

PERFORMANCE OF LOCAL ROADS BY INSITU STABILISATION

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ABSTRACT

There is very little to no literature that substantiates a method of analysis for pavements that have stabilised depths of 200 mm or less and experiencing relatively light traffic. Whilst there is some qualitative data which is based on past performance there is little information regarding the structural nature of the pavements and their response to repeated loading over time and the appropriate method of design. The paper focuses on investigating the appropriateness of the current fatigue relationship used in mechanistic design of stabilised pavements, and assessing the predicted life of thin-stabilised layers with reference to these models and also through non-destructive field testing.

The methodology of assessing performance was through the selection of ten local roads in the Macquarie Lakes district of NSW that had been previously stabilised at different periods with varying traffic volumes. Each road underwent data collection including, traffic volume and composition, and Benkleman beam. Computer modelling was undertaken using EFROMD2 and CIRCLY.

The analysis indicated that it was not possible to assess the design or remaining life of an insitu stabilised pavement with a cemented base layer less than 200 mm given the mechanistic design principles with the fatigue relationship in common use. Further research is required to understand the performance of these pavement subject to light traffic.

INTRODUCTION

The process of insitu stabilisation of road pavements is a technique that has been used since post World War 2 as a means of pavement rehabilitation (Wilmot, 1996). The extent of its use and the degree of success has varied widely since its inception. However, due to continuing technology improvement of purpose-built machinery and the development of specialised additive blends insitu stabilisation has now become an accepted and widely used viable alternative in the treatment of failing pavements. Its popularity in local government roads stems from a number of factors, with cost effectiveness and reuse of existing materials (i.e. avoiding waste) being the main attributes (Wilmot, 1997).

Insitu stabilisation can be undertaken in varying depths depending upon the pavement material type, available pavement material depth, and the type of equipment used. State Road Authorities have been stabilising heavily trafficked roads to about 400 mm in depth for several years. Local Government Authorities are typically stabilising at depths in the order of 150 to 200 mm. The design method for a stabilised pavement typically greater than 200 mm is document in the Austroads Pavement Design Guide and provides some degree of certainty in predicting the trafficked life. However, there is less information in the Guide about pavements stabilised at shallower depths that are exposed to only light to moderate traffic. The recently

published APRG Report on the design of lightly trafficked pavement notes that the design of stabilised pavements may be treated as unbound pavements (APRG, 1998). This approach is unduly conservative and researchers are currently addressing it.

For many years local government engineers have been approaching the design of these shallow stabilised pavements by selecting a binder that has proven success with the soil and the stabilised sample reaches a 7-day UCS value in the range of 1.5 to 2 MPa. These pavements have been built to simple design guidelines and have performed in excess of 20 years without structural rehabilitation. It is important to understand the performance of these pavements in context to their loading if optimum design is to be achieved, as the design model in the Austroads Guide approaches the design based on multiple axle groups and loads typically near the legal axle limits.

There are a number of factors that may lead to pavement failure and there is usually more than one factor fully responsible for the failure. For example, a pavement may ultimately fail in fatigue but elements such as poor construction, marginal materials, climate, drainage etc contribute to the onset of fatigue. The most common forms of distress of insitu stabilised pavement materials are:

- Fatigue failure
- Transverse cracking
- Longitudinal cracking

Cracking of stabilised pavements may be due to:

- material shrinkage
- lack of curing
- overloaded heavy vehicle
- lack of subgrade support
- excessive binder for pavement material type
- poor mixing of binder with pavement material during construction
- insufficient pavement depth, leading to fatigue failure of material

This paper is based on a detailed investigation and assessment by Pike (1997) of stabilised pavements constructed in the City of Lake Macquarie, a region on the East Coast of New South Wales. A number of roads were selected that had been insitu stabilised to a depth in the range of 150 to 200 mm at various construction ages and with different degrees of light to moderate traffic loading. This approach allowed the possibility of any correlation to be established between performance of shallow depth stabilised pavements against time and traffic loading.

SELECTED EXISTING ROADS

The pavements selected for performance evaluation were those that represented current residential streets with kerb-to-kerb stabilisation construction (with the exception of Tennant Road) and some with Benkleman Beam data prior to stabilisation. A list of streets tested and evaluated are noted in Table 1, and these streets are representative of light-trafficked streets for the Lake Macquarie area. The roads were stabilised with a GP cement and fly ash binder (80/20) at 4 to 5% by mass of the pavement material.

Traffic volume and composition was determined by traffic surveys and the commercial vehicle content varied from 2 to 32%. Table 1 lists the type of street and Table 4 details the traffic volume estimated.

Table 1 List of streets used in study.

Street Name	Street type	Seal Type or Asphalt	Depth (mm) of stabilisation	Subbase Depth (mm)	In situ Subgrade Strength (CBR%)
Ian	Collector	2 coat chip seal	150	100-175	8-13
Gradburn	Collector	2 coat chip seal	180	100-170	>13
Stratham	Local in IA	40 AC	180	80-220	3-8
The Groves	Local in IA	40 AC	180	120-150	3.5
Dalwood Cl	Local access	40 AC	180	80-105	8-13
Tahlee Cres	Minor	2 coat chip seal	180	20-170	3-8
James	Local access	2 coat chip seal	180	20-150	3
Albert	Local access	2 coat chip seal	200	0-200	2-32
Tennent Rd	Collector	2 coat chip seal	200	100-150	3-22
Robina Dr	Local access	2 coat chip seal	180	70-220	3-8

Note: IA refers to industrial area.

ASSESSMENT OF PERFORMANCE

As Asset Managers for local governments continue to refine the value of the local road network, Austroads and ALGA are examining the harmonization of the measurement of the condition of the Australian Local Government road network. The results of this work should be published in late 1998.

In NSW various local governments have adopted the SMEC pavement management system. This system produces a pavement condition index (PCI) that attempts to quantify the "health" of pavements by focusing on both the structure and surface defects. In 1995 Meijer conducted a extensive study of stabilised pavements constructed in the Fairfield City Council (NSW) region over some 35 years (Meijer, 1995). The aim of Meijer's work was to establish the PCI for various roads stabilised over many years and then assess performance (i.e. PCI, see Table 2) with age and traffic levels (see Figure 1). The work was one of the most detailed studies carried out on in recent years on local government roads constructed by insitu stabilisation. The study concluded that the performance of stabilised pavements was reflected in the level of traffic rather than environmental or construction processes. Figure 1 highlights that whilst the performance varies with time it is not linear and only a few pavements have performed to less than PCI of 4 after 20 years of service.

Table 2 Pavement condition ratings for PMS devised by SEMC

PCI Scale	Road Condition
< 1.0	Failed
1 to 2.5	Very poor
2.5 to 4	Poor
4 to 5.5	Fair
5.5 to 7	Good
7 to 8.5	Very good
8.5 to 10	Excellent

Alternatively, one can approach the assessment of roads by both visual observations and a series of field measurements and pavement thickness analysis using CIRCLY. The selected roads in Lake Macquarie (see Table 1) were subject to:

- field testing to determine the pavement depth and subgrade condition
- traffic counts, and
- Benkleman Beam deflection bowl surveys.

The results from the deflection bowl surveys were then used in the back calculation of pavement modulus using the EFROMD2 computer software. The modulus values then being compared with recommended values for cemented materials in the Austroads Guide. A traffic survey was carried out to estimate the number of ESA's anticipated for a 20 year life.

To assess the performance and predicted life of each of the roads, CIRCLY was used in the pavement thickness analysis. Using the CIRCLY output and the Austroads recommended fatigue relationship, along with consideration of modulus, traffic loading, and current insitu performance, an assessment was made of the appropriateness of this type of modelling on shallow depth insitu stabilised pavements using cementitious binders.

A visual assessment of all roads was undertaken to identify any failure mechanisms, but in particular those more predominantly found in cemented pavements, such as cracking of the wearing surface. If pavement distress was observed an attempt was made to determine the correlation between the distress mode and the results obtained from the modelled results.

PERFORMANCE RESULTS

Visual Observations

Previous performance studies also relied on visual observations (Hodgkinson, 1991) as part of the overall assessment study. Each street was inspected for cracking, rutting etc to ensure that serviceability and structural distress could be clearly identified in the analysis.

The results of the visual observations of the ten streets are noted in Table 3, and no rutting or deformations were observed. Whilst the cracking in the wearing surface was not aesthetic it was not causing any concern with residents or road users.

Coring of samples from stabilised roads is difficult for pavements typically less than 6 months old using slow-setting binders as the "full" strength of the stabilised material has not been achieved. Therefore, the establishment of the stabilised pavement depth for "young" pavements is best carried out measuring the depth at an inspection hole.

Typically, roughness has never been an important criteria for local roads provided pot holes are not present. In many municipalities, smooth roads are seen as an invitation for local traffic to travel fast, and this is undesirable from both safety and nuisance noise.

Table 3 Visual observations of streets examined in the study.

Street Name	Age (years)	Wearing Surface Condition	Observed distress
Ian	5.4	Fair	Some stripping of seal, longitudinal & transverse cracking of seal and pumping of fines in some cracks
Gradburn	6.7	Good	Longitudinal & transverse cracking of chip seal
Stratham	6.2	Good	Longitudinal & transverse cracking of AC seal
The Groves	6.2	Good	Longitudinal & transverse cracking of AC seal
Dalwood Cl	4.7	Fair	Severe longitudinal & transverse cracking of AC seal
Tahlee Cres	2.9	Fair	Roughness is high
James	2.9	Fair	Roughness is high and minor seal failures
Albert	1.4	Good	Roughness is high
Tennent Rd	2.2	Good	Nil
Robina Dr	0.3	Good	Nil

The data in Table 3 demonstrates the presence of cracks on the wearing surface of most pavements, and for both AC and chip seal surfacing. All three roads with an AC seal exhibited cracking in the transverse and longitudinal directions, and the extent of cracking was generally uniform over the full area of the roads. Inspection pits indicated that the this distress pattern was shrinkage cracks in the base layer reflecting through the thin asphalt layer to the surface. The cracks on The Groves had been rubber sealed and those on Dalwood Close had been sealed with bitumen and very fine aggregate, both seals acting to prevent the ingress of water. Although this gave an unpleasant visual finish to the road there was neither noticeable reduction in the riding quality nor an increase in road roughness.

Insitu and Laboratory Testing

As listed in Table 1 the subgrade material of each road was clay typical of the Lake Macquarie region. The insitu CBR strengths, as measured by the dynamic cone penetrometer, were all in excess of 3.5%, except for isolated readings on Albert Street of 2%. The moisture content in the subgrade material would have reached equilibrium since initial stabilisation. Although a CBR of 3.5% is not considered a high or particularly good value, it was still adequate to support the wheel loads of spreaders and reclaimers during the construction phase.

The determination of the UCS of the stabilised material was only carried out in Robina Drive. The average of six samples from the 7-day accelerated UCS results were 1.31 MPa and 1.62 MPa for samples with additive mixed in the laboratory and samples with additive mixed in the field respectively.

The actual results of each survey for each particular road may be accessed in Pike' study and for each road a number of measurements were carried out in the wheel paths to provide an overall average deflection for each wheel path, as listed in Table 4. The deflection results for each wheel path are noted in Table 5. No measurements were taken before construction Dalwood Close, Tahlee Crescent, Tennant Road and Albert Street.

The Benkleman Beam results were input into the program EFROMD2 to back calculate the elastic modulus of the pavement layers and the results are listed in Table 6. The results indicate the typical variability found in this analysis due to the inaccuracies of the test method and the existing pavement material.

Table 4 Summary of estimated design traffic and Benkleman Beam results.

Street	Stabilised Depth (mm)	Cum. Traffic to date (ESA's)	20 Year Design ⁴ Traffic (ESA's)	Ratio of actual to design traffic	Benkleman Beam Data ¹	
					Before ²	After ³
Gradburn	180	9.70E+04	2.80E+05	0.35	0.62	0.45
Statham	180	5.90E+04	1.90E+05	0.31	0.78	0.48
The Groves	180	1.20E+05	3.90E+05	0.31	1	0.22
Ian	150	6.00E+04	2.20E+05	0.27	1.03	0.72
Dalwood Cl	180	3.80E+03	1.60E+04	0.24	N/A	0.61
Tahlee Cr	180	4.20E+02	2.90E+03	0.14	N/A	0.51
James	180	3.70E+03	2.60E+04	0.14	1.21	1.13
Tennent Rd	200	1.70E+04	1.60E+05	0.11	N/A	0.38
Albert	200	4.60E+03	6.70E+04	0.07	N/A	0.36
Robina Dv	180	2.60E+03	1.60E+05	0.02	0.72	0.49

Note: **1.** The Benkleman Beam deflections represent the average maximum deflection of four sites across the two lanes. **2.** Existing road data before rehabilitation. **3.** Test results at June 1997. Refer to Table 5 for full details. **4.** The 20 year design traffic is an estimate. N/A refers to no data collected before construction of the existing road.

Table 5 Mean maximum deflection (mm) from Benkleman beam results in various wheel paths.

Street	Before rehabilitation				June-97			
	1m (L)	3m (L)	1m (R)	3m (R)	1m (L)	3m (L)	1m (R)	3m (R)
Gradburn	0.63	0.75	0.54	0.54	0.41	0.54	0.39	0.46
Statham	0.77	0.81	0.76	0.78	0.51	0.47	0.50	0.42
The Groves	0.85	1.15	0.78	1.21	0.21	0.21	0.20	0.26
Ian	0.88	1.16	0.90	1.19	0.53	0.72	0.77	0.87
Dalwood Cl					0.48	0.85	0.55	0.54
Tahlee Cres					0.28	0.67	0.36	0.72
James	1.08	1.26	1.19	1.30	1.26	1.52	0.84	0.88
Tennent Rd					0.25	0.46	0.30	0.51
Albert					0.27	0.42	0.34	0.41
Robina Dve	0.65	0.87	0.60	0.76	0.42	0.63	0.41	0.49

Note: No data collection for "before construction" for Dalwood, Tahlee, Tennent and Albert streets. Offsets noted are based on road centreline. (L) is left wheel path and (R) is right wheel path

Table 6 Back-calculated Moduli (E)

Street Name	Base E (MPa)			Subgrade E Range (MPa)	Subbase E Range (MPa)
	Left Side	Right Side	Adopted Average		
Ian	1519	1399	1460	20 – 245	227 - 634
Gradburn	763	1800	1280	48 – 217	202 - 458
Statham	798	1319	1060	48 – 136	200 - 500
The Groves	4286	1571	2900	96 – 275	763 - 1000
Dalwood Cl	1028	1106	1070	20 – 500	164 - 499
Tahlee Cres	1697	1174	1435	20 – 406	N/A
James	301	679	490	20 – 138	N/A
Albert	2703	2900	2800	20 – 500	N/A
Tennent Rd	1651	1874	1760	20 – 428	397 - 754
Robina Dve	975	1495	1180	20 – 500	205 - 840

Evaluation of Results

For the roads with chip seals, only two of the seven exhibited any cracking, namely Ian (Bus route) and Gradburn Streets. These streets had the highest traffic loading of any of the chip sealed streets and it is likely that the heavier loading induced the cracking. Although, these roads are subjected to heavier traffic loads the structural integrity of these roads was similar to the other roads tested in terms of beam and bowl readings. One could conclude that the cracks at the surface were not adversely affecting the performance of the pavement. Therefore, it is difficult to conclude with any certainty that heavier loading leads to cracking of the pavement. Further investigation of this issue may be warranted. These cracks are typically sealed in the Lake Macquarie district to prevent ingress of water.

There was no rutting of the pavement in the wheel paths of any of the roads investigated, and while rutting was not expected it was still an encouraging result considering thickness of the base layer (i.e. typically less than 200mm) and with no subbase layer.

It was difficult to fit the predicted curve of EFROMD2 to the measured bowl readings, resulting in probable errors of the back-calculated moduli. Experience would indicate that a higher values of modulus would be expected than those measured through the test process. The problem observed during the evaluation was in the accuracy of recording the actual rebound bowl of the pavement.

The back-calculated modulus of the base and subgrade was used to determine the pavement life. The modulus values in Table 6 indicate a lightly bound pavement by the Austroads definition (1998), and hence a value of 2000 MPa was used in the initial design process. The fatigue relationship adopted for the cement material was (Jameson, 1995):

$$N = \left[\frac{(112,664E^{-0.804} + 190.7)}{m\epsilon} \right]^{12}$$

This fatigue relationship was used to predict the allowable ESAs for various pavement depths assuming, a factor of 10 for converting axle repetitions to ESAs, a chip-seal surface and three values for subgrade modulus. The results are listed in Table 7 and indicate a low-design traffic for these stabilised layers, and yet the traffic to date has outstripped the design predictions.

A higher stabilised pavement modulus, such as 5000 MPa would indicate that the design ESAs for a 200 mm thick layer on a subgrade of CBR 5 is 653. This value is still lower than experience would have us believe and therefore, one may conclude that fatigue may not be the failure mechanism for this type of pavement.

Table 7 The estimated ESAs for various pavement depths derived by CIRCLY analysis with a stabilised modulus of 2000MPa.

Base Depth (mm)	Base Strain ($\mu\epsilon$)	Subgrade Modulus (MPa)	Number of Repetitions	ESAs
150	465	35	5.24E-01	0
150	418	50	1.88E+00	0
150	357	80	1.25E+01	1
180	369	35	8.40E+00	1
180	333	50	2.88E+01	3
180	286	80	1.79E+02	18
200	320	35	4.64E+01	5
200	291	50	1.45E+02	15
200	251	80	8.56E+02	86

CONCLUSION

Pavements that are insitu stabilised with predominantly GP cement binders at relatively high binder contents are prone to reflective cracking that appears on thin layers of surface asphalt. However, of the roads investigated that experienced reflective cracking, there was no indication, based on Benkleman Beam readings, that the cracking would lead to lower life expectancy of the pavement. It is recognised that continual ingress of moisture through these cracks may ultimately adversely affect the structural integrity of the pavement and lead to premature failure, and therefore, timely sealing of cracks is important.

The desirable range of UCS for insitu stabilised pavements of 1.5 to 2.0 MPa as recommended by various road authorities appears reasonable and should be used as a guide to insitu stabilisation projects. Of the ten roads investigated only one had Unconfined Compressive Strength (UCS) testing done on it to assess the strength characteristics of the parent material plus binder additive. The average UCS for this road was 1.6 MPa, and the Benkleman Beam readings taken after stabilisation indicate that the pavement will attain its 20 year design life.

Insitu stabilisation of granular pavements resulted in considerably improved Benkleman Beam readings. It was found that after insitu stabilisation the Benkleman Beam deflections of all roads tested, except one, reduced substantially, by between 14 and 66%. The standard deviation of results also reduced markedly, resulting in more homogeneity of deflections over the length of each road. It was found that these favourable beam readings could be sustained over long periods, at least in excess of five years, and hence the process of insitu stabilisation does substantially add strength and stiffness to the stabilised layer, even for relatively thin stabilised layers.

The AUSTRROADS recommended value of 2000 MPa for stabilised marginal materials appears too high for pavements insitu stabilised in the city of Lake Macquarie. The typical range of stabilised base course moduli for the subject roads studied, each with a stabilised base depth less than 200 mm, was 1100 – 1800 MPa.

Pavement moduli results back-calculated from Benkleman Beam readings and EFROMD2 software should be considered as indicative only. Variations in curve fitting between measured beam readings and the synthetic generated curve of EFROMD2 were present to some degree in most of ten roads analysed.

The widely accepted fatigue relationship for cement materials appears to be not appropriate for estimating the fatigue life of stabilised pavement layers less than 200 mm in thickness. Based on CIRCLY analysis and the fatigue criteria as set by each of the authorities, the life of shallow depth cemented pavements was very low. It was found in this study that the roads surveyed had a cumulative traffic loading far exceeding the predicted values yet show no signs of fatigue pavement failure. The principles of mechanistic analysis may be appropriate, but further investigation needs to be undertaken to find more suitable relationships, which is complementary to actual observed field performance for lightly trafficked roads.

It was not possible to assess the design or remaining life of an insitu stabilised pavement with a cemented base layer less than 200 mm given the mechanistic design principles with the fatigue relationship in common use. Unfortunately, the qualitative analysis, such as Hodgkinson (1991), and past experience and history still remains an appropriate guide to design life.

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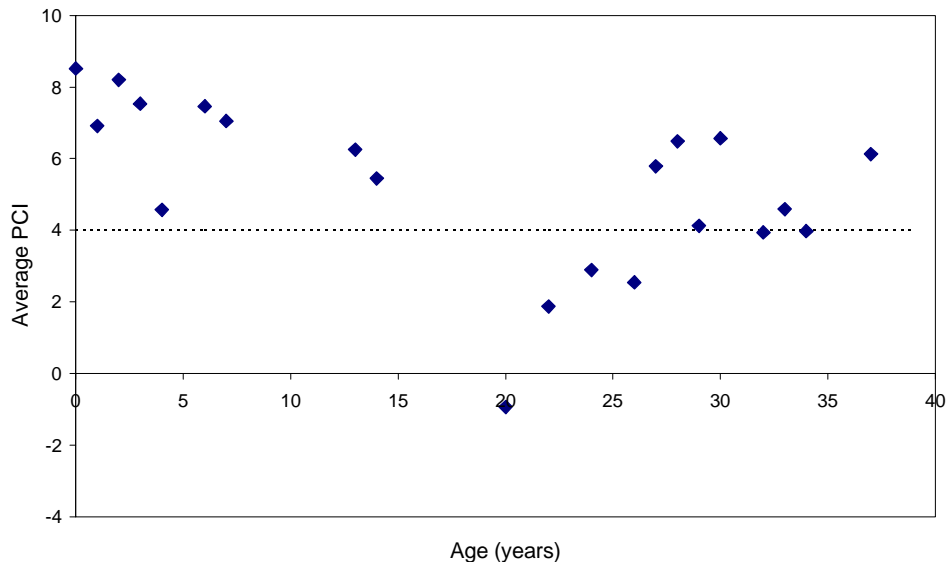


Figure 2 PCI versus pavement age for streets with traffic volume ranging from 500 to 2000 vehicles per day.

[END]