BITUMEN EMULSION SEALING: NEW ZEALAND FIELD TRIALS

Transfund New Zealand Research Report No. 99

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Transfund New Zealand Research Report No. 99

ISBN 0-478-11057-X
ISSN 1774-0574

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J.E. Patrick 1998. Bitumen emulsion sealing : New Zealand field trials.
Transfund New Zealand Research Report No. 99. 27 pp.

Keywords: bituminous emulsion, chipsealing

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EXECUTIVE SUMMARY

Over the 1993/94 sealing season a number of chipseal field trials were constructed in Australia and New Zealand in order to compare the performance of bitumen emulsions with the traditional hot applied cutback bitumen. The objective was to determine if there was any significant difference in the initial performance of the two binder types.

This report gives the results of the New Zealand trial using bituminous emulsions with 60% and 68% binder with a grade 5 chip, and the 68% binder with a grade 4 chip. In both test sections the binder application rate was varied from –0.3 to +0.3 l/m^2 from design. A control site using hot applied cutback 180/200 grade bitumen at the design binder application rate was constructed.

The test sections have been monitored for changes in texture depth since the time of construction in April 1994 until May 1997.

Three sections failed in the first winter. Two were grade 5 chip sites at application rates of –0.2 and –0.3 l/m^2 from design. The third failure was with the grade 4 chip at –0.2 l/m^2 from design. These results show that the Transit New Zealand sealing design methodology, in respect to the determination of binder application, is appropriate.

After three years there is no obvious difference in the texture as affected by binder application rate, or the use of an emulsion or cutback bitumen.

It is concluded that similar performance can be obtained with bituminous emulsions and cutback bitumen.

ABSTRACT

In April 1994 a comparative trial of the performance of bitumen emulsion and cutback bitumen as chipsealing binders was constructed. The trial contained bitumen emulsions with 60% and 68% binder content using a grade 5 chip, and 68% binder content with a grade 4 chip. The binder application was varied from –0.3 to +0.3 l/m^2 from the design value. With both chip sizes, a control section using cutback bitumen at the design application was also constructed.

After three years of monitoring texture depth, it has been found that there is no obvious difference in performance of the two types of binder. It has been concluded that the Transit New Zealand sealing design methodology is appropriate.

1. INTRODUCTION

Over the 1993/94 sealing season a number of chipseal field trials were constructed in Australia and New Zealand in order to compare the performance of bitumen emulsions with the traditional hot applied cutback bitumen. This report records the results of the New Zealand trial only.

The objective was to determine if there is any significant difference in the initial performance, i.e. up to two years, of chipseals using the two binder types. The influence of factors such as emulsion binder application rate and emulsion class was assessed.

Emulsions have the advantage of containing relatively low levels of environmentally harmful solvents; they cure quickly after application, provide a strong bond, and are safe to handle.

The most significant differences between the Australian and New Zealand trials were:

(a) the base bitumen used for the trials was 180/200 penetration grade in New Zealand and class 170 grade in Australia. The Australian bitumen grade is similar to New Zealand's 80/100 penetration grade;

(b) traditionally New Zealand does not use precoated aggregate, whereas in Australia precoating in the norm.

Through New Zealand's participation in this trial a greater range of conditions, especially in terms of temperature, was able to be assessed. Greater confidence in the use of emulsions was gained and a better appreciation of the factors controlling their successful use was obtained.

The New Zealand trials were limited to resealing, and used two chip sizes (grades 4 and 5). The basic outline is given in Table 1.

Table 1.

Binder	Chip grade		Application rate
180/200 cutback	4	5	Normal design
60% cationic emulsion	-	5	Normal design, ±0.2, ±0.3 l/m^2
70% cationic emulsion	4	5	Normal design, ±0.2, ±0.3 l/m^2

Note that grade 4 was not trialed with the 60% emulsion. The combinations given above result in the construction of 17 test sections.

This report summarises the construction and monitoring of the New Zealand trials.

2. TRIAL SITES

The trial sites consisted of two sections of pavement on State Highway 53 between Featherston and Martinborough. The area is flat farmland and both trial sites were on straight, flat sections of highway. The sites are illustrated in Figures 1 and 2. Traffic volume is 500 v/l/d (vehicles per lane per day). Trial site 1, using grade 5 chip (10 mm), was 1540 m in length at RP 0/1.45-2.98, and trial site 2, using grade 4 chip, was 900 m in length at RP 0/7.04-7.94.

Typical meteorological data for the area was: average daily maximum temperature in January/ February 23 °C, average daily minimum temperature in July –3.2 °C, and mean yearly rainfall 1109 mm.

2.1 Pavement Condition

The trial sites were selected as they were relatively uniform throughout their length and had a granular basecourse with a number of seal coats. The grade 5 site had a grade 2 seal in 1979 and a grade 5 in February 1990. The grade 4 site had a grade 2 seal in 1981 and a grade 5 in February 1991.

Flushing in the wheeltracks had occurred, as illustrated in Figure 3.

Results of sand circle (TNZ T/3) and ball penetration tests in the outer wheeltrack and between wheeltracks is given in Tables 2 and 3. The consistency of results confirms the visual uniformity.

Table 2. Test site 1, grade 5 chip - preseal condition.

Location	Sand circle (mm)		Ball penetration (mm)	
	Between wheelpath	Outer wheelpath	Between wheelpath	Outer wheelpath
40	209	265	3.8	3.8
80	203	255	3.9	3.8
180	200	238	3.9	3.9
220	195	245	3.9	3.9
320	220	278	3.8	3.9
360	211	313	3.8	3.7
460	213	260	3.8	3.9
500	215	255	3.8	3.9
600	213	265	4.1	3.9
620	200	300	3.9	3.8
740	197	235	3.9	3.7
780	263	270	3.8	3.7
880	200	248	3.7	3.8
920	238	280	3.8	3.7
1020	232	255	3.6	3.7
1060	235	270	3.8	3.7
1160	258	290	3.8	3.7
1200	244	278	3.8	3.8
1300	223	308	3.6	3.7
1340	245	350	3.7	3.8
1440	295	350	3.7	3.8
1480	210	280	3.7	3.7
Mean	223.6	276.7	3.80	3.79
Std Dev	25.5	31.6	0.11	0.08

Table 3. Test site 2, grade 4 chip - preseal condition.

Location	Sand circle (mm)		Ball penetration (mm)	
	Centre	Outer wheelpath	Centre	Outer wheelpath
40	195	258	3.8	3.7
80	200	280	3.9	3.8
190	204	267	3.8	3.8
230	207	232	3.8	3.8
340	230	242	3.7	3.8
380	250	293	3.8	3.7
490	190	242	3.9	3.8
530	180	250	4.0	3.7
640	205	217	3.8	3.8
680	190	235	3.8	3.8
790	185	248	3.8	3.7
830	195	200	3.9	3.7
Mean	202.6	247.0	3.83	3.76
Std Dev	19.7	25.7	0.08	0.05

Figure 1. Site 1.

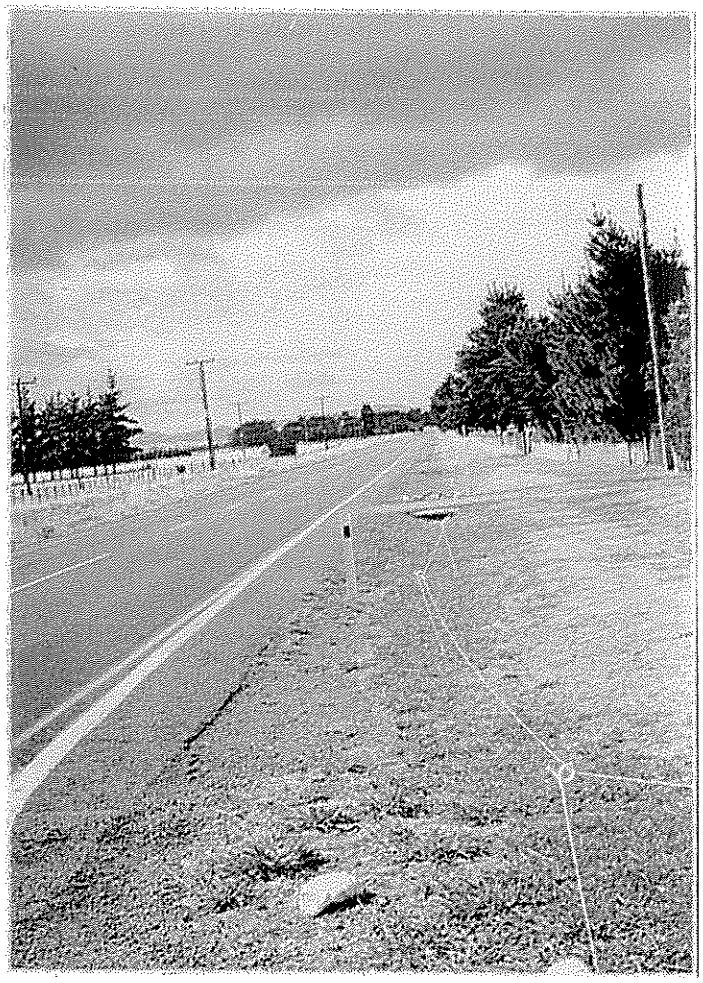


Figure 2. Site 2.

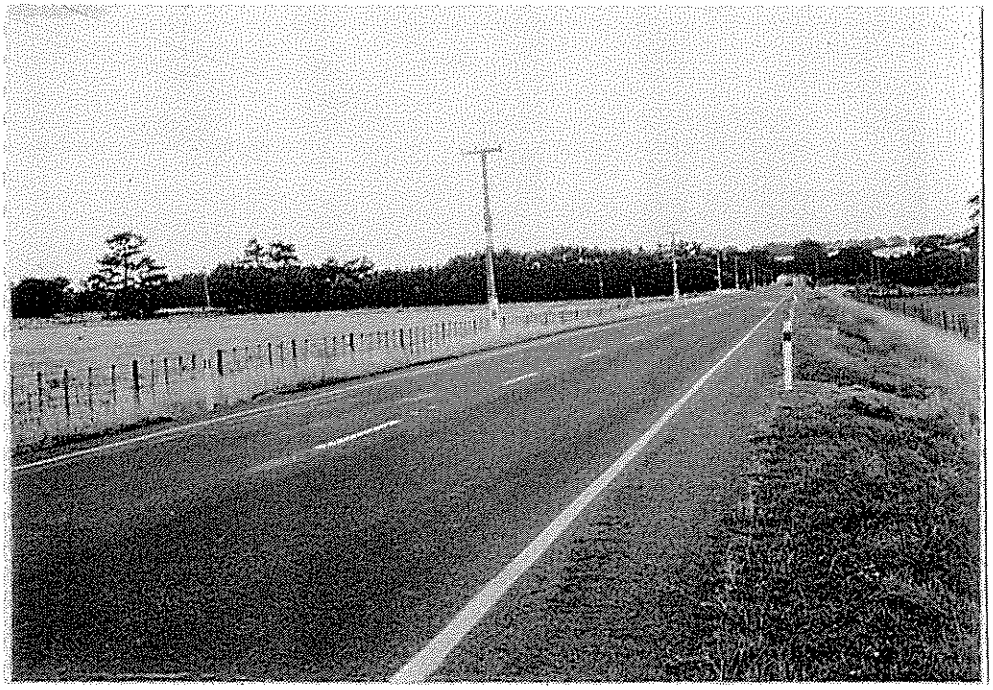
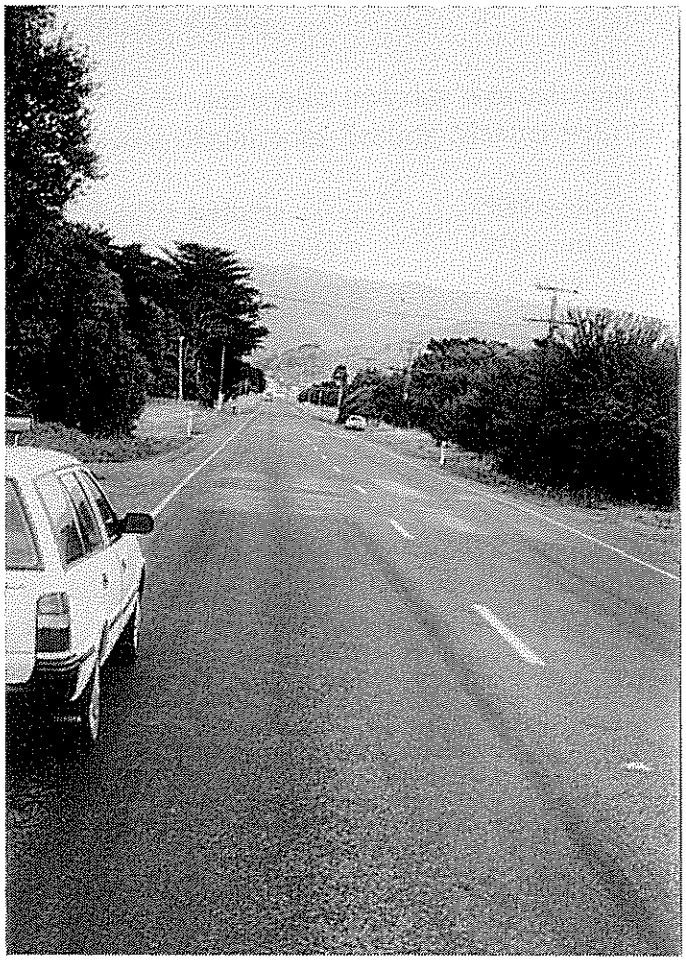


Figure 3. Typical wheeltrack flushing.



3. BASIS OF SEAL DESIGN

3.1 Grade 4 Chip

The residual binder application rate was calculated based on the algorithm given in the Transit New Zealand Bituminous Sealing Manual with the following input:

Traffic volume	500 v/l/d
Sand circle diameter	200 mm
Chip ALD	6.8 mm

giving a residual application rate of 1.4 l/m^2. No adjustment for the site conditions was considered necessary.

3.2 Grade 5 Chip

The design of grade 5 seals has traditionally been based on a base application rate of 0.8 l/m^2 with adjustments made for site conditions. In this trial an increase of 20% due to the low traffic volume was considered appropriate, giving an adjusted residual application rate of 0.96 l/m^2.

4. MATERIAL PROPERTIES

Test results on the emulsions used are given in Table 4.

The hot binder used was 180/200 grade bitumen with 4 pph lighting kerosene and 0.5 pph adhesion agent.

Sealing chip was greywacke aggregate. Test results are given in Table 5.

Table 4. Emulsion properties.

Test	CQ65	TNZ M/1	CQ55	TNZ M/1
Binder content (%) BS 434, Part 1, Appendix F	70.8	65 min	63.7	55 min
Residue on 710 µm sieve (%) BS 434, Part 1, Appendix D	0.02	0.05 max	0.03	0.05 max
Viscosity, Saybolt Furol (sec), 70°C	208	100-300		
Viscosity, Brookfield HAT spindle 1 (centipoise), 25°C				
5 rpm			80	40 min
50 rpm			66	150 max

Table 5. Chip properties.

Test	Grade 4	Grade 5
ALD (mm)	7.36	5.15
ALD/AGD	1.96	2.14
% within ALD ±2.5 mm	91	91
% passing 4.75 mm	0.1	-
% with two or more broken faces	100	100
Sieve analysis - cumulative % passing		
13.2 mm	100	100
9.5 mm	60	100
6.7 mm	1.6	48
4.75 mm	0	4.0
2.36 mm		0.1
Cleanness value	90	88

5. CONSTRUCTION OBSERVATIONS

Construction began on the grade 5 site on 8 April 1994 at about 7.45 am. This section was completed, except for the control section, and the first 600 m of the grade 4 site was also constructed.

On 9 April 1994 the final 300 m of the grade 4 site was completed and the control sections, using hot binders, were constructed.

During construction no problems were encountered.

Spray application rates were obtained by dipping the sprayer. Chip application rates were obtained by placing two trays at the end of the spray run and ensuring that the chip truck stopped well past the section.

Residual bitumen application converted to litres/m^2 at 15°C based on the test sample binder contents are given in Tables 6 and 7. Chip application rates converted to m^2/m^3 for both trays are also given in Tables 6 and 7.

Table 6. Construction summary - grade 5.

Location	Binder type	Residual binder l/m^2		Chip application m^2/m^3	
		Target	Achieved	Tray 1	Tray 2
0 - 140	CQ60	1.0	1.11	117	115
140 - 280	CQ60	1.2	1.27	111	120
280 - 420	CQ60	0.8	0.88	75	68
420 - 560	CQ60	1.3	1.38	112	114
560 - 700	CQ60	0.8	0.74	135	136
700 - 840	CQ70	1.0	0.99	138	147
840 - 980	CQ70	1.2	1.14	140	185
980 - 1120	CQ70	0.8	0.8	163	177
1120 - 1260	CQ70	1.3	1.35	138	135
1260 - 1400	CQ70	0.7	0.74	194	223
1400 - 1540	180/200	1.0	0.99	111	-

Table 7. Construction summary - grade 4.

Location	Binder type	Residual binder l/m^2		Chip application m^2/m^3	
		Target	Achieved	Tray 1	Tray 2
0 - 150	CQ70	1.4	1.50	89	85
150 - 300	CQ70	1.6	1.66	96	95
300 - 450	CQ70	1.2	1.21	92	98
450 - 600	CQ70	1.7	1.84	117	113
600 - 750	CQ70	1.1	1.15	141	131
750 - 900	180/200	1.4	1.53	132	138

6. WEATHER CONDITIONS

Details of the weather conditions on 8 and 9 April 1994 are given in Table 8.

Table 8. Weather conditions.

Date	Time	Temperature (°C)		Humidity (%)	Wind	Sky
		Air	Pavement			
8/4/94	7.40 am	13	17	70	Light	Overcast
	9.00 am	22	18	56	Gusty	Overcast
	10.00 am	23	20	57	Gusty	Overcast
	11.00 am	22	21	53	Gusty	Cloudy
	12.00 pm	26	26	49	Gusty	Cloudy
	2.20 pm	23	24	35	Gusty	Scattered clouds
	3.30 pm	21	20	35	Gusty	Cloudy
9/4/94	8.00 am	19	18	36	No wind	Clear
	8.55 am	22	21	35	Light	Clear

7. SAND CIRCLE TEST METHOD

Australia and New Zealand use the sand circle test as a measure of texture depth. There are, however, differences in the method, especially the size of the sand. In New Zealand, sand between 0.6 and 0.3 mm is used while Australia uses glass beads of 0.3 to 0.15 mm.

A number of tests were performed on five sites using the Transit New Zealand Method T/3 and the Australian Method T240. Results are given in Table 11.

Table 11. Sand circle comparison.

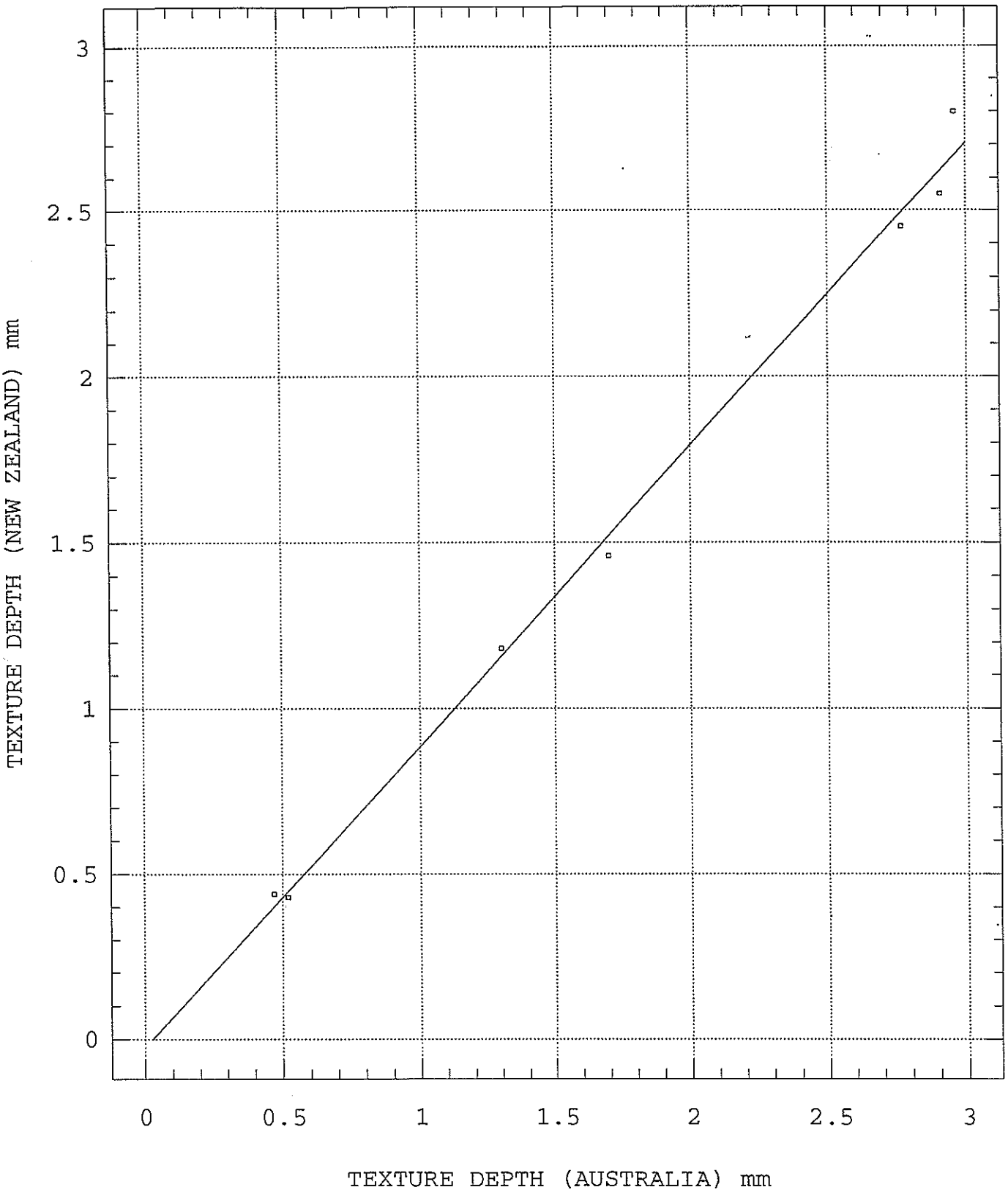
Surface	**Texture depth (mm)**	
	New Zealand	**Australia**
Grade 5	1.18	1.30
	1.46	1.70
Asphalt	0.43	0.52
	0.44	0.47
Grade 4	2.55	2.91
	2.80	2.96
	2.45	2.77

A linear regression of the results gives a correlation coefficient of 0.997. The results are also illustrated in Figure 4 which indicates that on coarser textures the Australian method gives a greater texture depth than the New Zealand method.

The relationship between the two methods can be expressed as:

$$T_{D\ \text{New Zealand}} = 0.909\, T_{D\ \text{Australia}} - 0.025$$

Figure 4. Comparison of Australian and New Zealand sand circle methods.



8. MONITORING

On each section, sand circle tests were performed and photographs taken at three longitudinal locations (40, 80 and 120 m from the section start). At each of these locations tests were performed at the outer wheelpath (OWP) and between the wheelpaths (BWP). This gave a total of six tests per section.

Initial monitoring was performed on 19 April 1994 (10 days after construction) and in December 1994, December 1995, May 1996 and May 1997.

A summary of the average texture depths for each site is given in Tables 9 and 10.

Table 9. Grade 5 chip - summary of measurements.

Location	Lane position	Average texture depth					Emulsion type (%)	Application rate difference from design (l/m^2)
		4/94	12/94	12/95	5/96	5/97		
0-140	Centre	2.23	1.60	1.35	1.25	0.89	60	0
	OWP	2.10	1.40	1.09	1.04	0.67		
140-280	Centre	2.17	1.84	1.39	1.40	0.94	60	+0.2
	OWP	1.95	1.45	1.34	1.21	0.81		
280-420	Centre	2.14	1.76	1.57	1.47	1.13	60	–0.2
	OWP	2.01	1.37	1.01	0.82	0.51		
420-560	Centre	2.05	1.54	1.36	1.13	0.84	60	+0.3
	OWP	1.86	1.27	1.10	0.91	0.69		
560-700	Centre	2.34	1.81	1.49	1.32	1.06	60	–0.3
	OWP	1.91	1.46	1.23	1.10	0.78		
700-840	Centre	2.12	1.47	1.17	1.17	0.76	68	0
	OWP	1.84	1.11	0.91	0.97	0.64		
840-980	Centre	2.06	1.45	1.15	1.12	0.80	68	+0.2
	OWP	1.73	1.22	0.97	0.97	0.69		
980-1120	Centre	2.29	1.59	Failed			68	–0.2
	OWP	1.86	1.31					
1120-1260	Centre	2.05	1.42	1.16	1.07	0.78	68	+0.3
	OWP	1.73	1.20	0.91	0.93	0.71		
1260-1400	Centre	2.32	1.06	Failed			68	–0.3
	OWP	2.00	1.21					
1400-1540	Centre	2.04	1.35	1.10	1.00	0.65	Control	0
	OWP	1.72	1.07	0.77	0.77	0.57		

Table 10. Grade 4 chip - summary of measurements.

Location	Lane position	Average texture depth					Emulsion type (%)	Application rate difference from design (l/m²)
		4/94	12/94	12/95	5/96	5/97		
0-150	Centre	2.90	2.02	2.12	1.66	1.48	70	0
	OWP	2.44	1.82	1.97	1.50	1.43		
150-300	Centre	2.69	1.86	1.92	1.51	1.35	70	+0.2
	OWP	2.21	1.50	1.53	1.30	0.95		
300-450	Centre	3.01	2.23	2.41	1.70	1.91	70	–0.2
	OWP	2.39	1.78	1.76	1.77	1.19		
450-600	Centre	3.10	2.39	2.51	2.14	2.17	70	+0.3
	OWP	2.29	1.76	2.05	1.80	1.62		
600-750	Centre	3.18	1.80	Failed			70	–0.3
	OWP	2.75	1.94					
750-900	Centre	2.86	1.98	2.07	1.94	1.62	Control	0
	OWP	2.46	1.66	1.61	1.67	1.37		

9. SECTION FAILURE

Three sections suffered chip loss to the extent that they have had to be repaired. This chip loss occurred in the first winter and the sections were repaired in early 1995.

The affected sections were:

Site 1, grade 5 chip	980-1120 m	application rate –0.2 l/m^2 from design
	1260-1400 m	application rate –0.3 l/m^2 from design
Site 2, grade 4 chip	600-750 m	application rate –0.3 l/m^2 from design

10. COMPARISON OF PERFORMANCE

Table 11 summarises the average texture depth measurements in the outer wheelpaths for 1995, 1996 and 1997, and allows a comparison of the effect of binder application on the resulting texture depth.

The texture depth decreased over the years but the binder application rates did not correlate with the resulting texture depth.

In order to determine if chip application rate at the time of construction was a significant influence on the resultant texture, the outside wheelpath texture depth for each section, as a function of the measured chip application rate, is shown in Figures 5 and 6. It can be seen that for each monitoring period up to 1996, texture depth does not appear to be affected by the chip application rate.

Table 11. Influence of binder application rate on resulting texture depth.

Chip size	Binder application (l/m^2)	Texture depth (mm)		
		12/95	5/96	5/97
Grade 5	0.74	1.23	1.10	0.78
	0.88	1.01	0.82	0.51
	0.99	0.91	0.97	0.64
	0.99	0.77	0.77	0.57
	1.11	1.09	1.04	0.67
	1.14	0.97	0.97	0.69
	1.27	1.34	1.21	0.81
	1.35	0.91	0.93	0.71
	1.38	1.10	0.91	0.69
Grade 4	1.21	1.76	1.77	1.19
	1.50	1.97	1.50	1.43
	1.53	1.61	1.67	1.37
	1.66	1.53	1.30	0.95
	1.84	2.05	1.80	1.62

Figure 5. Texture depth variation with chip application rate.

Site 1. Outside wheelpath

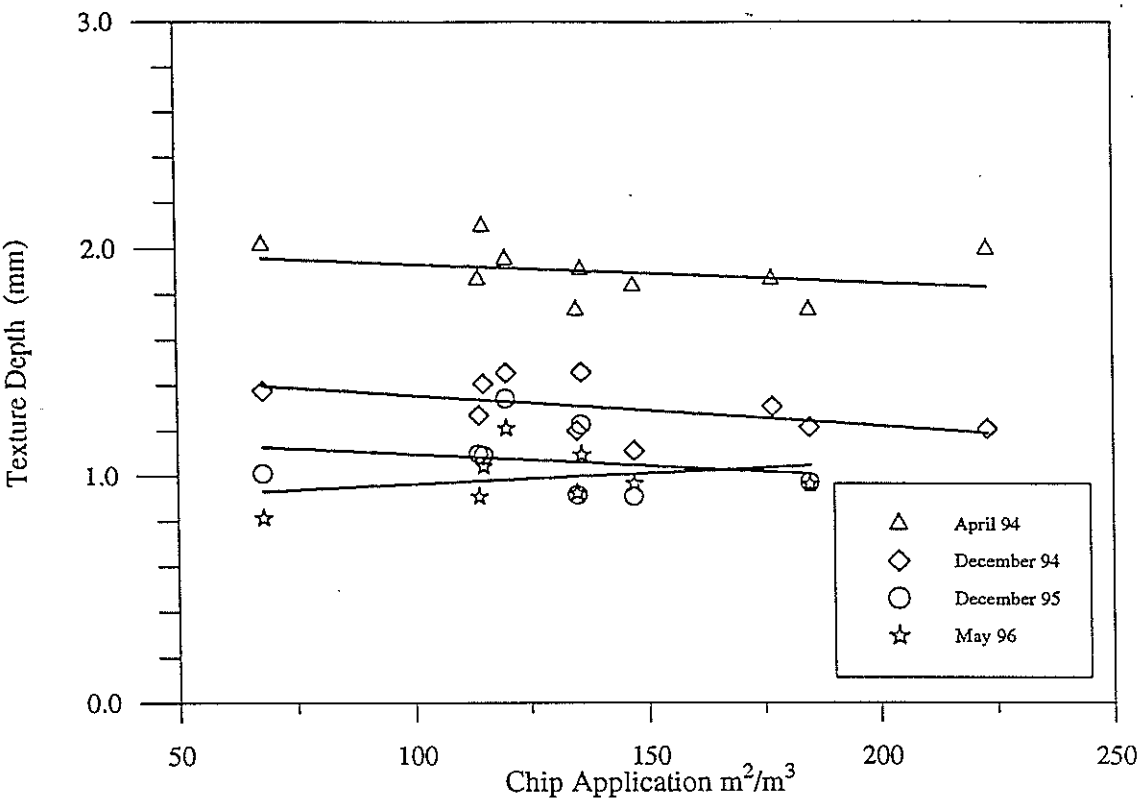
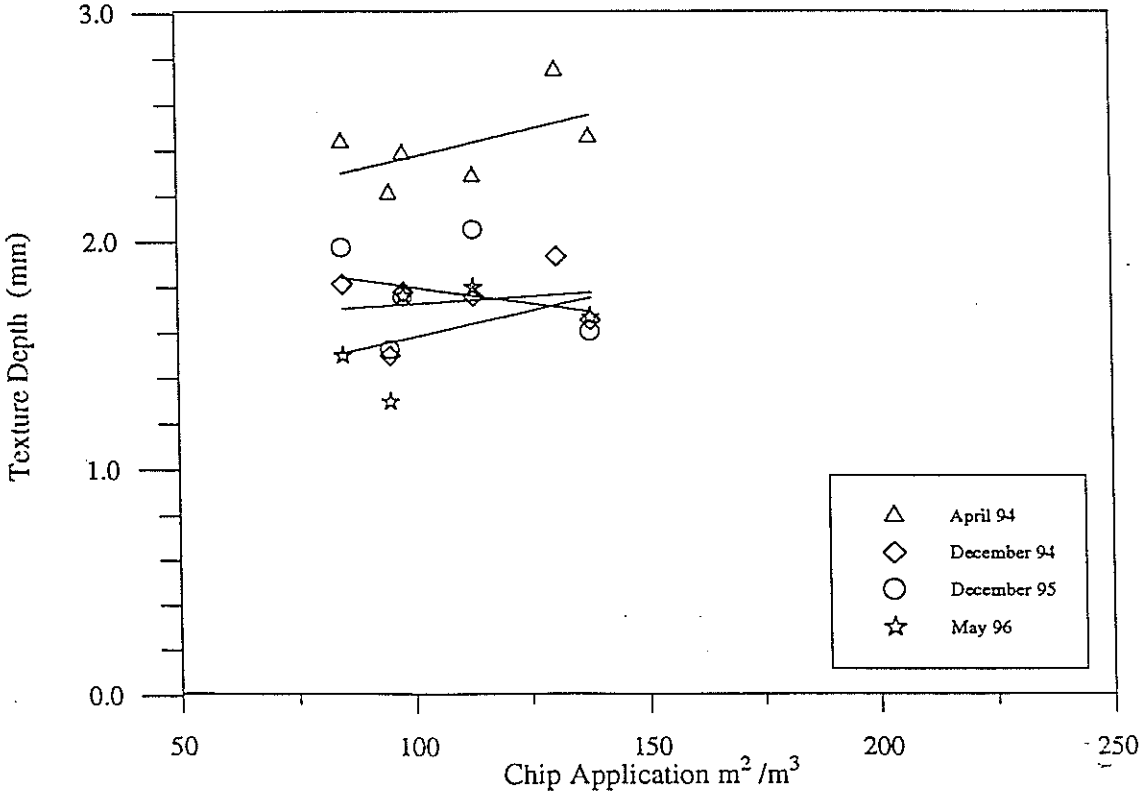


Figure 6. Texture depth variation with chip application rate.

Site 2. Outside wheelpath



11. CONCLUSIONS

(1) This comparative trial has demonstrated that similar performance in terms of changes in texture depth with time is obtained with bituminous emulsions and cutback bitumen.

(2) It has also demonstrated that the Transit New Zealand Bituminous Sealing Manual design methodology, in respect to the determination of the binder application rate, is appropriate. On sections where the application rate was significantly below the design, chip loss occurred in the first winter.

(3) There is a significant difference between the Australian and New Zealand test methods to determine texture depth, especially at higher texture depth values (2 mm). There is, however, a very good correlation between the two methods.

12. RECOMMENDATIONS

The three years of monitoring on these sites has given confidence in the early life performance of bitumen emulsion seals.

As the sections with the grade 5 chip are now showing signs of flushing, a reseal will soon be required. It is therefore recommended that this trial now be terminated.