REPORT

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CHIP SEAL TRIALS FOR OFF-HIGHWAY FORESTRY ROADS

(YEAR THREE) - Greig Larcombe

Figure 1 - Off-highway Double Bailey truck transporting logs to Kawerau

Summary

For the past three years, 40 chip seal trial sections have been monitored on an off-highway forestry road in Kaingaroa Forest. These trials were established to determine an appropriate treatment to prevent flushing recurring. Flushing occurred soon after the second coat seal had been applied in 1986. The likely causes were high bitumen content and high wheel loads (up to 16 tonnes per dual tyred axle). The main aim of these trials was to develop a suitable chip seal design procedure for arterial forestry roads carrying single dual tyred axle loads up to 16 tonnes.

The variables in the 40 trial sections were: (i) level of stress (straight level road versus adverse gradient), (ii) type of bitumen binder (6% PMB 100, Emoflex, 80/100 and 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, two and three years after sealing. Chip loss occurred predominantly on the shoulder and centre line on 26 of the 40 sections.

Flushing of the 180/200 bitumen stressed section occurred within the first year and had deteriorated to total failure by the second year. The 6% PMB 100 had the best chip holding ability and is comparative with Emoflex for its resistance to flushing. Texture depth reduction in the first year was significant in all sections, although there was no significant reduction in texture depth in the second and third years. However, the stressed sections experienced less texture depth reduction in the third year than the unstressed sections. This has been attributed to the chips taking longer to align on their longest side due to traffic loading times being less.

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The most appropriate binder application rate for future re-seals on the stressed sections would be 1.02 l/m^2 with a Traffic Factor of 0.58 using 6% PMB 100. For the unstressed sections, a binder application rate of 1.05 l/m^2 should be used with a Traffic Factor of 0.62 also using 6% PMB 100.

Introduction

In 1986, public highway design criterion was used by Fletcher Challenge Forests Limited, (formerly Tasman Forestry Limited), to design the chip seal for the off-highway road between Murupara and Kawerau. This semi-empirical design procedure (Transit, 1993) provides corrections for existing surface texture and vehicle loading based on observations and studies involving public highways carrying traffic that typically consisted of 10% to 15% heavy commercial vehicles, with an average axle load of about five tonnes. This procedure did not take into account the effects of off-highway trucks with axle loads up to 16 tonnes.

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). The lane carrying unloaded vehicles flushed, but to a lesser degree.

Bitumen application is critical to the performance of the chip seal. Too much bitumen will result in flushing in the wheel tracks creating a very slippery and dangerous surface when wet. Too little bitumen will result in chip loss and a lack of waterproofing. However, in this case, flushing was caused by a too soft a bitumen and too much bitumen being applied.

In an attempt to remedy the flushing, there have been various trials of new chip seal designs undertaken since 1989, under the direction of Dr Bryan Pidwerbesky (University of Canterbury). The results of this research concluded that a re-seal with a polymer-modified bitumen (PMB) and a low bitumen 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 unmodified, standard grades of bitumen. Therefore, in 1994 a total of forty 50m chip seal trial sections were sealed and have been monitored over the past three years (Arnold *et al* 1994, Arnold and Williams 1995, Arnold and Howard 1996 and Larcombe 1997).

The third year of the trial was to be the last. However, after consultation with Fletcher Challenge Forests Limited, Waiotapu (formerly Forestry Corporation of New Zealand Limited), it was decided to continue the trials for a further year to confirm the results obtained in January, 1997. This report summarises the performance of the 40 chip seal trials, and provides recommendations for future re-seals.

Definitions

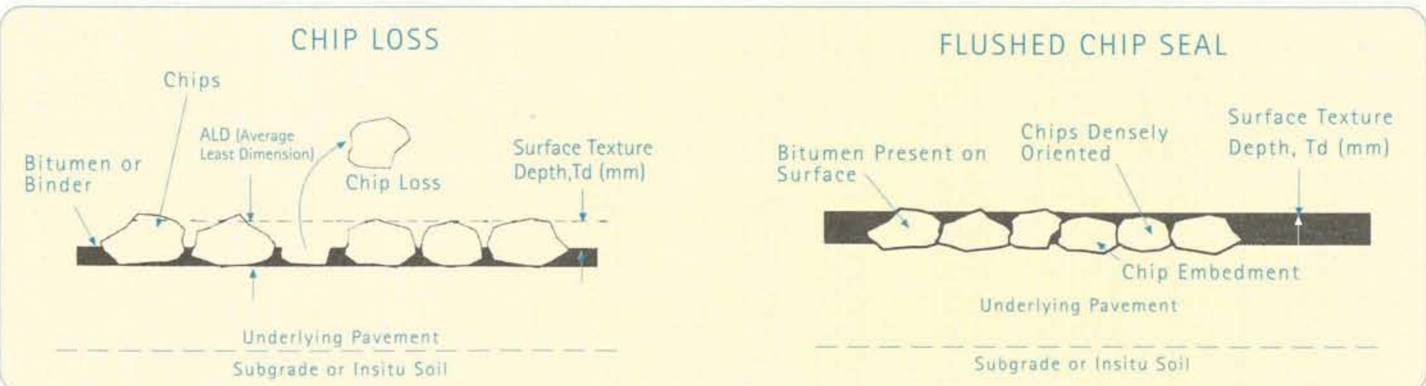

Figure 2 - Terminology

Binder Types

PMB100, Emoflex and PMBs are proprietary brands of polymer-modified bitumens. These are synthetic rubber-based additives, which greatly improve the performance of bitumen binders. Resilience to high and low temperatures is increased and strength and ductility is improved. This may inhibit flushing, reduce chip loss and prevent cracking. PMBs are used in areas of extreme environmental and/or traffic conditions, where the existing binder has failed. The 80/100 and 180/200 bitumens are common standard grades of bitumen that are 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.

Chip Seal Design

Binder application rates were designed using the Transit New Zealand (Transit) design algorithm RD286 (Transit, 1993):

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

where:

R = Residual Bitumen Application Rate (l/m^2)

e = Existing Surface Texture Adjustment (l/m^2)

ALD = Average Least Dimension (mm) (Figure 2)

Tf = Traffic Factor (unitless)

The Transit design algorithm has been adequate in designing an appropriate application rate for re-seals on Bonisch and Railway Roads, provided an appropriate coefficient is used. This coefficient is the unitless multiplier known as the Traffic Factor (Tf). The Transit design guidelines suggest a minimum Tf of 0.8, which corresponds to one on-highway truck being equivalent to 10 vehicles per day per lane (v/l/d). The equivalent traffic on Bonisch and Railway Roads is 310 v/l/d, which corresponds to a Tf of 1.27. Previous experience has shown that a Traffic Factor of 0.7 may be an appropriate number to use (Pidwerbesky *et al*, 1992).

However, this is still a guess and the best Traffic Factor to use is not known. Ideally, the Traffic Factor used should be as low as possible to reduce the binder application rate without losing any chips.

For each of the test sections, the Traffic Factor has been calculated using the formula below. This Traffic Factor is the number that would be used if the binder application rate was designed to equal the binder application rate that was actually applied. A low Traffic Factor (for example, 0.55) would indicate a low binder application rate and some chip loss would be expected. Conversely, a high Traffic Factor (for example, 0.90) would indicate a high binder application rate and some flushing would be expected (Figure 2).

Transit's RD286 can be solved for Tf (Traffic Factor) yielding the formula:

$$Tf = R/(0.138 \times ALD + e)$$

where:

R = Actual residual bitumen application rate used (l/m^2).

ALD = Average Least Dimension of the stone chip used (mm).

e = $0.21 \times Td - 0.05$, (l/m^2) existing surface texture adjustment.

Td = Sand circle texture depth = $57{,}300/d^2$ (mm), and d = sand circle diameter(mm).

or using Mini Texture Meter (MTM) readings,

$$Td = 1.64\ MTM_{texture} - 0.13 \qquad \text{(McNaughton } et\ al.\ 1994)$$

Flushing

The Traffic Factor used in the future 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.

Flushing occurs when the surface of the road is smooth due to the bitumen binder rising and chips are pushed into the underlying layer due to wheel loading (Figure 2). Flushing is caused by either of three factors:

(1) Too much bitumen applied at sealing or,

(2) The bitumen used was too soft for the conditions.

(3) The wheel loading and time of loading

Flushing occurs gradually over time as the traffic reorientates the chips to lie on their longest side and the resulting arrangement of chips reduces the volume of voids between the stone chips.

Test Sections

All of the trials were situated on a private arterial forestry road, in the loaded lane (heading north towards Kawerau) known as Bonisch and Railway Roads. Four different binder types (6% PMB 100, Emoflex, 80/100 and 180/200) were trialled on two locations, a flat and hill section, each 250 m long. These trial sections were further divided into five 50 m trial sections to vary the bitumen application rate.

The bitumen application rates trialled were the optimum application rate (X) l/m^2, X$\pm$ 0.15 l/m^2 and X$\pm$0.3 l/m^2 (Figure 3). The optimum application rate was designed using the procedure outlined in the Bituminous Sealing Manual (Transit, 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 were measured using carpet mats and are listed in Table 1.

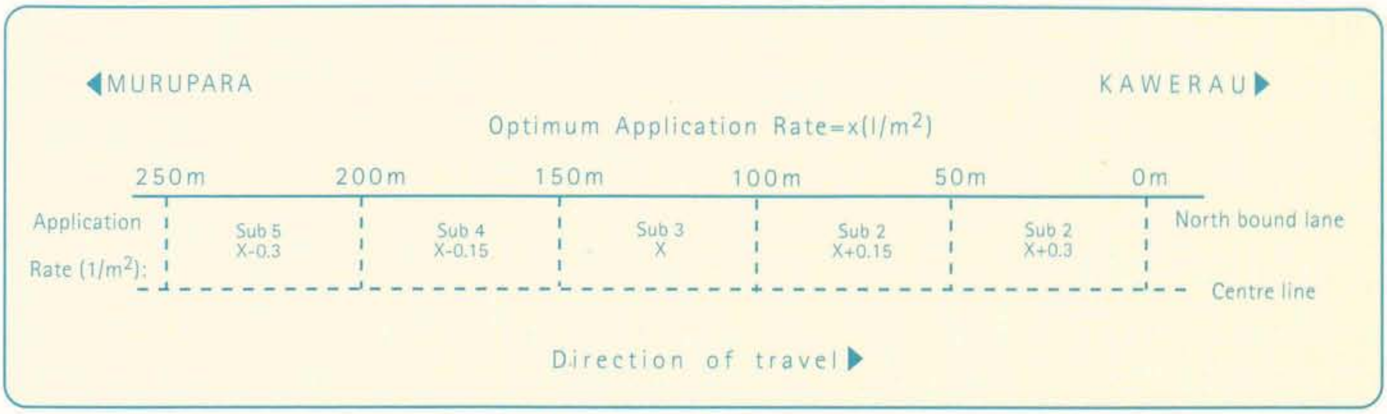

Figure 3 - Typical layout and target application rates

Table 1 - Table of actual binder application rates (l/m^2)

BINDER	SUB-SECTION				
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
6%PMB 100	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
6%PMB 100	1.67	1.52	1.37	1.22	1.07
EMOFLEX	1.68	1.55	1.42	1.24	1.11

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. The majority of this volume was carted by off-highway Double Bailey units with an average gross weight of 99.5 tonnes (Figure 1).

As the bitumen within the chip seal is affected by loading time, the truck speeds were also measured using a hawk radar (Arnold *et al.*, 1994 and 1995), and by travelling in a sample of trucks over the sections (Arnold and Howard 1996).

There was a significant difference in speed between the hill and flat sections. Speeds on the flat sections were from 60 to 80 km/hr, while the speeds on the hill sections ranged from 18 to 30 km/hr. The only exception being the 80/100 sections located on the hill where speeds were on average 50 km/hr due to their location at the beginning of a hill climb. Effectively all other sections on the hill endured twice the loading time of the sections on the flat.

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, and after, sealing (Arnold *et al.*, 1995).

A Road Assessment and Maintenance Management System (RAMM) (Transit, 1994) visual survey was conducted each year to determine the degree of rutting, cracking, edge breaking and pot holes. However, these types of distress are not as important as flushing and chip loss and did not occur in most sections over the past three years.

Flushing

The rate of flushing was determined by measuring the surface texture depth (Td) 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. The sand circle test is the diameter achieved after 45 ml of sand is spread, by revolving a straight edge, until the sand is level with the tops of the chips (NRB, 1980).

Sand circle diameters are standard measures used in road design. However, the MTM results were used in the analysis of the first, second and third years, due to their accuracy and low variability (McNaughton *et al.*, 1994)

Chip loss

Chip loss occurred predominantly on the shoulders and centre line of the trial sections . This is mainly caused by insufficient bitumen binder, due to the underlying existing surface texture being higher on the shoulders and centre line than in the wheel paths (Arnold *et al.*, 1995). The bitumen application rates were designed for the existing texture of the wheel paths, resulting in applying too little bitumen on the shoulders and centre line to hold the chips in place. Another factor causing chip loss, is that the stone chips obtain most of their holding ability from the surrounding chip matrix. Therefore, the shoulders and centre line are more prone to chip loss. Chip loss is of concern because of the loss of skid resistance and water-proofing.

Results

Flushing and Surface Texture

Most of the bitumen binders situated on the hill section experienced some degree of flushing in the high application rates, with 180/200 failing in the first year. Generally Emoflex and 6% PMB 100 had low levels of flushing during the first two years and continued to show resistance to flushing. The flat bitumen binder sections showed signs of increased flushing and a reduction in texture depth greater than the hill sections. This has been attributed to the rate of deterioration being faster on the hill sections due to longer loading times. Comparing the reduction in texture depth shows that there is a large decrease in texture depth during the first year, but the rate of decrease had reduced in the second and third years. This was expected as the chips reoriented themselves under traffic and lie on their longest side.

Chip Loss

Chip loss predominantly occurred on the centre line and shoulders in the first two years (Arnold and Williams 1995, and Arnold and Howard 1996). In the third year, this was still occurring with some added chip loss from a number of the trial sections within and between the wheel tracks, most of which had occurred in the low application rates as was expected. Results show the 6% PMB 100 sections had the best overall chip holding ability (Larcombe 1997).

Discussion

The predominant form of chip loss occurred on the shoulders and near the centre line. This is due to the high underlying existing surface texture and the gradual loss of chips from the edges. Chips receive most of their holding strength and protection from the surrounding chip matrix. Therefore, chips on the edges are easily dislodged, generating a chain reaction effect as stripping moves towards the wheel tracks.

The flushing problem is dependent on the type of bitumen used, the wheel load and the time of loading. Both the 80/100 and 180/200 sections had experienced extreme to medium flushing. Both 6% PMB 100 and Emoflex had moderate to low or nil flushing (Larcombe 1997).

The conclusions drawn after three years were that overall 6% PMB 100 had the best chip holding ability and flushing resistance which was consistent throughout the range of application rates (Figure 2). This bitumen should be used with a Traffic Factor of 0.58 which corresponds to a binder application rate of 1.02 l/m^2 for the stressed sections and for the unstressed sections a Traffic Factor of 0.62, application rate of 1.05 l/m^2, should be used.

Acknowledgments

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