LOGGING INDUSTRY RESEARCH ORGANISATION
NEW ZEALAND
ISSN 1171-6932
REPORT
Vol. 21 No. 25 1996

CHIP SEAL TRIALS FOR OFF-HIGHWAY FORESTRY ROADS

(Year Two of a Three Year Research Project)

Greg Arnold
David Howard

Figure 1 - Construction of chip seal trial sections on Railway Road in Kaingaroa Forest

ABSTRACT

The misuse of public highway chip seal design criteria on a off-highway forestry in Kaingaroa Forest resulted in premature failure of the surfacing. A range of chip seal designs are being trialled and monitored annually with the aim of developing a suitable chip seal design procedure for arterial forestry roads carrying single dual tyre axle loads up to 16 tonnes.

Forty chip seal trial sections were established in January, 1994. The variables were: (i) level of stress (straight *level road versus adverse gradient), (ii) type of bitumen (PMB100, Emoflex 80/100, 180/200 bitumens, and (iii) residual bitumen rate (five rates for each type of bitumen).*

Surface texture and distress measurements were conducted at zero, one and two years after sealing. Chip loss occurred on the road shoulder and near the road centreline on 22 of the 40 sections. Flushing of the 180/200 bitumen hill test section occurred within the first year. PMB100 sections had the best chip holding ability. Emoflex sections retained the highest texture followed closely by PMB100. Texture depth reduction in the first year was significant in all sections, although there was no significant reduction in texture depth in the second year.

The Traffic Factor (as used in the Transit New Zealand chip seal design algorithm) corresponding to each bitumen rate was calculated. Based on the performance of the trial sections, recommendations have been made on the Traffic Factor for use in design of re-seals for similar binder type, environmental conditions, and traffic loading.

INTRODUCTION

A semi-empirical design procedure (TNZ, 1993) providing corrections for existing surface texture and vehicle loading was used by Tasman Forestry Limited to design the chip seal for the off-highway road between Murupara and Kawerau in 1986. Less than two months after the second seal coat had been applied, the bitumen in the wheel paths of the loaded lane had flushed to the extent that free bitumen was present on the surface (Pidwerbesky, 1994). Wheel paths in the lane carrying unloaded vehicles also flushed, but to a lesser degree.

In an attempt to remedy the flushing, Bryan Pidwerbesky (University of Canterbury) trialled various new chip seal designs since 1989. The study found that a re-seal with a polymer-modified bitumen and a low application rate with large chips was probably the best option (Pidwerbesky *et al.*, 1992). However, it was not known exactly how much bitumen to apply nor how well it would perform compared to standard grades of bitumen. Therefore, in 1994 a total of forty 50 m chip seal trial sections were sealed (Figure 1), and are being monitored annually over a three-year period (Arnold *et al.*, 1994). At the end of the three-year period, guidelines for the design of chip seals to withstand axle loads up to 16 tonnes will be available.

This report summarises the performance of the 40 chip seal trials, two years after establishment. For comprehensive information on the performance of the chip seal trials after two years, refer to the previous reports by Arnold *et al.*, (1994 and 1995b), Arnold and Williams (1995a), and Arnold and Howard (1996).

Chip Seal Design

Binder application rates are determined using the Transit New Zealand design algorithm RD286 (TNZ, 1993):

$$R = (0.138 \times ALD + e) \times T_f$$

where:

R = Bitumen application rate (l/m^2)
ALD = Average Least Dimension of the stone chip (mm)
T_f = Traffic Factor (unitless)
$e = 0.21 \times T_d - 0.05$, ($l/m^2$) (existing surface texture adjustment)
T_d = Texture Depth (mm)
using sand circle diameters (d, mm),
$T_d = 57{,}300/d^2$, (mm)
or using MTM readings ($MTM_{texture}$),
$T_d = 1.64\ MTM_{texture} - 0.13$ (McNaughton *et al.*, 1994)

This design algorithm has been adequate for designing an appropriate application rate for re-seals on Bonisch and Railway roads, provided that an appropriate Traffic Factor (T_f) is used. The TNZ design guidelines suggest a minimum T_f of 0.80, which corresponds to 10,000 vehicles (one on-highway truck is equivalent to 10 vehicles) per lane per day (v/l/d). The equivalent traffic on Bonisch and Railway Roads is 310 v/l/d, which corresponds to a T_f of 1.27. Previous trials have shown that a T_f of 0.70 may be appropriate (Pidwerbesky *et al.*, 1992).

For each test section the T_f was back calculated using the RD286 formula. A low T_f (for example, 0.55) would indicate a low binder application rate and conversely a high T_f (for example, 0.90) would indicate a high binder application rate.

The Traffic Factor used in the future design of re-seals will correspond to the Traffic Factor of the best performing chip seal sub-section with a similar binder type, environmental and traffic loading.

TEST SECTIONS

There are a total of forty 50 m long trial sections, located in one lane only (heading towards Kawerau) on the major haul road between Kawerau and south of Murupara. Four different bitumen types (PMB100, Emoflex, 80/100 and 180/200) are being trialled with five different binder rates on flat and hilly sections, sealed in January 1994.

These trial sections are located in a climate which varies from a minimum recorded air temperature of -4.2°C to a maximum of 30.2°C.

Bitumen Application Rate

Bitumen application was trialled at the optimum rate (X), X±0.15 l/m^2 and X±0.30 l/m^2 (Figure 2). The optimum application rate was calculated using the procedure outlined in the Bituminous Sealing Manual (TNZ, 1993), using a Traffic Factor of 0.7, based on previous trials. At the highest rate, the binder is expected to flush, whereas at the lowest rate, chip loss may result.

Due to the inherent inaccuracies of the sealing equipment, the actual bitumen application rates achieved were measured and are listed in Table 1.

Table 1 - Bitumen type and application rates trialled on flat and hill sections

Bitumen type	Bitumen Appln Rate (l/m^2) Sub-section (50 m)				
HILL	1	2	**3**	4	5
80/100	1.50	1.39	**1.28**	1.21	1.11
180/200	1.62	1.47	**1.32**	1.17	1.02
PMB100	1.62	1.47	**1.32**	1.17	1.02
Emoflex	1.64	1.46	**1.33**	1.20	1.02
FLAT	1	2	**3**	4	5
80/100	1.68	1.51	**1.49**	1.13	1.20
180/200	1.73	1.58	**1.43**	1.28	1.13
PMB100	1.67	1.52	**1.37**	1.22	1.07
Emoflex	1.68	1.55	**1.42**	1.24	1.11

Polymer-Modified Bitumens

PMB100 and Emoflex are proprietary brands of polymer-modified bitumens (PMBs). These synthetic rubber-based additives greatly improve the performance of bitumen binders by increasing resilience to high and low temperatures and improving strength and ductility. This may inhibit flushing, reduce chip loss and prevent cracking.

Standard Grade Bitumens

The 80/100 and 180/200 bitumens are common standard grades of bitumen used in New Zealand. The 180/200 is softer and used in colder climates, but is more susceptible to flushing on hot days. The 80/100 is a hard bitumen which is less likely to flush but may crack in temperatures less than 0°C.

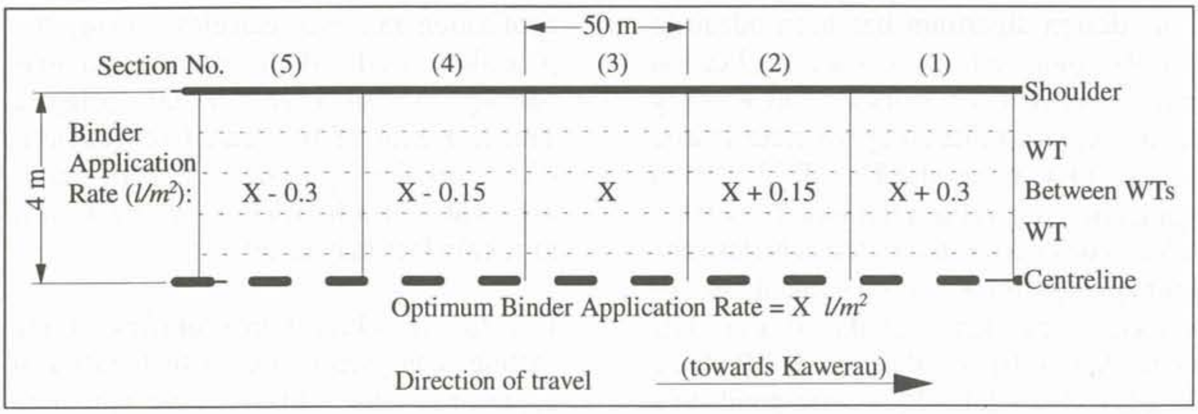

Figure 2 - Typical layout and target application rates of a 250m trial section. (Where OWT, BWT and IWT refer to the Outside, Between and Inside Wheel Tracks)

Traffic Loading and Speed

Each year, approximately 570,000 tonnes of logs are transported over the trial sections, by a mixture of on-highway and off-highway trucks (Table 2). The majority of this volume was carted by off-highway Double Bailey Units with an average gross weight of 99.5 tonnes. Figure 3 shows typical on and off-highway truck configurations and axle loads of a Double Bailey Unit that were measured at a weighbridge.

As the flushing potential of bitumen within the chip seal is affected by loading time as well as the wheel load, the truck speeds were measured by travelling in a sample of trucks over the sections.

There was a significant difference in speed between the hill and flat sections. Speeds on the flat sections were from 60 to 85 km/hr, while the speeds on nearly all of the hill sections ranged from 20 to 30 km/hr. For the 80/100 sections located on the hill, speeds were on average 60 km/hr, because these sections are located at the beginning of a hill climb. Therefore section 80/100 on the hill should be discarded as a hill section and only compared with other sections on the flat.

Table 2 - Truck usage per year and average weights.

Type of Units	Gross Weight (tonnes)	Payload (tonnes)	% Usage	No. of Trips (Feb 94 to Jan 95)
SINGLE	54.5	35	5.0	808
DOUBLE BAILEY	99.5	70	92.5	7473
TREBLE	149.5	105	2.5	135

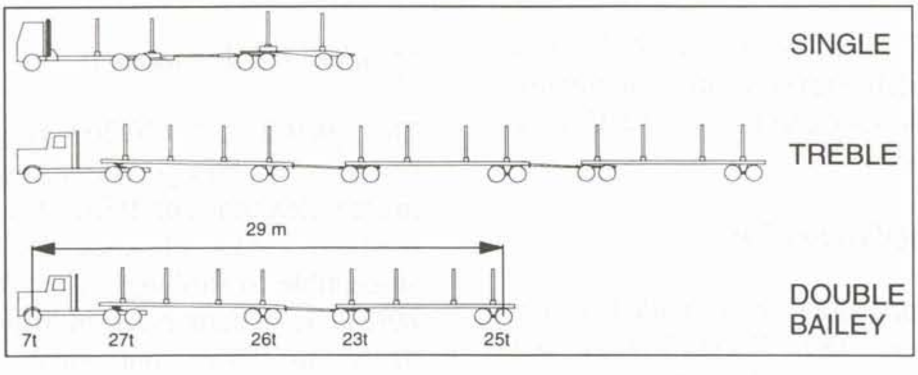

Figure 3 - Typical truck configurations

TESTING and ANALYSIS

Detailed tests examining the surface texture, structural integrity, and geometric characteristics of the pavement were conducted on all of the trial sections prior to sealing and after sealing (Arnold *et al.*, 1995b).

Surface distress such as potholes and wheel ruts were estimated visually (TNZ, 1994). However these types of distress are not as important as flushing and chip loss and did not occur in most sections.

Flushing

Flushing occurs where the surface of the road is smooth, with bitumen present on the surface (Figure 4). Flushing occurs gradually over time as the traffic re-orientates the chips to lie on their flattest side and the resulting arrangement of chips reduces the volume of voids between the stone chips. Chip embedment in the underlying layer also contributes to flushing. The rate of flushing is determined by measuring the surface texture depth (T_d) annually in the wheel tracks and between the wheel tracks for each sub-section using the Mini Texture Meter (MTM) and the sand circle method.

The MTM is a device walked along the road, which takes readings of texture every 300 mm using a laser. The average texture is reported every 10 m. For each new section, the MTM is calibrated using a special mat of a known texture. The sand circle test is the diameter achieved when 45 ml of sand is spread by revolving a straight edge until the sand is level with the tops of the chips (NRB, 1980).

MTM results are precise with low variability (McNaughton *et al.*, 1994) and were used in the analyses of the first and second year. Sand circle diameters are standard measures still used in road design. The range and standard deviation of the sand circle measurements were larger than the MTM. Sand circle diameters were used to calculate the texture depth immediately after sealing (year 0) as the MTM could not measure the texture as it was too high.

Chip Loss

In order for a chip seal to be a durable, water-proof and skid resistant surface, it is imperative that the stone chips remain firmly in place. Chip loss (Figure 4) is usually due to insufficient binder and usually occurs in cold weather when the bitumen is hard and brittle.

The severity of chip loss was estimated visually in and between the wheel tracks, and near the shoulder and centreline. The resulting area (m^2) of chip loss is calculated by multiplying the severity (% of chip loss) by the area (m^2) where this occurs.

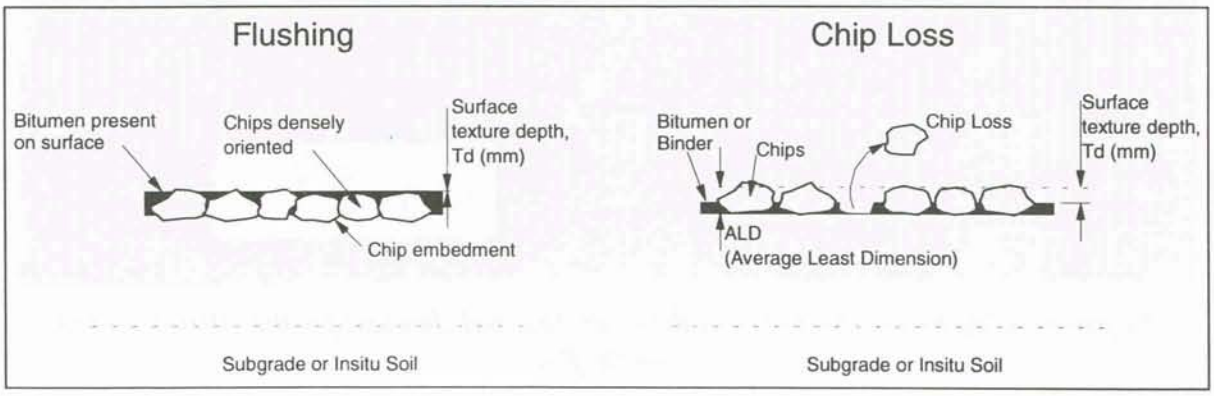

Figure 4 - Occurrence of flushing and chip loss

RESULTS

Chip Loss

Chip loss predominantly occurred on the centreline and shoulders of 22 out of 40 sections (Figure 5). Results show the PMB100 sections having the best overall chip holding ability (Arnold and Howard, 1996). Table 4 summarises the chip loss in all sections. Some chip loss occurred in and between wheel tracks for sub-section 5 of Emoflex and 80/100 on the hill and 80/100 on the flat.

Flushing

Figure 6 summarises the change in surface texture over time for each sub-section. The results each year are the average of 10 readings in the wheel tracks. The corresponding Traffic Factors for each sub-section are also listed.

- The surface texture of the 180/200 section on the hill was less than 50% of that of the other trials. This section flushed within the first year.

- Generally both the PMB100 and Emoflex sections retained the highest texture.

- Texture depth reduction in the second year was substantially less than in the first year.

Generally all of the sections have shown a large decrease in texture depth during the first year, but the rate of decrease has reduced in year two. This is expected as the chips will quickly rearrange themselves under traffic and lie on their flattest side.

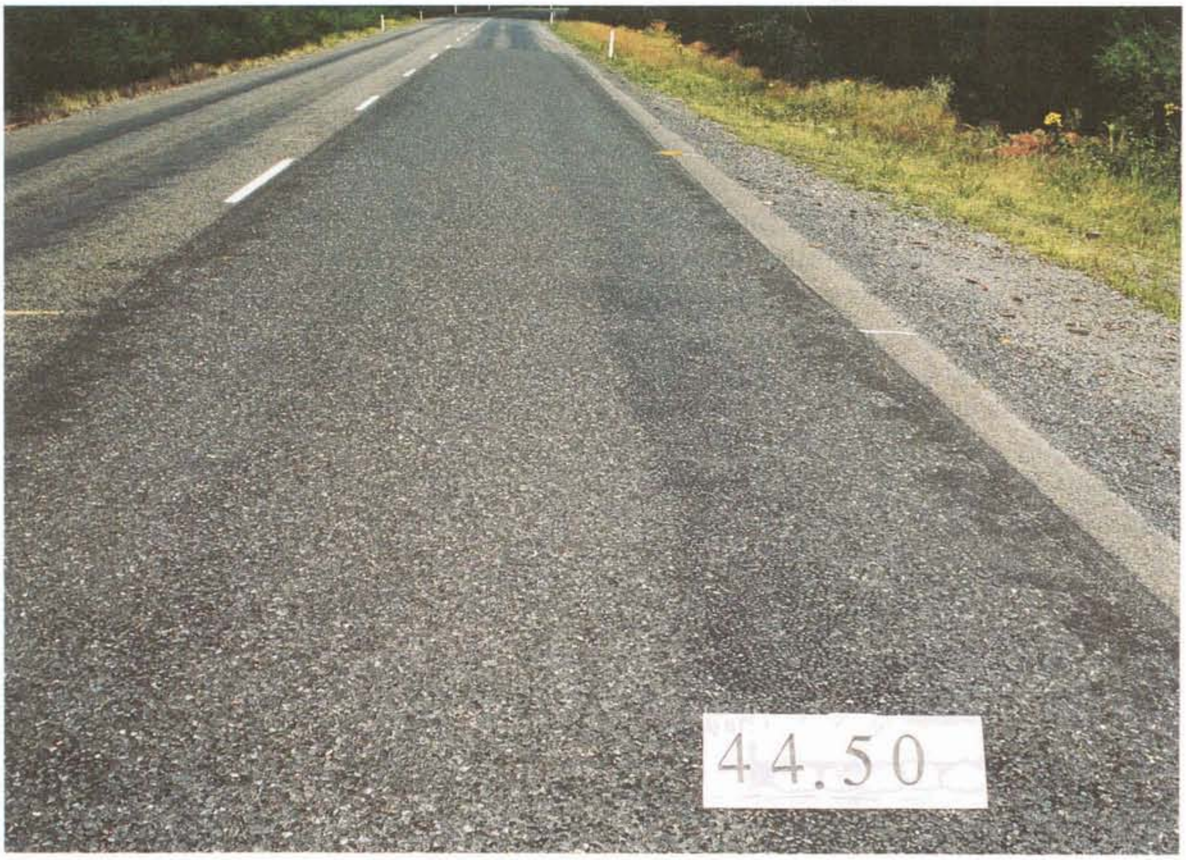

Figure 5 - Chip loss occurring near the centreline and shoulder for the 80/100 section on the flat

Table 4 - Chip loss in and between wheel tracks near the centreline and shoulder (WT = Wheel Tracks; BWT = Between Wheel Tracks; T_f = Traffic Factor; CL = Chip Loss, m^2).

Binder Type & Section	FLAT SECTIONS						HILL SECTIONS					
	WT & BWT		Centre		Shoulder		WT & BWT		Centre		Shoulder	
	T_f	CL	T_f	CL	T_f	CL	T_f	CL	T_f	CL	T_f	CL
PMB100												
1	0.83	-	0.80	-	0.63	-	0.84	-	0.81	-	0.68	-
2	0.75	-	0.75	-	0.61	-	0.75	-	0.79	-	0.72	-
3	0.68	-	0.66	-	0.58	-	0.69	-	0.70	**1**	0.64	**2**
4	0.61	-	0.56	-	0.51	**1**	0.61	-	0.64	**1**	0.49	-
5	0.54	-	0.52	-	0.45	**2**	0.53	-	0.58	-	0.43	-
Emoflex												
1	0.89	-	0.74	-	0.71	-	0.85	-	0.85	-	0.69	-
2	0.83	-	0.76	-	0.62	-	0.75	-	0.70	-	0.73	**2**
3	0.75	-	0.66	**1**	0.60	-	0.69	-	0.70	**3**	0.61	**1**
4	0.65	-	0.58	-	0.52	-	0.63	-	0.62	**23**	0.52	**2**
5	0.59	-	0.49	**1**	0.49	-	0.54	**1**	0.55	**9**	0.46	-
180/200												
1	0.88	-	0.82	-	0.73	-	0.86	-	0.89	-	0.71	-
2	0.79	-	0.85	-	0.67	-	0.78	-	0.80	-	0.62	-
3	0.73	-	0.77	-	0.65	-	0.70	-	0.73	-	0.58	-
4	0.65	-	0.62	-	0.57	**4**	0.62	-	0.64	-	0.49	-
5	0.57	-	0.51	-	0.50	**8**	0.54	-	0.55	-	0.46	-
80/100												
1	0.83	-	0.85	-	0.63	**8**	0.79	-	0.79	-	0.56	**8**
2	0.73	-	0.83	-	0.57	**5**	0.74	-	0.74	-	0.55	**18**
3	0.71	-	0.77	-	0.62	**5**	0.68	-	0.67	**1**	0.54	**13**
4	0.56	-	0.57	**4**	0.47	**17**	0.64	-	0.61	**4**	0.51	**10**
5	0.59	**24**	0.56	**13**	0.56	**22**	0.59	**13**	0.58	**3**	0.48	**23**

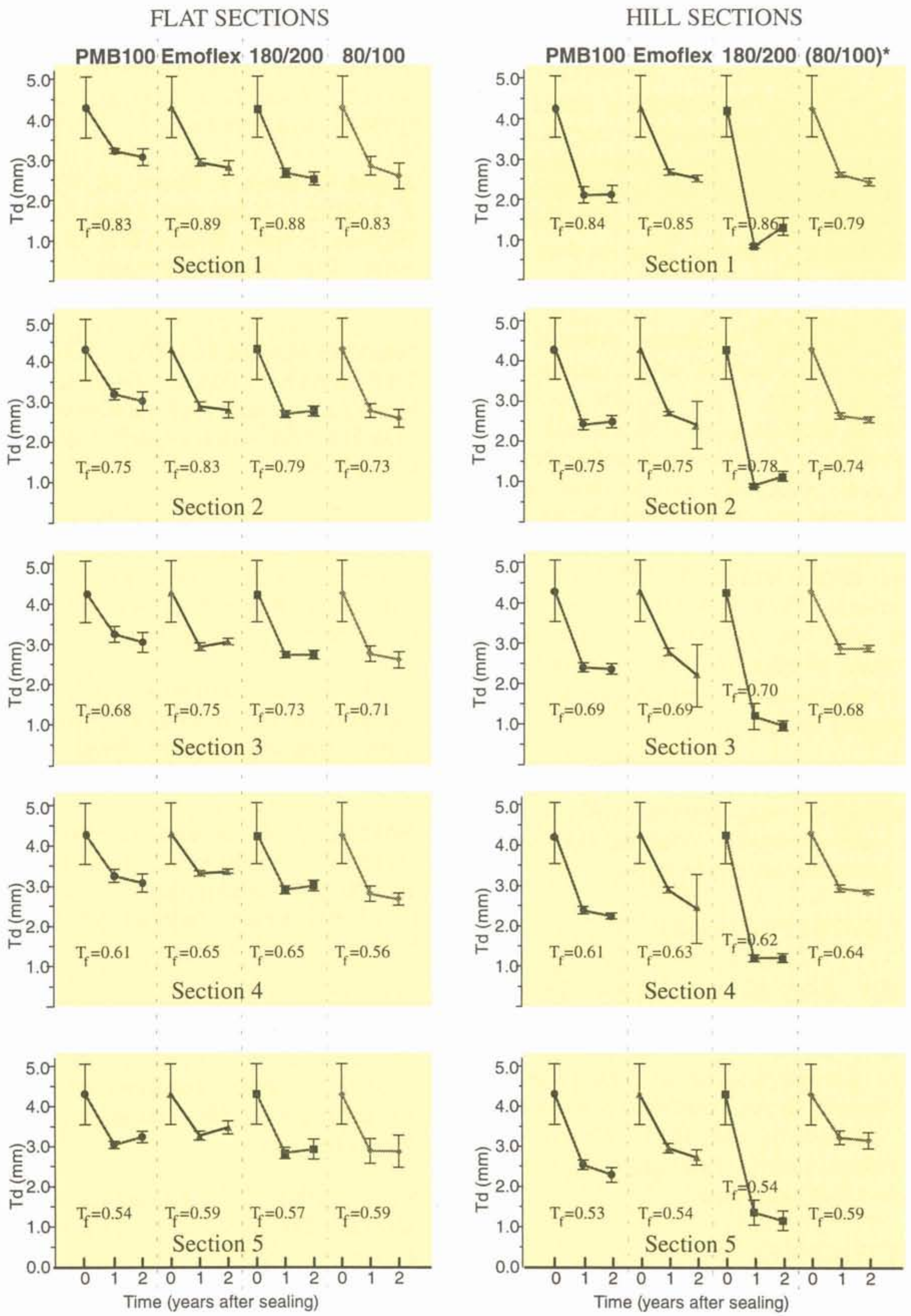

Figure 6 - Average change in texture depth for 0, 1, 2 years after sealing for both wheel tracks (n=10) for each 50 m section with 95% confidence intervals. (T_f = Traffic Factor; T_d = Texture depth). (Section 80/100 on the hill is effectively another section on the flat as the speeds are as high and should not be compared to the other bitumen types located on the hill)*

DISCUSSION

Chip loss occurring on the shoulders and near the centreline is probably due to the high underlying existing surface texture and the gradual loss of chips in from the edges. Most of the chips' holding strength and protection is from the surrounding chip matrix. Therefore, chips on the edges are easily dislodged.

The bitumens flushing potential is dependent on both the wheel load and the time of loading. Trucks travelling over the 80/100 sections located on the hill were travelling at a similar speed as over the flat sections, which are two to three times faster than the other sections located on the hill. This faster speed will explain the high surface texture (the same as the flat sections). The 80/100 sections located on the hill were not subject to the same stresses as other sections on the hill and therefore should not be compared to the other hill sections.

The conclusions drawn after two years, although showing definite trends, should be used cautiously. After the third year, firm conclusions can be made.

ACKNOWLEDGMENTS

LIRO acknowledges Bitumix Limited, Tauranga for constructing the chip seal trial sections, Forestry Corporation of New Zealand Limited for their financial assistance, Bryan Pidwerbesky, University of Canterbury and Works Consultancy Services, Central Laboratories for their advice and equipment.

REFERENCES

Arnold, G; Martin, M; Smith, J; Pidwerbesky, B. (1994) : "Chip Seal Trial Sections." Forestry Corporation of New Zealand Limited. (Work Performed on Chip Seal Trial Sections, Summer 1993/94). LIRO, Rotorua.

Arnold, G; Williams, A. (1995a) : "Chip Seal Trial Sections." Forestry Corporation of New Zealand Limited. (Work Performed on Chip Seal Trial Sections, Summer 1994/95). LIRO, Rotorua.

Arnold, G; Smith, J; Martin, M; Williams, A. (1995b) : "Chip Seal Trials For Off-Highway Forestry Roads (Year One of a Three Year Research Project)". LIRO Report, Vol. 20 No. 17.

Arnold, G; Howard, D. (1996) : "Chip Seal Trial Sections." Forestry Corporation of New Zealand Limited. (Work Performed on Chip Seal Trial Sections, Summer 1995/96). LIRO, Rotorua.

McNaughton B. D, Cenek P. D, Jamieson N. J (1994): Variability of Mini Texture Meter (MTM) Readings, Central Laboratories Report 94-29344. 02, Works Consultancy Services Limited.

N.R.B. (1980) : "Standard Test Procedure for Measurement of Texture by the Sand Circle Method". National Roads Board Technical Recommendation T/3.

Pidwerbesky, B. Arnold, G. Wylie, T. (1992) : "Development of a Flexible Pavement Management System." Concluding Report Prepared for Tasman Forestry Limited. April.

Pidwerbesky, B. (1994) : "Fundamentals of Chip Seal Design for Forestry Roads and Pavement-Vehicle Interaction Research at CAPTIF." Forestry Transport 2000. The Proceedings of a LIRO Seminar Held in Wellington. July.

T.N.Z. (1993) : "Bituminous Sealing Manual, 2nd Edition." Transit New Zealand, Wellington.

T.N.Z. (1994) : "RAMM. Road Assessment and Maintenance Management System. Road Condition Rating Manual." Transit New Zealand, Wellington. June.

For further information, contact:

LOGGING INDUSTRY RESEARCH ORGANISATION
P.O. Box 2244,
ROTORUA, NEW ZEALAND.

Fax: 0 7 346-2886 *Telephone: 0 7 348-7168*