Maintaining the road infrastructure in saline prone areas

by
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Abstract

Both government and industry emphasise the need to ensure that our road infrastructure is capable of carrying goods and services from farms to the cities and ports. One of the key elements of this requirement is the successful operation of our unsealed and sealed roads during all weather conditions. This is particularly necessary for roads with granular pavements where structural strength is reduced by the ingress of water from whatever means. The current issues relating to rising water tables and the introduction of higher salt levels in the pavement impact on the pavement strength and reduce the effectiveness of the seal leading to the deterioration of roads.

Stabilisation of pavement materials to minimise or eliminate the migration of the salt and water to the trafficked area is known to increase the life of the pavement. Road stabilisation also significantly increases the strength of the pavement to carry heavily loaded vehicles.

This paper looks at pavement material properties that are likely to affect the performance of stabilised pavements in regions of high salinity. Guidelines are provided to assess existing pavement materials and subgrades, and for design rehabilitation solutions that provide pavement engineers with a rational approach to make the roads last longer under less than desirable road environments.

1 Introduction

There is no doubt that salinity and the rising water tables affect the road infrastructure. The casual observer will see culverts and roads deteriorating, leading to conditions that are unacceptable. The effects on road infrastructure may be summarised as:

- Rutting in granular pavements,
- Differential shape loss resulting in rough pavements,
- Seal "blister" leading to loss of seal, water infiltration and potholing, and
- Increased flooding leading to greater siltation and lower the capacity of hydraulic structures to discharge floodwaters.

Whilst much of the focus on salinity and the state of the infrastructure appears to be in rural Australia, urban areas can have similar problems, where the removal of native vegetation by developers and new water supply systems, that unfortunately leak, cause distress to roads [1]. With road replacement costs in the range of $250,000 to $500,000 per km [2] several options need to be evaluated in the laboratory and sometimes trailed before an extensive rehabilitation road program can commence.

Both State and Local Government Authorities have to work together to find a solution, as salinity issues do not distinguish between the various jurisdictions. Research carried out by SRA's is most likely to have direct application for local government engineers even though in many instances traffic loadings may be lower.

This paper takes into consideration the issues facing pavement engineers and asset managers and offers practical guidelines for engineers to consider in designing low and heavy trafficked rural roads in areas with high water tables and salinity. There is also no one unique solution, and each site may require a range of solutions to accommodate road funding levels, and the needs of property owners adjacent to the road reserve.

2 The issues

In the middle of the 20th century road builders and railway engineers created a formation for the road (and railway) to allow a significant rise above the natural ground formation (see Figure 1). As road construction activity expanded in the later half of the 20th century road construction techniques were taken for granted, and limited funding, shorter-time periods to construct roads and minimising flood structures resulted in roads being constructed at the surrounding grade. The cost to now raise the road well above the surrounding grade is prohibitive, and road engineers are seeking new solutions.

Figure 1 Typical formations for roads built to cross rivers and flood plains over 50 or more years ago.

It has been documented for many years, and well expressed by Skender and Leach [3] that

… the performance of many naturally occurring materials is strongly dependent on their moisture content and confident use of such materials requires an ability to predict likely service moisture conditions.

Unsealed roads commonly consist of a basecourse material that has been built up in thickness over the years on the natural subgrade level. Ground water levels are usually well below formation level, except where rivers or irrigation channels are close by the road or in wet cuttings. Culverts, side drains and other drainage structures are normally provided to intercept or discharge water and prevent pooling on or near the pavement.

Over the last 5 years road owners have been increasing the seal width of rural main roads to improve safety. This has generally done by improving the existing shoulder and sealing. Evidence [4] has shown that wider lanes and sealed shoulders can reduce truck accidents by 60% (see Figure 2). This approach has also benefited road performance by keeping runoff water from wetting the granular material near the outside wheel paths. Additionally the water ponding effects of grass growing on the unsealed shoulder and up to edge of seal are mitigated (see Figure 3).

Salt damage to spray seals is related to high concentrations of soluble salts in the basecourse material immediately below the surface. As the salt dries out subsequent hydration exerts pressure on the seal resulting in a “blow-out” (see Figure 4). The loss of seal integrity exposes top of the pavement material allows water into the pavement and consequent potholing and loss of strength.

Figure 2 The seal now extends well past the lane markings to increase safety and reduce the ingress of water into the pavement material. Newell Highway, just north of Jerilderie (NSW).

Figure 3 With the shoulder unsealed, water is allowed to pond in the outside wheel path and this increases pavement damage.

Figure 4 Bitumen seal "blow-out" as a result of salt under the seal.
(Photo courtesy of RTA)

Figure 5 Very stiff and thin stabilised pavements are likely to crack when built on wet and weak subgrades. (Photo courtesy of RTA)

As noted previously, granular pavements loose shape and crack due to the ingress of moisture into the pavement and subgrade. For stabilised pavements a thin stiff layer overlaying a weak subgrade also crack as shown in Figure 5.

The selection of an appropriate pavement material contributes to its long-term success pavement performance under differing traffic and climatic conditions. With a high water table, a material with low permeability is important, but so too is sufficient strength to carry traffic loading. A limited supply of rural quarries and borrow pits usually places pressure on pavement engineers to use marginal road making materials and the above two needs are difficult to meet.

Finally, if the best materials are not available and the moisture of the material is above OMC, the contractor has the challenge to achieve suitable compaction against a weak subgrade. The odds continue to mount up and oppose the ideals of suitable road construction, and one could even ask is the road located in the best place to serve its purpose.

3 Potential treatments

Apart from the impact of salt on seals, possible treatments are based on trying to solve the problem of changes in pavement moisture content. The sources of moisture change may result from:

- Infiltration and transfer through shoulders
- Cracks in sealed surfaces
- Movement of water from subgrade due to rising water table or vapour movement
- Inadequate or poorly constructed surface drainage
- Moisture content at construction being greater than equilibrium moisture.

These sources can be addressed by better road profile designs and better management of road construction. The Department of Main Roads Queensland (QDMR) has examined better ways of dealing with rural road cross sections and they have issued undesirable and desirable road sections for Western Queensland rural roads as shown in Figures 6 and 7 respectively [5]. Although they are intended for expansive soils, this approach is also applicable for high water tables.

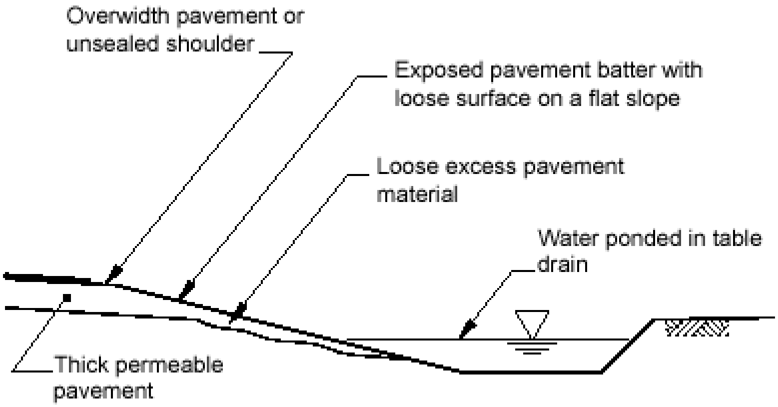

Figure 6 Undesirable features for road drainage for expansive soils [5]

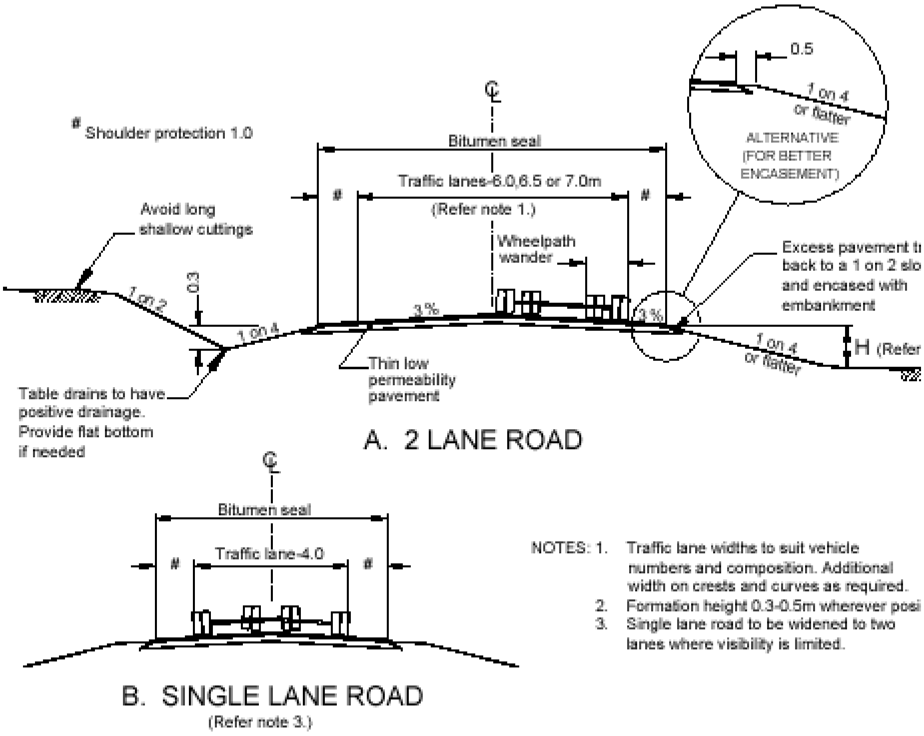

Figure 7 Desirable features for road drainage for expansive soils [5]

Other treatments that should be considered are:

a) Raising the embankment by 1 m and constructing a new pavement.

b) Reduce the water table by planting trees near and adjacent to the road easement.

c) Install a drainage blanket and new pavement.

d) Deep-lift stabilisation with 200 mm additional granular material (lime subgrade stabilisation where required).

e) Dual layer stabilisation consisting of bottom layer stabilised with polymer/lime binder and upper layer stabilised with cementitious binder.

f) Granular resheeting with at least 200 mm of material and mechanically stabilised[1].

[1] A polymer type binder may also be applicable.

Option (a) is similar to rural highway reconstruction and it is estimated that increasing the road level by 300 to 1,000 mm would cost between $250,000 to $500,000 per km, where option (b) may be the first alternative to reduce the water table. However, this option may need up to 10 years for an effective reaction and does not remedy the short-term need to rehabilitate the road. In addition, care should be taken when locating trees and the need for safety barriers to be recognised on some routes to minimise the chance of vehicular impact.

A drainage blanket (c) and new pavement option is more suited to green field sites as the removal of the existing pavement material is a costly exercise, and the overlapping of blankets to effectively keep the moisture from rising is difficult to achieve when using mechanical equipment to replace the pavement material above the blanket.

Options (d) to (f) use some form of stabilisation with or without binders. As with all forms of pavement construction care needs to be exercised in the selection of methodology used . For instance, Chapter 8 of the Austroads pavement design guide [6] shows a granular layer over a cement treated base, sometimes referred to as an "upside down pavement". Depending upon the permeability of the pavement materials forming the pavement, moisture can be trapped above the stabilised layer leading to a weakening of the unstabilised material. It is now recognised that this configuration is more suited to dry climate environments.

A current Austroads project examining the characterisation of stabilised materials[2] has defined modified and bound stabilised materials as listed in Table 1. It is recognised that heavily bound materials are more suited to deep-lift construction for heavily trafficked roads and lightly trafficked roads use either modified or lightly bound base pavement layers with a sprayed seal or 30 mm of asphalt. Modified materials are constructed with lime, cement or polymers in the range of 1.5% to 3%. The practical lower limit of a powder binder application for modification has been found to be 1.5% by weight of pavement material, and the modulus is in the range of 500 to 1000 MPa.

Table 1 Typical properties of modified, lightly bound and heavily bound materials. [7]

Degree of Binding	Design Strength (MPa)	Design Flexural Modulus (MPa)
Modified	UCS < 1.0	≤ 1,000
Lightly bound	UCS: 1-4	1,500 – 3,000
Heavily bound	UCS > 4	≥ 5,000

Notes: 1. 28 day test results, standard compaction and moist curing to AS 1141.51
2. For slow setting binders the 28 day test results will be less than the values shown but will continue to increase in the field for at least 6 to 12 months

A recent trend in Victoria is to mechanically stabilise existing pavement materials by importing quarried material such that the particle distribution complements the existing material [8]. This approach is initially being adopted for shoulder reconstruction but it also has merit in the trafficked lanes. More details of the test results and application can be found in the VicRoads Report No.TR110.

When to use lime, cement or polymers is still a vexed questions for many pavement engineers and new publications prepared by an Austroads pavements group and about to be released provide guidelines, and these are covered in the next section. AustStab and its members have a view that a binder should be chosen for both its cost and applicability to the soil. In Australia, about 25% to 50% of the cost of a project is in the supply of the binder, and therefore, the selection of the binder for large projects becomes a primary concern for the road owner.

[2] For more information on this topic refer to www.auststab.com.au/research/

4 Laboratory guidelines

There are numerous laboratory tests to characterise unbound and bound materials, and in this instance the following tests should be considered for an evaluation in the laboratory of the existing material and preferred stabilising binder. The properties and tests are:

- CBR to AS
- UCS to AS 1141.51 using Standard compaction
- Degree of saturation
- Permeability to AS 1289.6.7.1
- Capillary rise and swell to AS 1141.53

Excessive moisture in granular materials reduces dry strength and durability. Both granular (unbound) and stabilised pavement materials can be tested in the laboratory to give a relative indication of their likely performance. This is achieved by looking at the degree of saturation the material will be subjected to.

The degree of saturation (S) of a granular material may be calculated using the following equation:

$$S = \frac{1}{\frac{P_w}{P_d} - \frac{1}{APD}} \times w\%$$

Where APD = Apparent Particle Density (m^3)
w = moisture content (%)
P_w = 1.0 t/m^3 (density of water)
P_d = dry density (t/m^3)

The degree of saturation method has been based on work by Qld Main Roads [9] and Figure 8 provides a sensible approach to assessing whether the material will perform as is, requires additional testing or to be stabilised.

Another important test is the capillary rise and swell test, as detailed in AS 1141.53. In this test the capillary rise is given as a ratio in percent of the moisture rise in the specimen to the initial specimen height. There is no absolute level of acceptance for capillary rise for stabilised materials and a suggested maximum is 25 mm rise in a 100 mm high sample (i.e. 25% rise limit) in 24 hours.

Capillary rise testing is suited for comparative purposes on road projects to discriminate between binder types or contents for a specific pavement material, and untreated granular material. The Australian Standard test for capillary rise also determines the absorptivity and the swell of the specimen.

The various test methods for lime stabilisation, and modified and bound stabilised pavements using cementitious binders has been examined by an Austroads project and detailed in a report to be published in the later half of 2001 [7]. This report outlines various flowcharts (see Figures 9 and 10) to establish the minimum binder content.

It is recommended that where the water table and traffic loadings are high the capillary rise test be conducted. Whilst it is agreed that this test is not very common today, it does present more information on whether a binder is suitable for the material being used.

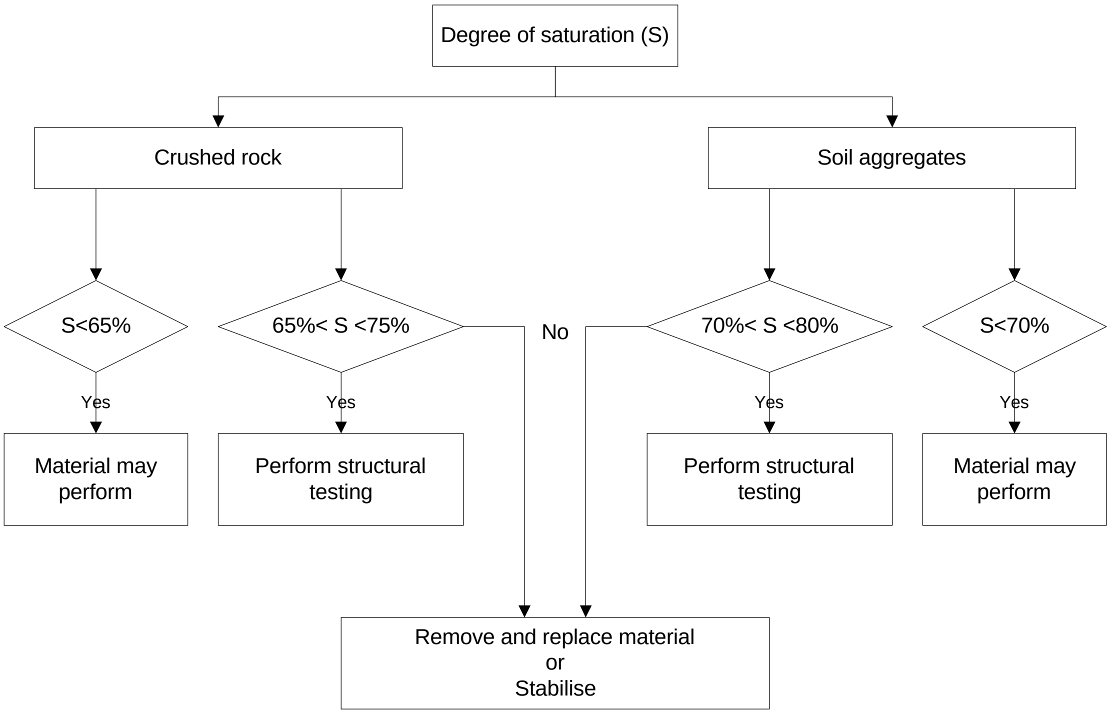

Figure 8 The degree of saturation and suggested procedures for further action [9].

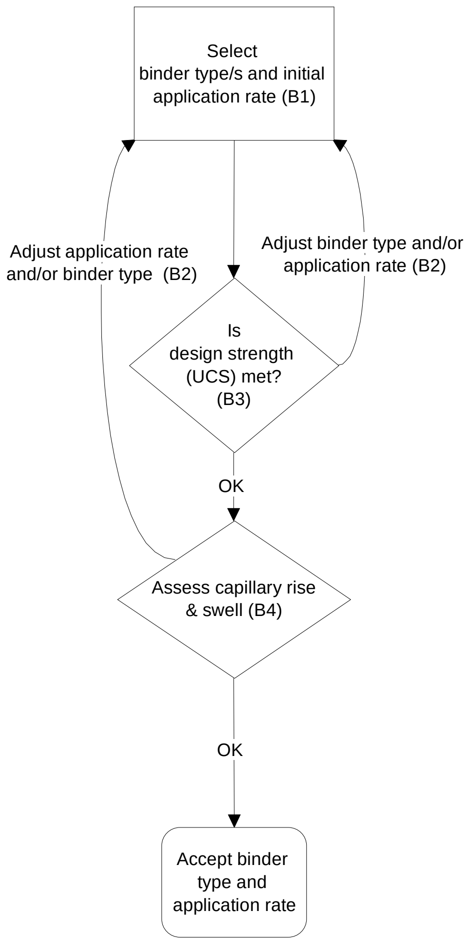

Figure 9 Flowchart for the modification of pavement materials using cementitious binders. [7]

NOTE: Refer to Austroads Report for flowchart notes.

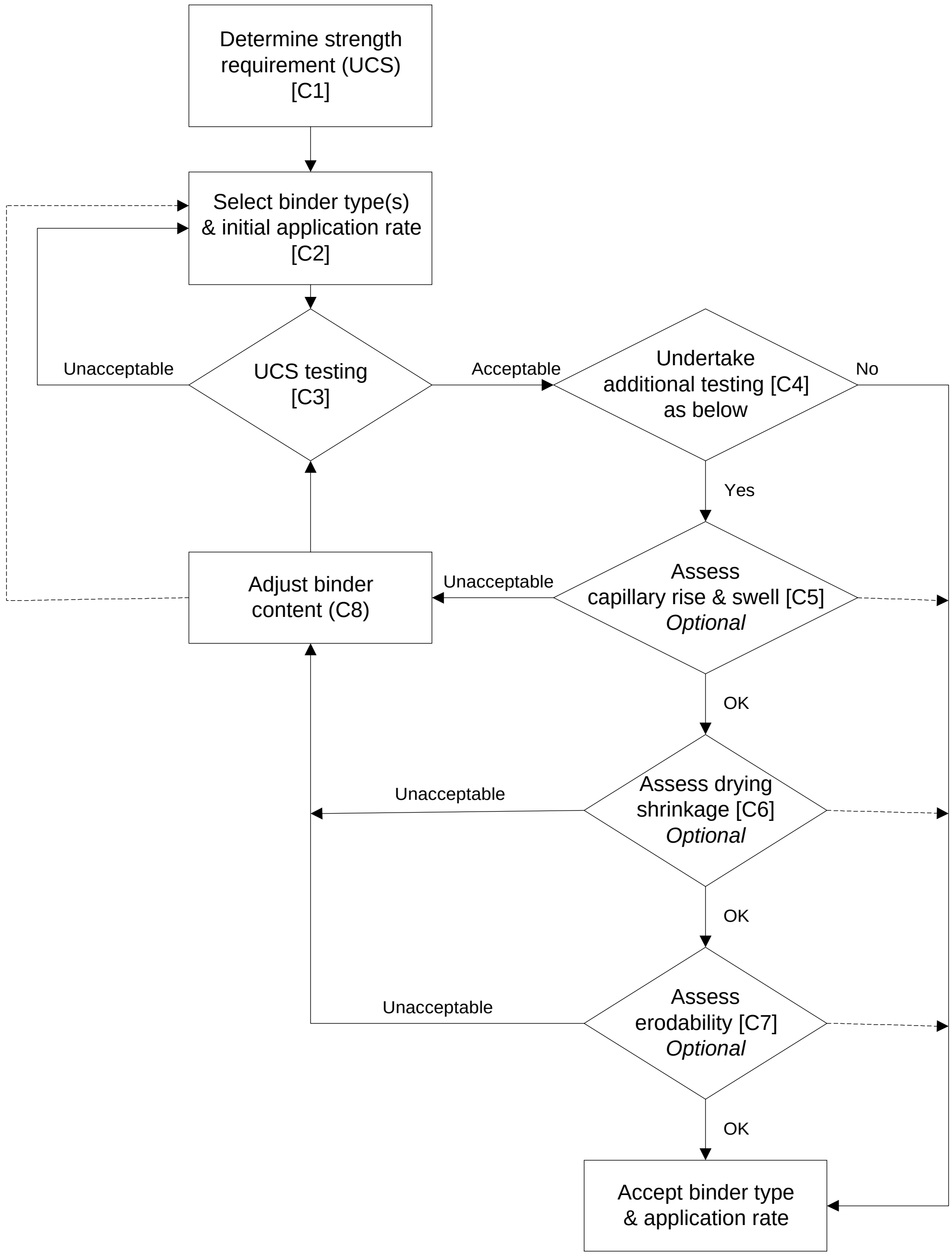

Figure 10 Flowchart for lightly and heavily bound pavement materials using cementitious binders. [7]
NOTE: Refer to Austroads Report for flowchart notes.

The Wagga Wagga office of the RTA has been considering various solutions for the rehabilitation of its roads in the Riverina District [10]. Five trial sections were designed (see Table 2 with three of the sections listed) and corresponding laboratory testing was carried out in 1996 to examine if laboratory testing could provide a clear indication of field performance. The deflection results in Table 3 indicate that the mechanical stabilisation provides substantial stiffness benefits without being overly stiff. The dry powder polymer binder [11] showed a reduction in PI and stiffness, and is now being used as a binder where the water table is high as the roadway, such as the Riverina Highway near Blighty (NSW). Figure 11 shows a road following a typical irrigation channel and the road is subjected to high water tables. Whilst de-watering is a potential approach to reduce the water table, in this instance the road material was stabilised with a dry powder polymer to provide a "water proof" basecourse material that could cope with a continuously wet subgrade and "survive" without significant deformation after the road was flooded. After 5 years, the material shows no sign of cracking or deformation.

Figure 11 A section of the Riverina Highway where the upper 200 mm of the road base has been stabilised with Polyroad.

Table 2 Trial section details on Newell Highway, West Wyalong (1996). [10]

Sections	Designation	Description
1	Control section	Mechanical stabilisation of existing material
2	Polyroad	Existing pavement mixed with Polyroad PR21L at 1.5% (by mass of existing material)
3	DGB20	50 mm of DGB20 added to and mixed with existing material.

Table 3 Several test results on the laboratory and before and after construction of the three trial alternatives [10].

Designation	PI		Deflection results (mm)			Costs ($/m2)
	Pre	Post	Before	After	% ch.	
Control section	8.5	10.0	0.66	0.54	-18%	$6.36
Polyroad	10.5	9.5	0.82	0.64	-22%	$9.76
DGB20	5.5	10.5	0.82	0.76	-7%	$8.70

5 Performance of stabilised pavements

Visual observations of stabilised pavements in NSW in known salinity areas indicate that material stabilisation is successful at coping with rising water tables and salinity. Where bound pavements have been constructed on very wet subgrades, the stabilised layer has cracked, usually in the outer wheel path, due to the lack of support from the subgrade. Here the stabilised layer was made too stiff on the premise stronger is better with out recognising the failure mechanism of a bound pavement, ie fatigue due to excessive tensile strain.

The stabilisation trial noted in the previous section with the use of Polyroad as the binder has shown promise with no signs of rutting or cracking. Further analytical site investigation is required.

No documented case studies in Australia and USA could be found on the performance of stabilised roads in known salinity areas, and only anecdotal evidence is available. Thus, this paper cannot furnish any quantitative findings except the outcomes of the laboratory testing.

6 Research

The laboratory testing carried out by the RTA and other road authorities provide an initial indication that stabilised materials perform well in the laboratory. However, laboratory testing does not mimic the field condition of the materials under repeated traffic and climatic changes. Laboratory testing does provide an excellent relative performance comparison of suitable materials treated or untreated.

Austroads continues to use the Accelerated Loading Facility (ALF) to test pavement materials and configurations under high wheel loading to predict the performance of the trial pavements. Engineers in NZ, USA, South Africa and Europe use this type of device to provide guidance on the performance of new design techniques and pavement materials. The authors believe this is a cost effective approach to quickly assess the performance of the pavement material without having to wait for several years to see in field performance under actual conditions on a road trial.

Local and State Government road authorities have installed a myriad of trial sections over the last 10 years and there should be a suitable level of funding for research organisations, such as ARRB Transport Research, to now investigate the performance of these trials and provide some initial conclusions of the performance of the various trial pavements.

Currently it is estimated that the road infrastructure network is valued at $78 billion [12] and a total of about $2 to $3 million[3] or 0.003% is spent on research per annum. Private industry would not make decisions on very scant information, why should government do less on researching the performance, maintenance and upgrading of public assets? More research dollars are required and now! The recognised investigation spend on geotechnical investigations for a civil engineering project is 3% and at 0.003% the current effort is hardly conducive to developing a growing body of knowledge on how our pavement materials behave generally, let alone when subjected to salinity issues.

7 Conclusions

It is now recognised that road maintenance alone cannot address the long-term problems associated with rising water tables and salinity. Possible options available are:

- raise the existing pavement level with suitable material and stabilise the top layer/s to strengthen the material to carry heavy traffic,
- stabilise the subgrade to reduce its susceptibility to moisture changes,
- design subsurface drainage systems, and
- extensively plant trees in the road reserve to bring the water table down.

In examining options it may be necessary to look at new testing options.

Consequent with the immediate actions to address current urgent problems there needs to be a commitment by all the stakeholders to a far greater expenditure on pavement related research. It is suggested that an annual research budget of at least $5million be established to research the effect of salinity related issues on pavement materials.

[3] Estimate based on Austroads, SRA and Local Government spending on research last year.

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