sheeting Life (Years)	Equivalent Annual Cash Flow (6% discount rate)
Unstabilised	12	$5 217
Roadbond EN-1	17	$5 081
Reynolds RT 12	15	$5 271
Reynolds RT 20	14	$5 125
Bitumen Emulsion	12	$5 669
Dustex	18	$5 541

In comparing different treatments in Table 15, only the EACF’s can be used because the life of the treatment varies such that capital investments occur over different terms.

In all cases except the bitumen emulsion, the analysis indicates some cost benefit of adopting chemical stabilisation with Reynolds RT-20 and Roadbond EN-1 probably offering the highest cost savings.

7.2.3 Product Comparisons – Extended Maintenance Intervention

The actual maintenance intervention period for the Copley trial was 18 months (July '99) therefore this analysis reflects this. No increase in sheeting life above that determined from rutting on each trial section is considered appropriate.

Treatment with 18month Wet Maintenance	Estimated Sheeting Life (Years)	Equivalent Annual Cash Flow (6% discount rate)
Unstabilised	12	$5 217
Roadbond EN-1	17	$4 389
Reynolds RT 12	15	$4 584
Reynolds RT 20	14	$4 440
Bitumen Emulsion	12	$4 992
Dustex	18	$4 847

7.2.4 Product Comparisons – Extended Maintenance with Periodic Stabilisation

In discussion with a number of product suppliers, they recommend that a 25% dilution of the original dosage used during sheeting be adopted for intervention maintenance. This analysis is therefore based upon increasing the maintenance intervention period to two years.

Treatment with 25% Stabilised Maintenance Every Two Years	Estimated Sheeting Life (Years)	Equivalent Annual Cash Flow (6% discount rate)
Unstabilised	12	$5 217
Roadbond EN-1	17	$4 449
Reynolds RT 12	15	$4 601
Reynolds RT 20	14	$4 243
Bitumen Emulsion	12	$5072
Dustex	18	$5 675

In this analysis, the cost of adding the product essentially balances out the benefit of extending the maintenance intervention period by six months. The main benefit of this strategy could be a build up effect of the binder which progressively decreases permeability and increases the binding nature of the material. In this scenario, both increased sheeting life and increased maintenance intervention periods could be achieved to lower the overall operating costs.

7.2.5 Life Cycle Cost Analyses Summary

From the above analyses it is evident that chemical stabilisation does present an opportunity to lower road operating costs or permit a larger length of the overall network to be maintained.

Data from Northern & Western Region indicates that about 288 kilometres of road is maintained annually using wet maintenance. The relative reduction in network operating costs (excluding container disposal and handling) could therefore be:

Table 16 Potential Annual Reductions in Network Operating Cost

Treatment	12 month wet maintenance	18 month wet maintenance	24 month stabilised maintenance
Roadbond EN-1	$39,168	$238,464	$221,184
Reynolds RT-12	-$15,552	$182,304	$177,408
Reynolds RT-20	$26,496	$223,776	$280,512
2% Bitumen	-$130,176	$64,800	$41,760
Dustex	-$93,312	$106,560	-$1,728

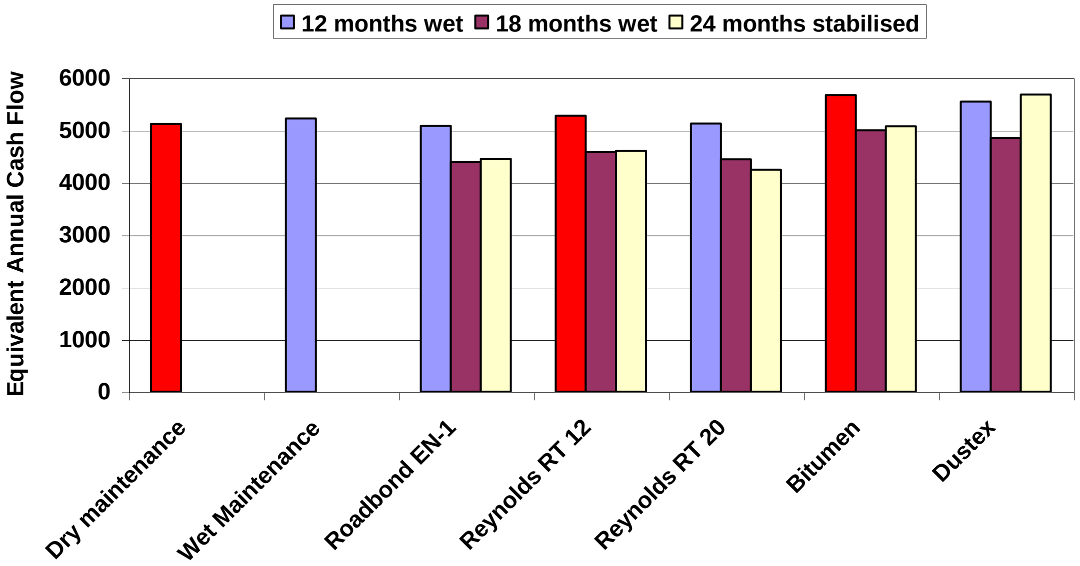


Figure 30 Relative EACF's for Different Products & Strategies

The above analyses indicates that chemical stabilisation can potentially offer up to a 20% reduction in road maintenance costs.

8. SUMMARY & RECOMMENDATIONS

8.1 Summary of Observations

Monitoring of the Copley trial sections over a two year period has indicated that immediate benefits are realised and sustained over a 12 to 18 month period before maintenance intervention.

The trial has revealed the following quantitative data :

- 10% - 20% decrease in roughness
- 0% - 50% reduction in permeability
- 0% - 10% increase in stiffness
- 10% - 30% reduction in rutting
- 20% - 50% reduction in loose surface material
- 20% - 50% decrease in maintenance
- 10% - 50% increase in sheeting life
- minus10% - 20% decrease in road operating costs
- a general recognition by road users of improvement over conventional sections
- Pavement behavioural patterns enabling targeted maintenance intervention to optimise surface condition.

Continued monitoring will be undertaken and observations to date following a wet maintenance intervention in August 1999 suggest that the stabilised surfaces are rejuvenated to their original condition.

It was evident that there were significant improvements in the wearing qualities of the surface during the first 12 months of the trial which were again realised after wet maintenance grading had been undertaken after 18 months. With a further light application of chemical stabiliser after 18 months even further improved performance could be realised.

In undertaking the economic analysis it was recognised that the sheeting life was a far more dominant factor than wet or dry grading interventions. Therefore using both rut development and measurement of loose material on the surface as measures of sheeting wear, the product do offer economic improvements.

For chemical stabilisation to be successfully adopted on outback roads, the liquid forms are far easier and more suited to use. In addition, with the low dosage rates, a semitrailer load of product will stabilise many kilometres whereas the amount of powder stabiliser to cover the same distance will be much more.

Of the products trialed it is considered that the Roadbond EN-1 and the Reynolds RT 20 have most to offer TSA and should be adopted on a range of projects to build a databank of performance and improve the technology.

8.2 Recommendations

It is considered that both "most weather" access to the network and road safety can be enhanced by the adoption of chemical stabilisation targeted to specific "black spot" areas viz; heavy wearing sections like grid approaches, bends, intersections, and seasonally impassable areas like swamps and clay pans etc.

On the rural sealed road network (which generally comprises poor quality pavement materials and typically shallow pavement depths) rehabilitation has traditionally been undertaken adopting a granular overlay. However, the availability of suitable overlay material is rapidly declining and insitu stabilisation to depths penetrating the subgrade has been adopted.

Chemical stabilisation in these circumstances can be of direct benefit where moderate plasticity materials are encountered acting as dispersants within the fine material. In addition, the dispersive characteristics permit more efficient penetration of a primary binder such as cement of lime/fly ash thereby reducing the quantity required.

Recommendations for incorporation of the products include:

- ♦ Heavy wear areas: Corners, intersections, slopes
- ♦ High impact areas: Grid approach & departures
- ♦ Access difficulties: Swamps, creeks
- ♦ Poor material areas: No natural gravels available
- ♦ Sealed widening: Converting shoulders into pavement
- ♦ Secondary additive: General stabilisation of poor materials

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Appendix A: Unsealed Roads Management System

DEPARTMENT OF TRANSPORT

NORTHERN AND WESTERN REGION

UNSEALED CONDITION RAT1NG (USCR)

Introduction

The primary purpose for this rating system is to provide data to:
- report on the overall condition of the road network,
- identify general trends,
- assist with performance of materials and work methods,
- assist with determining work priorities.

It is not proposed to use the information to set daily work programs as the information recorded is only a "snapshot" of conditions that vary substantially.

Instructions to Raters

Regional Superintendents will be responsible for rating roads in their area in accordance with the criteria set out below. Ratings should be assessed by travelling in the wheelpaths currently in use by the road user and at the "environment speed" for the road. Ratings have been set to suit experienced "dirt" drivers in conventional vehicles.

The general basis of ratings is as follows:

0	=	Unknown	Use only when no rating is possible
1	=	Negligible	Defect not present to any significant extent.
2	=	Slight	Defect causes slight safety risk and some discomfort at "environment. speed" but an experienced driver is not significantly affected.
3	=	Medium	Defect compromises safety and comfort to the extent that "environment speed" is not possible, but immediate intervention is not yet necessary
4	=	Severe	Intervention required as soon as possible.

When assessing the ratings for a segment it is important to record the overall. condition of the segment, ignoring exceptional, locations that are inconsistent with the rest of the segment. For example, a bad bull dust blowout in a segment that generally does not have a hole problem should be ignored. List it for separate attention by the patrol.

CORRUGATIONS

DEFINITION:

Transverse undulations, closely and regularly spaced with wavelengths less than 1 metre.

METHOD OF MEASUREMENT:

Place straight edge on adjacent crests and measure the maximum depth under the straightedge. Measurements should be taken in the wheelpaths currently in use.

RATING CRITERIA:

Consider the depth of the corrugations and their extent through the length of the segment and select rating in accordance with the following guidelines.

CORRUGATION ASSESSMENT MATRIX

CORRUGATION DEPTH

Extent	0 – 5mm	5 – 20mm	20 – 30mm	>30mm +
0% to 5%	1	2	2	3
5% to 25%	2	3	3	4
>25%	2	3	4	4

METHOD OF ASSESSMENT:

Judge the typical depth and extent of corrugations in the first 70% of the segment. Stop and check measure the depth at typical corrugations in the last 30%. (This may not always be necessary once driver has his eye calibrated.) At the end of the segment, confirm the extent and assess.

RAVELING

DEFINITION:

Loose material on the pavement surface either over the whole surface, or in narrow continuous mounds between wheel paths.

METHOD OF MEASUREMENT:

Use a straight edge to measure the maximum height of the mound between adjacent wheel paths. Measurements should be taken between the wheel paths currently in use.

RATING CRITERIA.

Consider the height of the ravelled mound and its extent through the length of the segment and select rating in accordance with the following guidelines.

RAVELLING ASSESSMENT MATRIX

HEIGHT

Extent	< 50mm	50 – 100mm	>100mm
0% to 5%	2	2	3
> 5%	2	3	4

Use rating 1 only where there is no loose material on the road surface.

METHOD OF ASSESSMENT:

Judge the typical depth and extent of ravelled mound in the first 70% of the segment. Stop and check measure the depth at a typical ravelled mound in the last 30%. (This may not always be necessary once assessor has his eye calibrated.) At the end of the segment, confirm the extent and assess.

WET RUTS

DEFINITION:

Longitudinal tyre impressions left in the road surface following wet weather.

RATING CRITERIA:

The depth of ruts is almost irrelevant as even very shallow ruts can pull a vehicle off line, particularly at speed.

Consider the avoidability and extent of rutting through the length of the segment and select rating in accordance with the following guidelines.

WET RUT ASSESSMENT MATRIX

AVOIDABILITY

Extent	Avoidable	Difficult	Unavoidable
< 10%	2	2	3
> 10%	2	3	4

Use rating 1 where there is no rutting in the pavement surface.

METHOD OF ASSESSMENT:

Judge the avoidability and extent of ruts and make the assessment at the end of the segment.

BULL DUST HOLES

DEFINITION:

Distinct areas where the pavement material has broken down to fine talc-like powder (bull dust) to its full depth. These holes have steep sides. are of irregular shape, and have a surface area in excess of 1 square metre.

RATING CRITERIA:

Consider the number of bull dust holes evident over the length of the segment only, as this is sufficient evidence of the extent of the problem.

BULL DUST HOLE ASSEUMENT MATRIX

0 - 1 Hole	1
2 - 3 Holes	2
4 - 9 Holes	3
>10 Holes	4

METHOD OF ASSESSMENT:

Count the number of bull dust holes and make the assessment at the end of the segment.

COARSE TEXTURE

DEFINITION:

Protrusion of stone generally larger than 50 mm from the pavement surface, with some loose on the surface.

METHOD OF MEASUREMENT:

Place the straight edge longitudinally in a wheelpath on adjacent stones and measure the depth under the straightedge to the average pavement surface. Measurements should be taken in the wheelpaths currently in use.

RATING CRITERIA:

Consider the protrusion of the stone and the extent of coarse texture through the length of the segment and select rating in accordance with the following guidelines.

COARSE TEXTURE ASSESSMENT MATRIX

DEPTH

Extent	0 – 15mm	15 – 30mm	> 30mm - loose
0% to 5%	1	2	2
5% to 25%	2	3	3
25% +	2	3	4

Use rating 1 where there is no significant loose stone larger than 50 mm obvious in the pavement surface.

METHOD OF ASSESSMENT:

Judge the typical protrusion and extent of coarse texture in the first 70% of the segment. Stop and check measure the depth at typical coarse texture in the last 30%. (This may not always be necessary once assessor has his eye in.), At the end of the segment confirm the extent and assess.

Appendix B: Life Cycle Costing Analyses

Appendix C: Project Definition Report

TRIAL DUST SUPPRESSION & SURFACE LONGEVITY TREATMENTS FOR OPEN SURFACE ROADS

97/PA/056

Date of Preparation: DECEMBER 1997

Prepared by: Bob Andrews, Materials Technology
Graham Cook, Technology Development

TRIAL DUST SUPPRESSION & LONGEVITY TREATMENTS FOR OPEN SURFACE ROADS

Project Number

97/PA/056

Project Title
Trial Dust Suppression & Longevity Treatments for Open Surface Roads

Scope
To trial various surface stabilisation products on unsealed pavements.

Problem Description
Maintenance by re-sheeting implies material search and opening new borrow pits. This process is becoming increasingly more difficult and undesirable from both an environmental and aboriginal heritage view.

The creation of dust represents a road safety hazard and impacts on the environment (ie roadside vegetation).

Needs Statement
To extend the resheeting intervention period and reduce erosion and surface wear of unsealed pavements.

Objectives and Desired Benefits
To increase the surface longevity and pavement condition to enhance road safety and reduce the use of natural materials.

Reduction in the overall maintenance cost of the unsealed road network and reduction in road accident related to surface condition.

Pavement behavioural models for optimisation of maintenance intervention

Failure/Success Criteria
Subject to agreement from Suppliers and Northern And Western success shall be judged on:

- Comparison with the untreated control section a minimum 20% reduction in dust suppression shall be achieved over the life of the project.
- A positive cost benefit is realised.
- Applicability of test procedures in quantitative evaluation.

Background
The unsealed road network contains significant freight and tourist transportation routes. The cost of maintaining these roads is in excess of $10 million per annum principally in grading and resheeting operations.

As an alternative recycling the existing pavement by insitu stabilisation offer a more economic and environmentally acceptable solutions depending upon the cost and effectiveness of stabilisation additive.

A number of stabilisation additives are marketed as dust suppressants as well as improving pavement stiffness.

These products have the potential to improve the performance of unsealed road surfaces.

Methodology

1. To establish a trial section on road number 16021 (Copley - Balcanoona) in which a variety of products can be incorporated.

2. In consultation with Northern & Western Region agree on products to be trialed.

3. Devise laboratory tests to provide quantitative assessment of product efficiency.

4. Regional maintenance to resheet a 6km trial section using local borrow material. In conjunction with product suppliers stabilise the resheeting material using only the existing equipment used by the maintenance gang.

5. Establish a monitoring program incorporating an environmental impact assessment to quantitatively access roughness, dust generation, surface texture, rutting, erosion and shape loss. Monitoring to be conducted over 1,3,6,12,& 24 months.

6. Adapt Unsealed Road Maintenance System (URMS) to the trial section to describe pavement condition rating over 1,3,6,12 & 24 months.
7. Undertake cost benefit analysis of the various treatments compared to current process of wet maintenance (refer 97/PA/057).

8. Technology Transfer through presentation to Regional Staff, Local Governments of Eyre Peninsula and York Peninsula Murray Bridge. Produce a work practice guidelines on wet maintenance / stabilising unsealed pavements.

Output

This project will have three main outputs they are:

- A technical and economic appraisal of four stabilisation products.

- Promulgation of new techniques to major stakeholders.

- Improved asset management of maintenance strategies for unsealed roads.

Total Estimated Duration of Project

This project will run for two years initially with an extension to be proposed for long term monitoring if considered appropriate

Proposed Budget for First Year

The proposed budget for the first year will be $30 000.

Total Project Estimate

The total project estimate would be $70 000.

Intellectual Property Arrangements

Project outcomes to be made available to product suppliers.

Risk Analysis

There would be no identifiable benefits from using the product.

Stakeholders
Pavebond Pty Ltd
BP Bitumen
Everlevel Drainage Systems
Regional Maintenance

Possible Service Providers
Northern & Western Region maintenance gangs
Materials Technology, Port Augusta
Transport Information Management Systems
Materials Technology, Walkley Heights
Environmental Unit, Walkerville
Traffic Operational Standards, Walkerville

Adoption Customers
Local Government
Department of Tourism SA
AUSTROADS
SANTOS

Other Potential Markets
Western Mining
South Africa
ASEAN Countries
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Canada

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INFORMATION RETRIEVAL

R.C.ANDREWS "Surface Longevity Treatments for Unsealed Roads" MTRD Report No. 97/PA/056   65 pages, 30 Figures, 16 Tables, 3 Appendices

KEYWORDS: Chemical Stabilisation, Stabilisation, Unsealed roads, Gravel roads, Low volume roads, Local roads, Dust suppression, Arid climates, Life Cycle Costs.

ABSTRACT:
This project reports on a two year monitoring period undertaken to evaluate five chemical stabilisers incorporated into an unsealed road surface. Details of the behavioural characteristics, structural enhancement and surface integrity of the pavement over a two year monitoring period are presented.

Life cycle costs and estimates of various treatment lives are presented from which an implementation strategy for outback roads In the north and west of South Australia has been formulated.

MTRD REPORT NO. 97/PA/056

SURFACE LONGEVITY TREATMENTS
FOR
UNSEALED ROADS

TECHNICAL SUMMARY

Objectives

To quantify the physical performance of various unsealed road surface treatments, life cycle costs and road user perceptions of road condition, measure of improvement and deterioration with time.

Background

The unsealed road network contains significant freight and tourist transportation routes which incur an annual maintenance expenditure in excess of $10 million as well as consuming large quantities of natural resources.

By comparison to sealed roads, unsealed road performance is typified by:

- Low traffic volumes but vital transport routes
- High operating costs in routine maintenance grading and re-sheeting.
- Restricted access in times of heavy rain.
- High accident risk.
- High environmental and heritage impact of material borrow pits.

Within Transport SA, these issues have been addressed with the introduction of "wet maintenance" techniques that provide improved surface characteristics. This technique has been achieved through with significant investment in support infrastructure to provide a source of water.

As an addition to wet maintenance, there are a large variety of chemical stabilisers on the market which could potentially further enhance the quality of the unsealed surface.

Methodology

- ♦ To establish a trial section on road number 16021 (Copley - Balcanoona) in which a variety of products can be incorporated.
- ♦ The products proposed are Roadbond EN-1, Reynolds RT12 & RT20, Bitumen Emulsion and Dustex.
- ♦ Devise laboratory tests to provide quantitative assessment for product selection.
- ♦ Regional maintenance to re-sheet a 6km trial section using local borrow material. In conjunction with product suppliers stabilise the re-sheeting material using only the existing equipment used by the maintenance gang.

- Establish a monitoring program incorporating an environmental impact assessment to quantitatively access roughness, dust generation, surface texture, rutting, erosion and shape loss. Monitoring to be conducted over 1,3,6,12,& 24 months.
- Adapt Unsealed Road Maintenance System (URMS) to the trial section to describe pavement condition rating over 1,3,6,12 & 24 months.
- Undertake cost benefit analysis of the various treatments compared to current process of wet maintenance (refer 97/PA/057).
- Technology transfer through presentation to Regional Staff, Local Governments of Eyre Peninsula, Yorke Peninsula, Murray Bridge.
- If appropriate, provide recommendations for implementation of the technology to maximise the benefits offered to the network.

Conclusions

The trial has revealed the following quantitative data :

- 10% - 20% decrease in roughness
- 0% - 50% reduction in permeability
- 0% - 10% increase in stiffness
- 10% - 30% reduction in rutting
- 20% - 50% reduction in loose surface material
- 20% - 50% decrease in maintenance
- 10% - 50% increase in sheeting life
- minus10% - 20% decrease in road operating costs
- a general recognition by road users of improvement over conventional sections
- Pavement behavioural patterns enabling targeted maintenance intervention to optimise surface condition.

Benefits

Monitoring of the Copley trial sections over a two year period has indicated that immediate benefits are realised from chemical stabilisation and are sustained over a 12 to 18 month period before maintenance intervention is required. In addition, continued monitoring is developing a behavioural model of an unsealed road which will lead to identification of timely maintenance intervention optimising the riding condition of the pavement.

A simple evaluation test has been devised to provide a visual indication of the benefits a particular product may have when used in conjunction with a particular soil type.

Recommendations for incorporation of the products include:

- Heavy wear areas: Corners, intersections, slopes
- High impact areas: Grid approach & departures
- Access difficulties: Swamps, creeks
- Poor material areas: No natural gravels available
- Sealed widening: Shoulders into pavement
- Secondary additive: General stabilisation of poor materials

Implementation

In conjunction with two other Technology Development Projects, two seminars were held at Port Augusta for Transport SA staff and external stakeholders. In addition recommendations have been made to incorporate the products into management of the unsealed road network.

March 2000

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