Increased Effective Life of Porous Asphalt

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Increased Effective Life of Porous Asphalt

N.J. Jamieson & J.E. Patrick
Opus International Consultants Ltd
Opus Central Laboratories
PO Box 30 845, Lower Hutt, New Zealand

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PO Box 2331, Lambton Quay, Wellington, New Zealand
Telephone 64-4-473 0220; Facsimile 64-4-499 0733

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Contents

Executive Summary 7
Abstract 8

1. Introduction 9

2. Porous Asphalt Mix Design 11
  2.1 Aggregates 11
  2.2 Binder Selection 12

3. Laboratory Testing 13
  3.1 Test Methods 13
    3.1.1 Indirect Tensile Strength Test 13
    3.1.2 Cantabrian Test for Abrasion Loss 13
    3.1.3 Measurement of Total and Interconnected Air Voids 14
    3.1.4 Measurement of Relative Hydraulic Conductivity (Permeability) . . 14
  3.2 Test Results 15
    3.2.1 Indirect Tensile Strength 15
    3.2.2 Cantabrian Test for Abrasion Loss 17
    3.2.3 Permeability 19
  3.3 Findings & Recommendations 21

4. Field Trials 22
  4.1 Construction 22
  4.2 Laboratory Testing 22
  4.3 On-Road Monitoring Programme 23
    4.3.1 Skid Resistance Measurements 24
    4.3.2 Noise Measurements 26
    4.3.3 Permeability Measurements 28
    4.3.4 Road Surface Condition 30

5. Conclusions 31

6. Recommendations 31

7. References 32

Executive Summary

This report describes the results of a Transfund New Zealand research programme to investigate the potential to increase the effective life of porous asphalt. It involved the development and trials of a new mix design system for porous asphalt, based on maximising the effective void content, but maintaining sufficient strength through the use of polymer-modified bitumen.

Using local Wellington aggregate, a number of different grades of aggregate were used to make porous asphalt mixes based on 80/100 grade bitumen. These mixes were designed to be more open, or porous, than the standard Transit New Zealand (TNZ) P/11 specification. A number of these mixes also incorporated varying amounts of polymer-modified binders. The results of a range of laboratory tests on the different mixes were used to decide on the mix design that would be most suitable for field trials.

A field trial of the chosen mix was laid on State Highway 1, near Porirua, in April 1999, immediately adjacent to a section of standard TNZ P/11 mix that had been laid less than two months earlier. Also laid at this time were a mix similar to the TNZ P/11 specification, but more open and using a high PSV (polished stone value) chip, and another proprietary TNZ P/11 mix known as Flexiphalt 150A. Skid resistance, noise and permeability measurements have since been conducted on a yearly basis, together with visual inspections of the general surface condition.

The significant findings can be summarised as follows:

- the more porous alternative mix that was developed utilising two different polymer-modified binders, and trialled, has stood up well to two years of heavy traffic;
- the skid resistance of these mixes has been at least as good over the trial period as the standard TNZ P/11 mix;
- their noise levels have been consistently lower than the standard TNZ P/11 mix;
- their permeabilities have been much better than the standard TNZ P/11 mix.

Recommendations are that:

- monitoring of the skid resistance, permeability and noise is continued on a yearly basis until the surface fails, or until the performance/condition of the trial mix falls below that of the standard TNZ P/11 mix;
- the interconnected air voids content is considered as an alternative to the total air voids in the TNZ P/11 specification;
- the Cantabrian test is introduced into the TNZ P/11 specification.

Abstract

A new mix design system for porous asphalt based on maximising the effective void content, but maintaining sufficient strength through the use of polymer-modified bitumen, was developed and trialled. The skid resistance, permeability, and noise characteristics were compared with those obtained for a control using the current TNZ P/11 mix, and found to be similar or better.

1. Introduction

Porous asphalt is widely used around the world, particularly in Europe, America, Australia, South Africa, and New Zealand. It is the predominant surfacing on New Zealand motorways, and is becoming increasingly common as a noise reduction treatment in other areas, e.g. the Taupo lakefront road.

The first Transit New Zealand specification for porous asphalt (friction course: TNZ P/11) was introduced in 1975 and was based on aggregate grading that would result in a total air void content of greater than 14%. In 1980 the specification was revised to ensure an air voids content of 20% or greater.

The New Zealand specifications are based on USA experience, especially on FHWA* guidelines of the 1970s. However, New Zealand experience has shown that, with the currently used materials, the free-draining characteristics contribute to high skid resistance, and to reduction in:

- aquaplaning potential,
- noise, and
- splash and spray,

are lost within 3 to 4 years of construction. Even though the average life of porous asphalt is greater than 8 years, the effective life is in reality less than half of this. The main factor contributing to this shorter life has been identified as the entry of detritus materials (silt, fine sand, dirt), clogging the pore spaces and adhering to the binder.

In attempts to maintain the porous nature of the surface, various cleaning techniques have been developed and adopted in Europe, and these have been claimed to be successful.

A research project commissioned by Transit New Zealand, and centred on maintaining the porous nature of friction course (Patrick 1995), identified a number of avenues that could be researched which had the potential to result in longer effective life for porous asphalt. One of these has been investigated by Dravitzki & Wood (1999) as TNZ Research Project PR3-0149, *Comparison of 14 mm and 20 mm Friction Courses*. This project found that using a different maximum sized aggregate, and laying the material at 40 mm thick instead of 25 mm, did not result in any substantial improvement in effective life. The two mixes used for TNZ PR3-0149 both had a total void content of approximately 20%.

Transit New Zealand Research Report No. 46 (Patrick 1995) reported USA research which indicated that the total void content approach did not necessarily reflect the "effective" void content, where "effective" void content is the proportion of the voids that are inter-connected and thus are contributing to the free-draining characteristics of the material

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*FHWA Federal Highway Administration

The project also reported on Australian experience which indicates that the use of polymer-modified bitumen (PMB) reduces the adherence of detritus in the mix, thus slowing the "blocking up" of the voids.

The primary objective of this project was to develop improved asphalt mix design procedures that will lead to an increase in the effective life of this type of surfacing. This was to be achieved through:

- development of a mix design system for porous asphalt based on maximising the effective void content but maintaining sufficient strength through the use of polymer-modified bitumen;
- trials of the new mix design on a road section with high traffic volumes, and
- assessment of the performance of the new design relative to the current TNZ P/11 (1996) mix by comparing the skid resistance, permeability and noise characteristics.

2. Porous Asphalt Mix Design

2.1 Aggregates

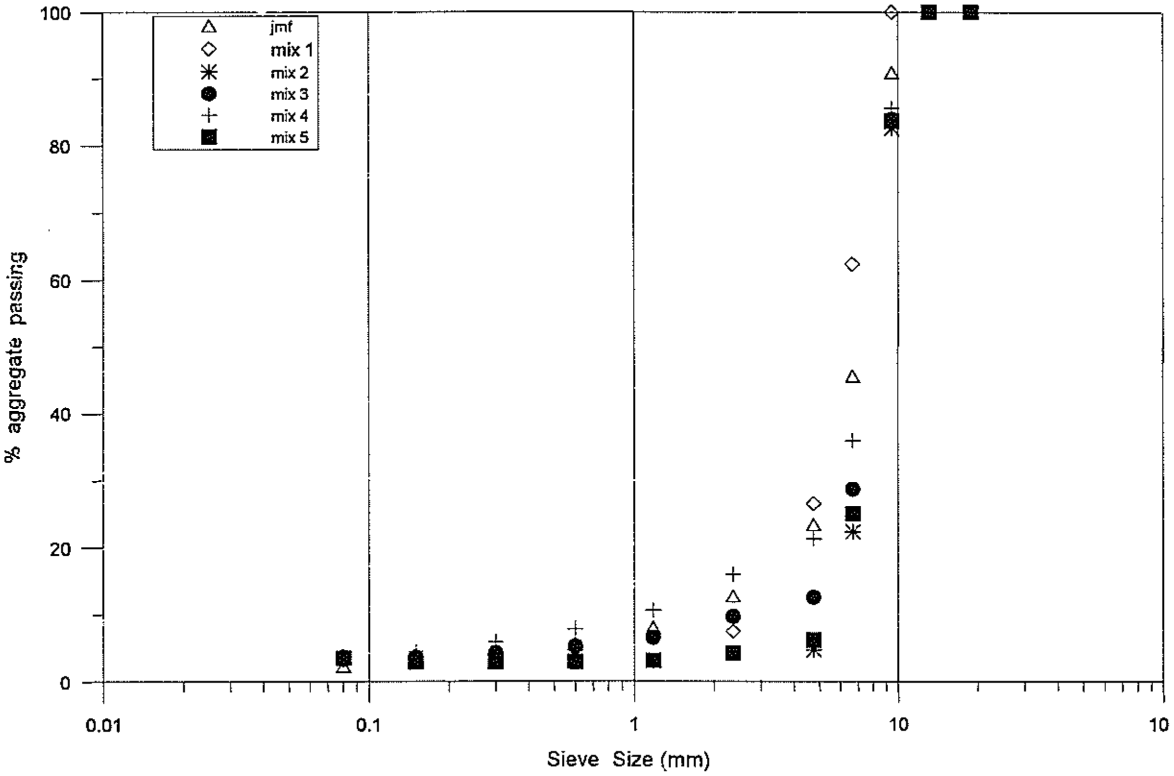
The aggregates employed in the study were commonly available greywacke material from Wellington. They were obtained from the Horokiwi Quarry stockpile, Wellington.

Seven mixes with appropriate characteristics were prepared using the aggregates. Two of them, identified by JMF and JMF(HS) labels, had gradings that complied with the TNZ P/11 and TNZ P/11(HS) specifications. The HS mix is less porous than the "normal" P/11 mix, but withstands higher shear stress. The JMF mix was used as a control. The remaining five mixes, identified as Mix-1 to Mix-5, were prepared so that they are more open than specified in the TNZ P/11 specification. In all the mixes, the fines were kept between 3-5%, with filler material being added where required. The filler material used in the study was hydrated lime. The grading data of the mixes along with the control are presented below in Table 2.1. The grading curves of mixes are plotted in Figure 2.1.

Table 2.1 Grading curves of the aggregate mixes and the control (JMF P11).

Sieve size	P/11 Mix 14 Lower	P/11 Mix 14 Upper	JMF (HS)	JMF P11	MIX-1	MIX-2	MIX-3	MIX-4	MIX-5
19.00	100	100	100	100	100	100	100	100	100
13.20	100	100	100	100	100	100	100	100	100
9.50	85	95	93.8	90.9	100	82.5	83.9	85.5	83.7
6.70			57.2	45.6	62.3	22.3	28.7	35.9	25.0
4.75	20	40	36.68	23.4	26.5	4.7	12.5	21.2	6.1
2.36	5	15	22.2	12.7	7.4	4.1	9.6	15.9	4.2
1.18			14.5	8.0	3.0	3.0	6.5	10.5	3.1
0.60			10.3	5.6	3.0	3.0	5.2	7.8	3.0
0.30			7.5	4.1	3.0	3.0	4.3	5.9	3.0
0.15			5.4	2.9	3.0	3.0	3.7	4.5	3.0
0.08	2	5	3.97	2.35	3.27	3.57	3.70	3.96	3.55

Figure 2.1, **Grading curves for aggregate mixes.**



2.2 Binder Selection

In the initial stages, standard bitumen grade 80/100 was used as a binder for making samples for all the mixes. The binder content was selected by making up mixes with a range of bitumen contents, and placing them in an 800 ml beaker in an oven at 130°C for an hour. The drainage of bitumen from the material was visually assessed, and the maximum bitumen percentage that resulted in minor spotting on the base of the beaker was selected as the "optimum" binder content.

For the polymer-modified binders the same binder content was used, but the mixing temperature was 150°C. Based on the results, Mix-1 was selected for further testing using polymer-modified binder with 3% SBS and 5% SBS. The binder source material used was Technics PMB-100.

The samples were subjected to various laboratory tests, and the results were qualitatively as well as quantitatively analysed to select a mix that gave better results. These tests are described in Section 3 of this report.

3. Laboratory Testing

The laboratory study was focussed mainly on improving the water drainage capacity of the mix, as well as the structural integrity of the pavement as a whole regarding fretting and durability, using locally available materials. Therefore the tests for the individual material properties, e.g. aggregate strength, PSV[†] values, binder qualities, etc., were not investigated because standard materials were being used in the study.

Marshall blocks were prepared with standard 75 blows mechanical compaction for all the mixes using a straight bitumen 80/100. These blocks were tested for:

- Indirect tensile strength at 40°C
- Durability test – Cantabrian (Cantabro) Test (Modified Los Angeles Abrasion Test)
- Total air voids
- Effective air voids (Interconnected air voids)
- Permeability

3.1 Test Methods

3.1.1 Indirect Tensile Strength Test

Splitting tests on Marshall blocks were carried out to measure the indirect tensile strength and deformation at the failure. The blocks were heated in a water bath at 40°C for 35 minutes. The test uses the Marshall test equipment with modified moulds on the blocks for loading in accordance with ASTM D4123 (ASTM 1995).

3.1.2 Cantabrian Test for Abrasion Loss

These tests were performed to quantify the fretting/abrasion resistance of the mixes. The test consists of putting a Marshall block into a Los Angeles rattler (without steel balls) at 18°C and measuring its weight loss after 300 revolutions of the drum. The speed of the drum is 30 revs/min. The sample undergoes abrasion during the test, and its weight loss depends on the cohesion of the mix being tested. The result of the test is expressed as the percentage of weight loss in relation to the initial weight.

$$P(\%) = \frac{P_1 - P_2}{P_2} x100 \qquad \text{(Equation 1)}$$

where: P = Cantabrian loss in percentage
P_1 = initial weight of sample in grams
P_2 = final weight of sample in grams

[†] PSV Polished Stone Value

3.1.3 Measurement of Total and Interconnected Air Voids

The total air voids in the samples were measured according to the standard method described in ASTM D3203-94 (ASTM 1994). This method is based on measurements of the mass and volume of the sample, by measuring its height and diameter, calculation of its density and bulk specific gravity, followed by calculation of the air voids using the theoretical maximum specific gravity. The percentage of interconnected air voids is based on measuring the difference between the total air voids and the unconnected air voids by placing the sample in water and determining its displacement relative to its volume (ASTM D2726-96 (ASTM 1996)).

3.1.4 Measurement of Relative Hydraulic Conductivity (Permeability)

As discussed in Section 1 of this report, the effective life of porous asphalt is significantly reduced through detritus (silt, fine sand and dirt) clogging the pore spaces. Consequently, permeability is an important parameter in determining performance, and hence the life of the mix.

Characterisation of drainage properties of porous asphalt by means of permeability measurements is complex. The flow through the material may not be laminar because large air voids may be present, which means Darcy's law is no longer valid. Bear (1972) stated that laminar flow exists if the Reynolds number lies within a range of 1 to 10. The Reynolds number (Re) is defined by:

$$\mathrm{Re} = \frac{V_V d}{\nu} \qquad \text{(Equation 2)}$$

where:
V_v = specific discharge velocity through pores
d = characteristic length of the pores imparting flow
ν = kinematic viscosity (1 m^2/s at 20°C)

For the drainage properties of porous asphalt, where the drainage flow is rapid and mean particle size is 10 mm, Darcy's law is no longer applicable. In such cases, the discharge velocity (V) is given by the equation:

$$V = ki^m \qquad \text{(Equation 3)}$$

where:
k = pseudo permeability
i = hydraulic gradient
m = coefficient determining the type of flow:
$m = 0.5$ fully turbulent and $m = 1$ laminar

A constant head permeameter was developed in Opus Central Laboratories to measure permeability specifically for Marshall blocks. This comprised of a vertical tube into which the Marshall blocks were fitted.

3.2 Test Results

The results of the tests described in Section 3.1 are given in Table 3.1 below. In addition to the mixes listed in Table 2.1, results are also presented for the Mix 1 using polymer-modified binder with 3% and 5% SBS. Note that standard bitumen grade 80/100 binder was used for all of the mixes.

Table 3.1 Summary of test results for all mixes, plus PMB mix.

Mix Designation	**JMF (HS)**	**JMF P11**	**MIX-1**	**MIX-1** (3%SBS)	**MIX-1** (5% SBS)	**MIX-2**	**MIX-3**	**MIX-4**	**MIX-5**
Binder content (%)	5.4	5.2	4.5	5.0	5.0	4.0	4.0	4.5	3.5
Total air voids (%)	14.6	24.0	31.5	28.5	28.1	32.2	29.6	24.3	30.6
Interconnected air voids(%)	7.4	19.4	27.6	23.4	23.8	30.6	25.7	20.8	27.9
Ratio of air voids*	0.5	0.8	0.9	0.8	0.9	~1.0	0.9	0.9	0.9
Permeability, k (mm/sec)	1.7	16.8	40.5	25.1	22.1	60.3	32.1	19.1	41.6
Cantabrian test loss (%)	9.8	35.4	65.1	17.0	6.4	100.0	85.8	71.0	89.6
Indirect Tensile Test:									
Tensile Strength (kPa)	108.7	33.3	32.5	39.2	38.2	25.9	38.8	46.5	39.3
Vertical Deflection (mm)	2.3	2.8	2.3	2.9	2.7	3.0	2.3	3.1	2.4

*	% interconnected air voids : % total air voids
SBS	styrene butadiene styrene

Two of the most important characteristics of porous asphalt, particularly with respect to permeability and drainage, are total air voids and interconnected air voids. Total air voids of the mixes measured ranged from 14.6% to 32.2% and interconnected voids ranged from 7.4% to 30.6%. The ratios of interconnected and total air voids were as high as ~1.0, and generally highest for the mixes with high total air voids.

The data in Table 3.1 show that the total and interconnected air voids have a significant effect on other characteristics of the mixes, including tensile strength, Cantabrian loss and permeability. These effects are described below.

3.2.1 Indirect Tensile Strength

The indirect tensile strength values for the mixes are plotted in Figures 3.1 and 3.2 against total and interconnected air voids respectively. These figures generally show a decreasing indirect tensile strength with increasing voids. Although there is a distinct trend, more data are required to develop a more exact relationship.

Figure 3.1 Variation of indirect tensile strength with total air voids.

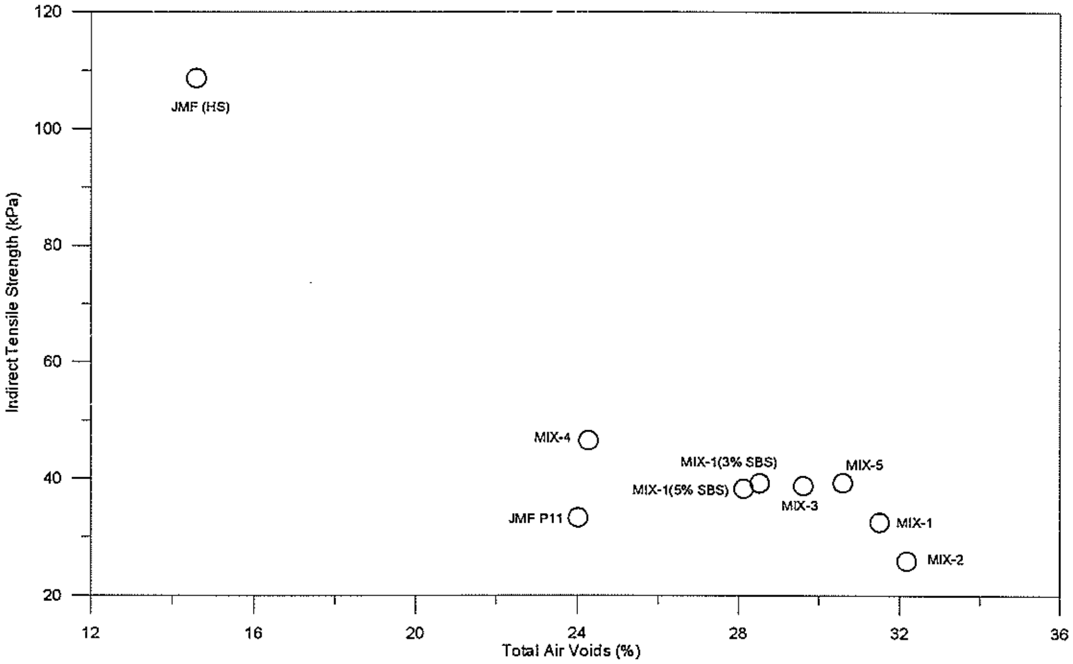
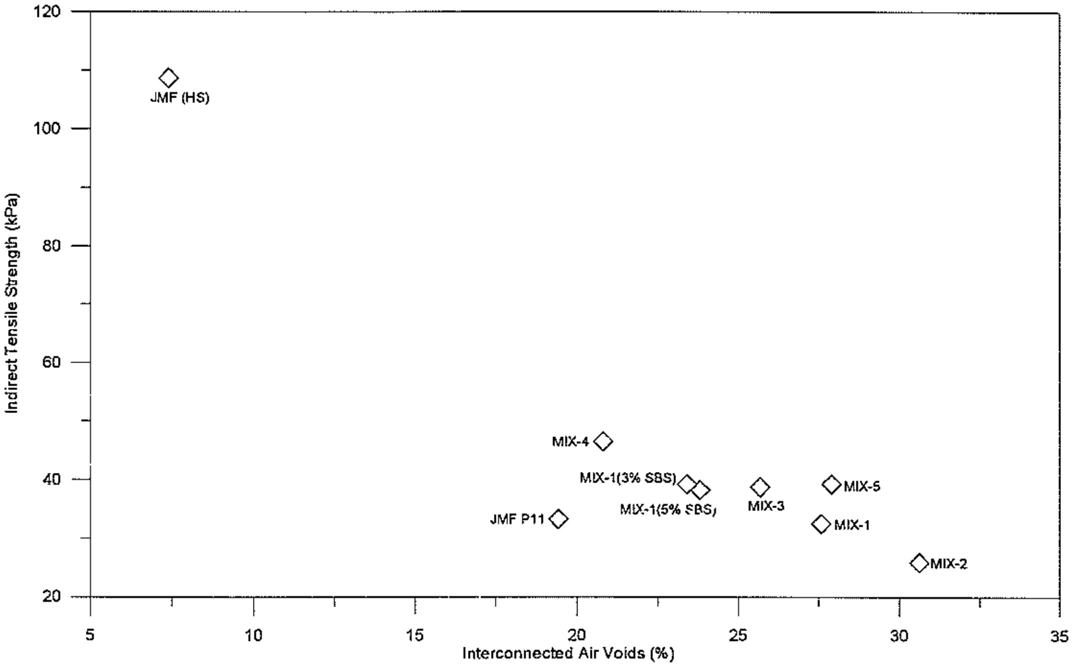


Figure 3.2 Variation of indirect tensile strength with interconnected air voids.



3.2.2 Cantabrian Test for Abrasion Loss

The design of porous asphalt in the laboratory is generally a compromise between porosity and durability. An increase in porosity reduces the resistance to disintegration or fretting, mainly due to inability of the binder to hold the aggregate together from external stresses (tangential and suction) from traffic. The Cantabrian test is gaining acceptance as a method to assess the likely occurrence of fretting because it most closely reflects the deterioration mechanism of the porous asphalt on the road surface (Khalid & Jiminez 1996).

The results of the Cantabrian tests are plotted in Figures 3.3 and 3.4 against the total air voids and interconnected air voids respectively. These results show an approximately linear relationship for the standard 80/100 binder, although there is some degree of scatter. Modifying the binder with the addition of the SBS significantly reduced the Cantabrian loss.

The Cantabrian losses were also plotted against the indirect tensile strengths in Figure 3.5. One of the most interesting features seen in the data here, is that for the binders modified with the addition of SBS, the indirect tensile strength remained similar to straight bitumen, yet Cantabrian losses were much smaller. This may be attributed to different mechanisms involved in Cantabrian and indirect tensile strength tests. In the Cantabrian test, the deterioration is mainly related to the shearing and impact (unrestrained), while in the latter the deterioration is mainly caused by splitting of the tensile bond.

Figure 3.3 Variation of Cantabrian loss with total air voids.

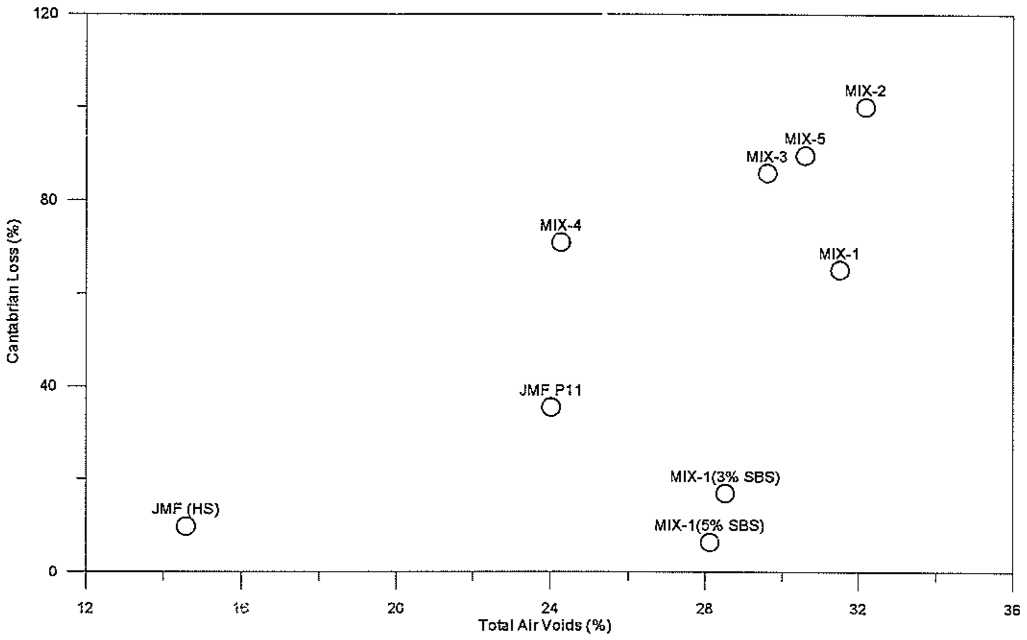


Figure 3.4 Variation of Cantabrian loss with interconnected air voids.

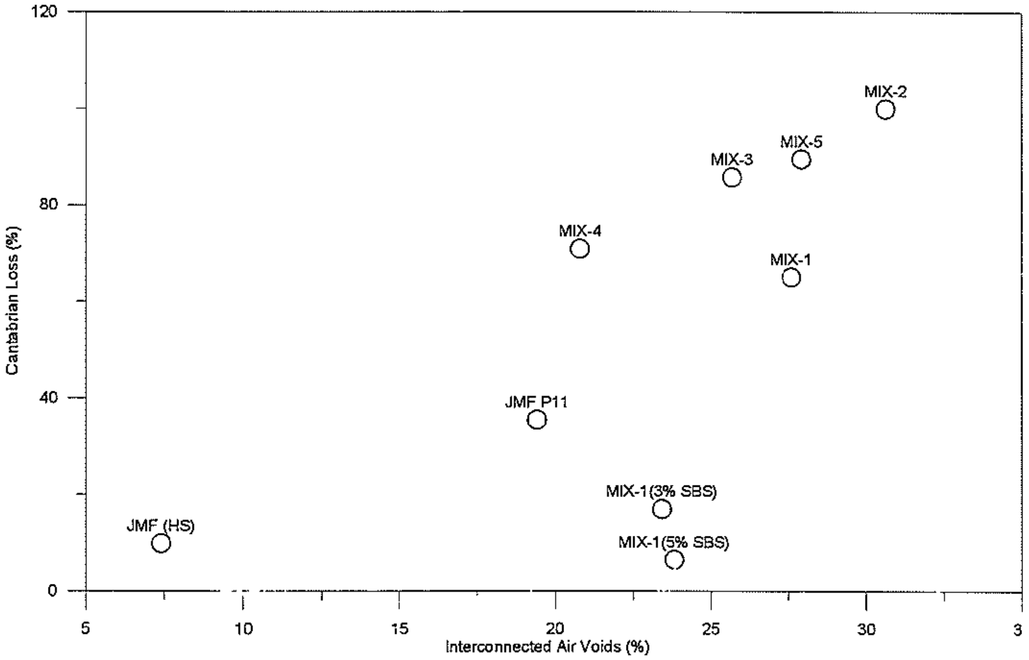
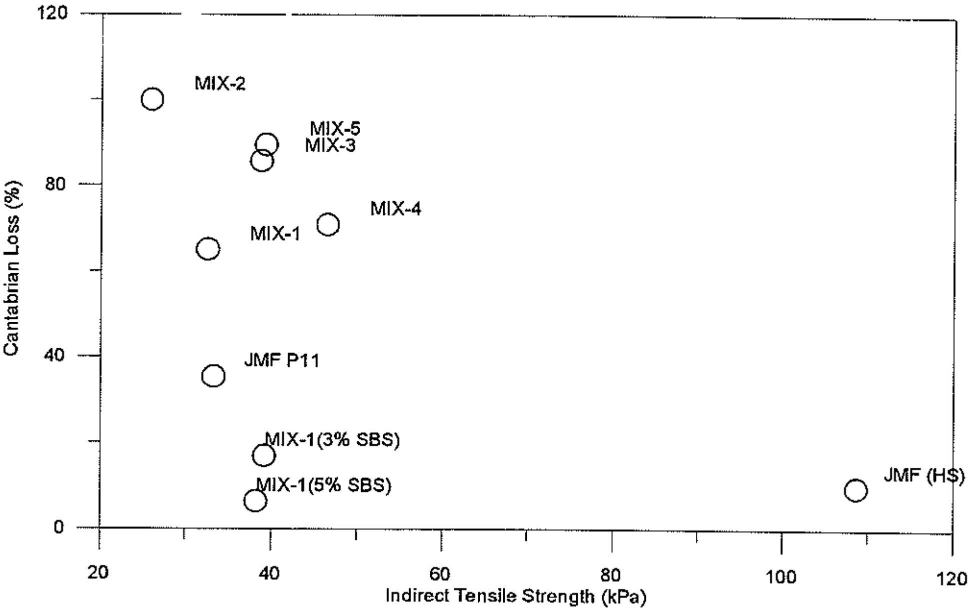


Figure 3.5 **Variation of Cantabrian loss with indirect tensile strength.**



3.2.3 Permeability

Permeability is a measure of drainage properties of the pavement and is directly related to interconnected air voids and to hydraulic gradient. Hydraulic gradient is defined as a head loss per unit length of pavement contributing a flow. The voids, permeability and hydraulic gradients are interrelated by equations depending upon the nature of flow, either laminar or turbulent, as described earlier.

The permeabilities of the Marshall block samples given in Table 3.1 are plotted in Fgures 3.6 and 3.7 against total voids and interconnected voids respectively. Power law curves, as described by equation 3, were fitted to the data. The values of the exponent 'm' ranged from 0.59 to 0.7, with an average of 0.64, clearly showing that the flow is turbulent in nature.

These figures clearly show that the more open porous mixes have permeabilities that are much higher than the standard TNZ P/11 mix (i.e. JMF P11 in this study).

Figure 3.6 Variation of permeability with total air voids.

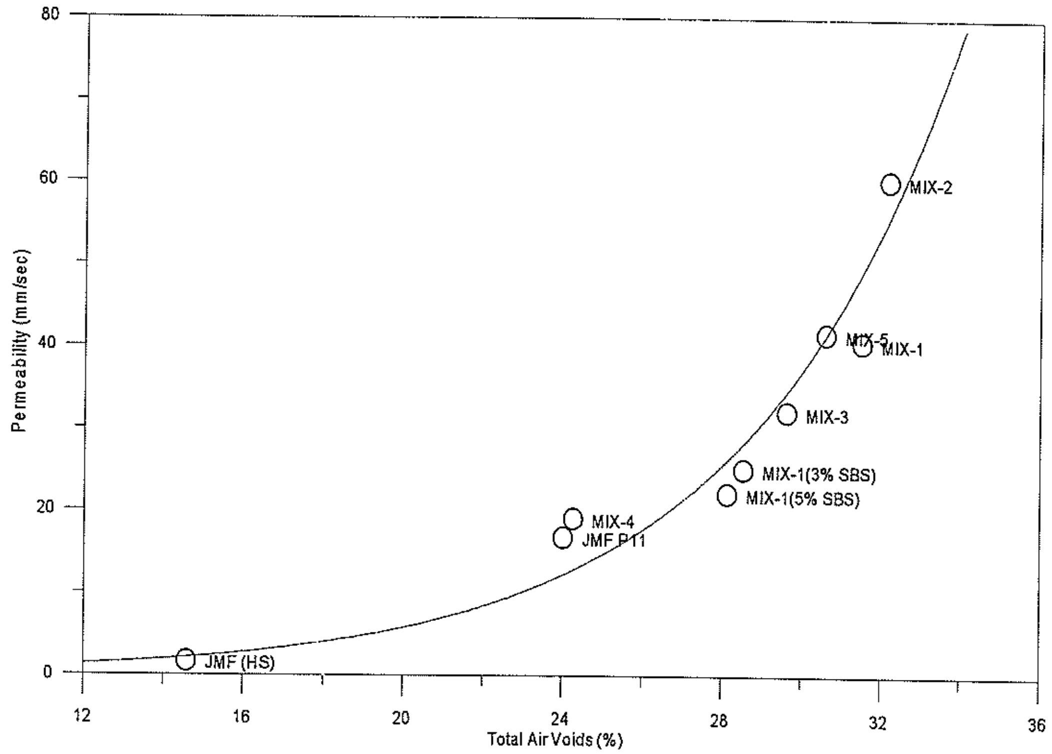
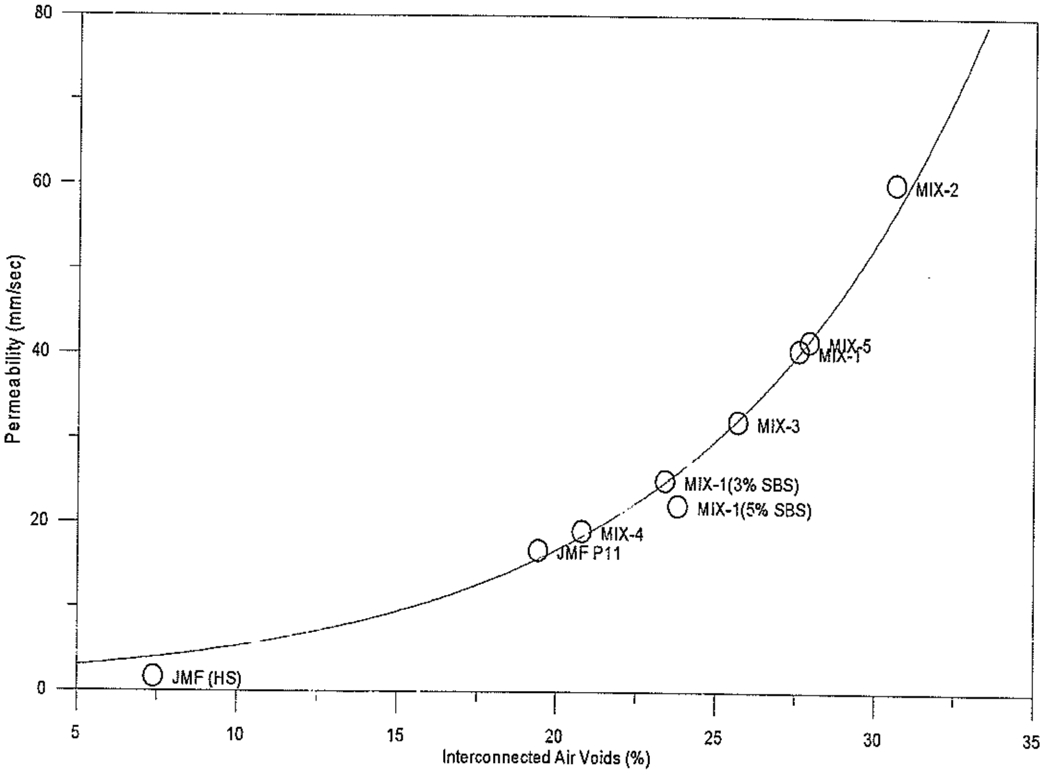


Figure 3.7 Variation of permeability with interconnected air voids.



3.3 Findings & Recommendations

The main findings from the laboratory study were as follows:

1. The drainage capacity of porous asphalt is improved by increasing the voids. This is done effectively by selecting more open or gap-graded material. In doing so, the asphalt mixes tended to loose their strength and fretting resistance significantly.
2. Modified binders did not improve the indirect tensile strength of the mix at 40°C. The reasons for this were not apparent.
3. Cantabrian losses were significantly reduced by using modified binders.
4. The grading of Mix-1 was considered to give the best results in terms of voids and permeability.

Thus the Mix-1 design, using 5% SBS-modified 80/100 bitumen, was recommended for the road field trial. This recommendation was based on the expected failure mechanism in the field being fretting, and on the Cantabrian test results which indicated that the loss of weight from the mix using the 5% SBS binder was less than that obtained with the standard P/11 mix with 80/100 binder.

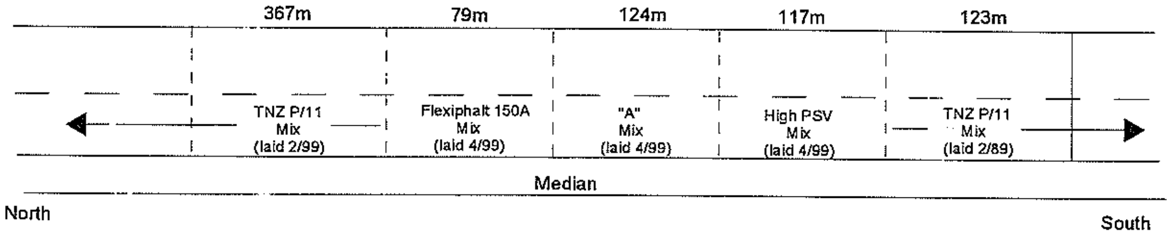
4. Field Trials

4.1 Construction

In February 1999, a section of State Highway 1 (SH1) between approximately RP (Reference Point) 969/4.0 and RP 969/5.08, at Porirua, near Wellington, was resealed using a standard TNZ P/11 mix. Arrangements were made in April 1999 to lay a trial section of the selected mix design, based on the Mix-1 from the laboratory tests, with 5% SBS-modified 80/100 bitumen, and referred to subsequently as Mix "A".

The opportunity was also taken to lay two additional trial sections, one with a proprietary mix TNZ P/11-type mix called Flexiphalt 150A which uses 5% EMA (ethylene methyl acetate), and the other with a standard TNZ P/11 mix using a high PSV (PSV = 62) chip. These were laid immediately to the south of the standard TNZ P/11 mix described above. South of the trial sections is a length of TNZ P/11 mix laid in 1989. Figure 4.1 shows the locations and lengths of the trial sections.

Figure 4.1 Locations and extent of test sections on SH1.



4.2 Laboratory Testing

Samples of the trial mixes were taken for laboratory testing. These tests included:

- binder content,
- aggregate grading,
- total and interconnected voids,
- permeability,
- indirect tensile strength,
- Cantabrian (Cantabro) abrasion.

The results of these tests are included in Table 4.1.

Table 4.1 Summary of test results for field trial samples.

Mix Designation	**Mix "A" (5% SBS)**	**Flexiphalt 150A (5% EMA)**	**TNZ P/11 High PSV**
Aggregate grading:	% finer	% finer	% finer
Sieve Size (mm):			
19.0	100.0	100.0	100.0
13.2	100.0	100.0	99.0
9.5	96.0	95.6	86.6
4.75	11.1	12.8	14.6
2.36	3.0	3.1	14.0
0.08	1.4	0.2	3.0
Binder content (%)	4.2	4.5	4.7
Total air voids (%)	30.8	31.6	22.7
Interconnected air voids (%)	27.7	30.3	18.1
Ratio of air voids*	0.9	~1.0	0.8
Permeability, k (mm/sec)	33.6	65.2	13.2
Cantabrian test loss (%)	23.3	82.6	28.5
Indirect Tensile Test:			
Tensile Strength (kPa)	39.9	48.6	77.1
Vertical Deflection (mm)	1.86	2.84	1.74

* % Interconnected air voids : % total air voids

Table 4.1 shows that in terms of the laboratory tests, the Flexiphalt 150A mix had the highest total air voids, highest interconnected air voids, highest permeability, and the highest vertical deflection to failure. However, it also had the highest Cantabrian abrasion test loss. The selected trial mix (Mix "A") produced better test results than the TNZ P/11 mix with the high PSV chip in all respects, except for tensile strength.

The laboratory testing provides information about the physical properties of the various mixes. However, it does not provide information about the performance of the different mixes with respect to the very important parameters of skid resistance, noise, and permeability. Accordingly, a monitoring programme was instigated immediately after laying of the trial sections, which is described in Section 4.3.

4.3 On-Road Monitoring Programme

The on-road monitoring programme comprised of measurements of skid resistance, noise and permeability. At the same time observations were made of the general condition of the surface.

4.3.1 Skid Resistance Measurements

Measurements of skid resistance were made using the Central Laboratories GripTester, a trailer-based device which takes simultaneous readings of drag and load on a single treadless tyre skidding at around 15% of the survey speed. Tests comprised of measurements at 50 km/h and 100 km/h in the left wheelpath. The data were then separated out into the different trial sections. Surveys were carried out in April 1999, immediately after the trial sections were laid down, again in August 1999, May 2000, April 2001, and June 2001. The results of the GripTester measurements are presented in Figures 4.2 and 4.2 for test speeds of 50 km/h and 100 km/h respectively, as Grip Numbers. These have been plotted against the number of months since being laid, apart from the section to the south, which was laid in 1989. Errors based on an assessment of the repeatability of the GripTester measurements have been included.

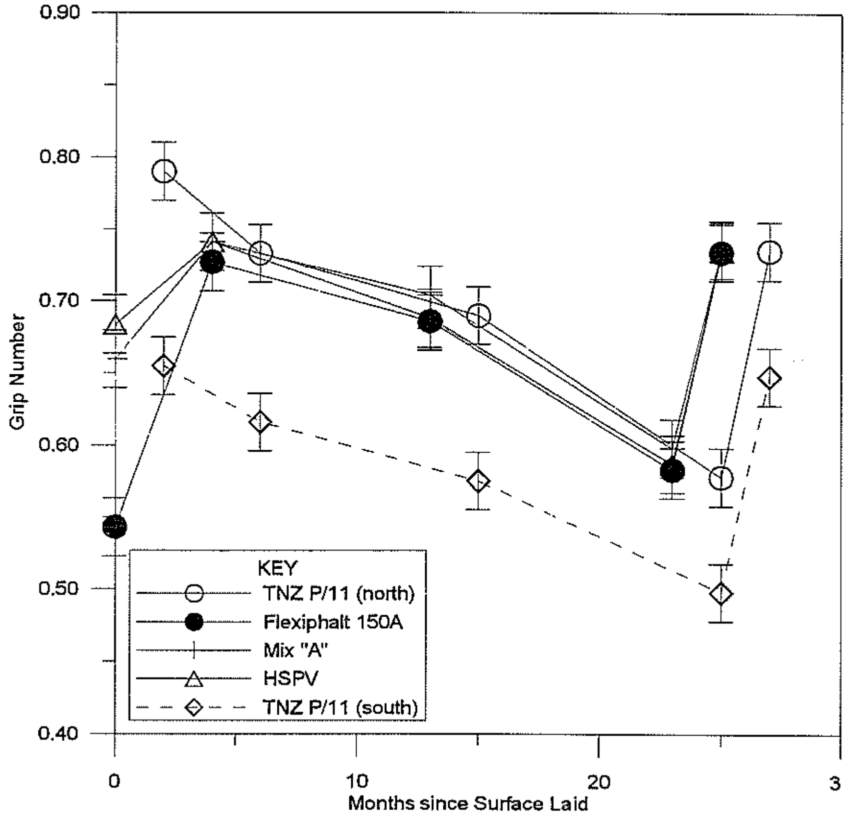


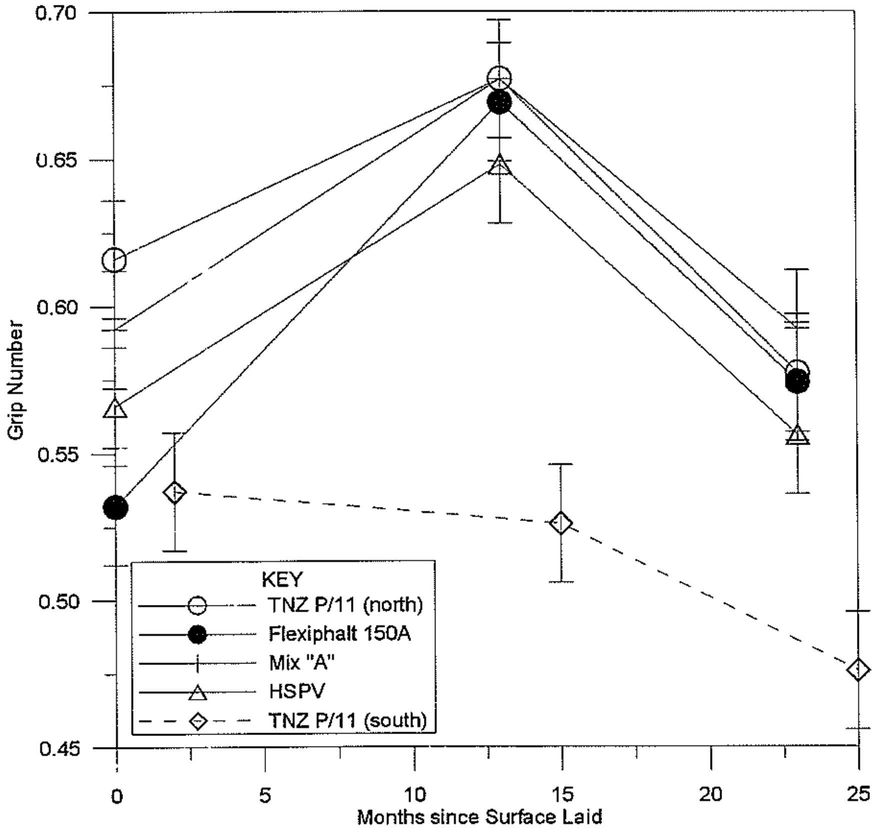
Figure 4.2 **Skid resistance measurements obtained by GripTester at 50 km/h.**

Figure 4.2 shows that, at 50 km/h, the skid resistances measured on the trial surfaces immediately after they were laid were significantly lower for each of the trial sections than the values achieved approximately four months later. Another interesting feature is the high skid resistance measured on the standard TNZ P/11 mix after two months. However, this decreases to fall into line with the other surfaces.

From four months and on, skid resistance on all of the surfaces reduces consistently, being the same within measurement error until the last set of measurements. Here the skid resistance on all of the surfaces is much higher than for the series of measurements made approximately two months earlier, and is in most cases similar to the highest values measured soon after the surfaces were laid. The reason for this is attributed to the cleaning action of a significant amount of rain that fell during this two-month period. These results tend to suggest that little significant change occurred in skid resistance subsequent to the initial six-month period.

Skid resistance on all of the surfaces is higher than on the TNZ P/11 mix located to the south of the trial site. However, it should noted that, when monitoring was started in 1999, this surface was already approximately ten years old.

Figure 4.3 Skid resistance measurements obtained by GripTester at 100 km/h.



At 100 km/h the trends are generally very similar, although monitoring at this speed was not carried out at four months after laying the trial. The trends in both figures tend to suggest that the skid resistance reaches its highest value after several months, and then reduces only gradually. However, further monitoring would be needed to confirm this.

4.3.2 Noise Measurements

The noise measurements made over the course of this project involved recording of "drive-by" noise levels using two sound-level meters. These sound-level meters were positioned at specified distances away from the road, next to two of the adjacent trial sections, e.g. TNZ P/11 (north) and the Flexiphalt 150A. A Daewoo Nubira EuroWagon, fitted with Kuhmo 185/65 R14 86H tyres, was then driven over the test sections at a constant speed of 100 km/h, at times when no other traffic was in the immediate vicinity. Recordings of the noise levels were made using a PC-based data acquisition system as the vehicle passed by. Multiple test runs were performed. All tests were carried out on days with little or no wind, and the same vehicle was used for all of the tests.

The data was analysed to provide "overall" noise levels for each of the surfaces. Third octave band analyses were also performed to identify changes in the frequency content of the noise where significant differences in noise levels were identified. Unfortunately only two of the four surfaces were monitored in 1999. Figure 4.4 shows the results of the noise measurements. Error bars based on an assessment of the repeatability of the measurements have also been included.

Figure 4.4 **Overall noise levels at 100 km/h.**

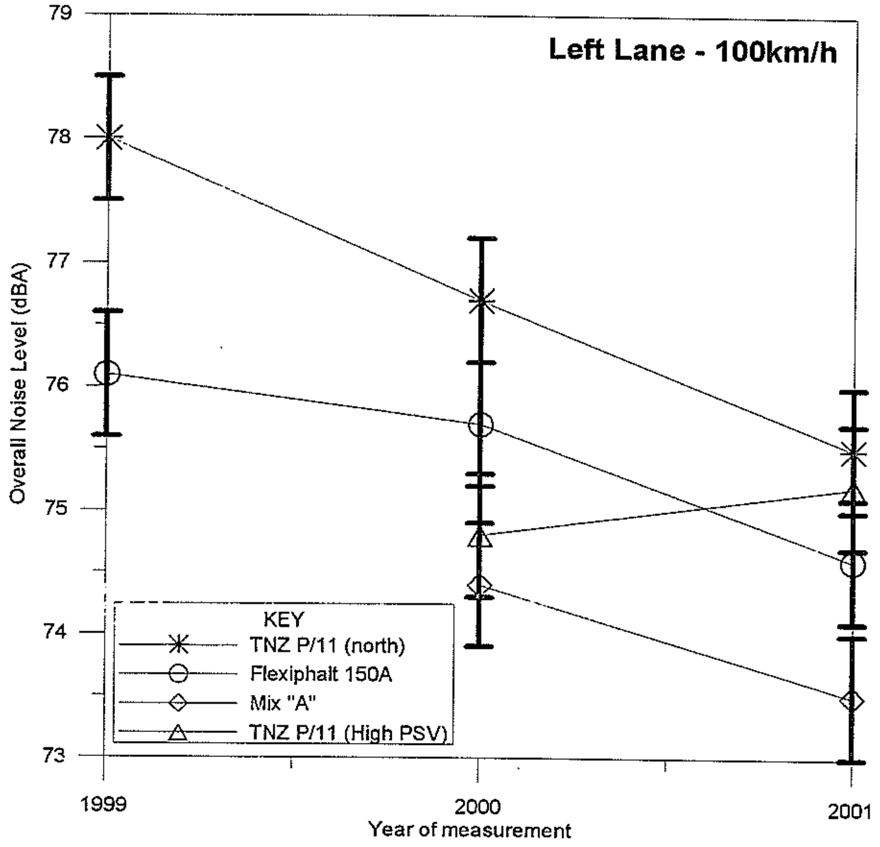


Figure 4.4 suggests that the noise levels on most of the surfaces, except for the TNZ P/11 high-PSV mix, have tended to decrease with time. The noise levels on this surface have remained approximately constant with time when measurement errors are allowed for.

The standard TNZ P/11 mix is consistently the noisiest, followed by the Flexiphalt 150A mix, with the Mix "A" mix being the quietest. The reason for the lowering of the noise levels with time is possibly related to a reduction in texture with time caused by traffic. The maximum range of overall noise levels over all of the surfaces, in any year, is less than the 3dBA generally accepted as the difference where people will discern a difference in noise level. However, even though noise levels can be similar, the frequency or tonal content can change, and this can be noticeable.

Figures 4.5 and 4.6 provide examples of the frequencies over which the changes in the noise levels occur. Figure 4.5 shows a comparison of the third octave band analyses for the TNZ P/11 mix over the three monitoring sessions. Figure 4.6 shows a comparison of the third octave band analyses for the TNZ P11 mix and Mix "A" for the 2001 monitoring session.

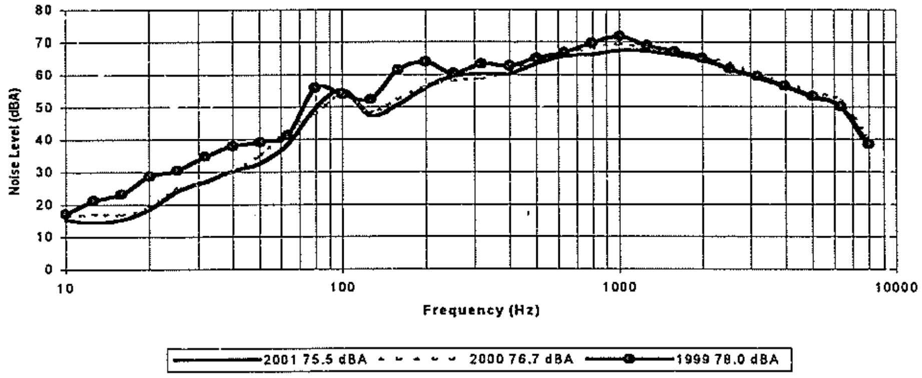


Figure 4.5 Third octave band analysis for TNZ P/11 (north) mix for the 3 monitoring times from 1999 to 2001.

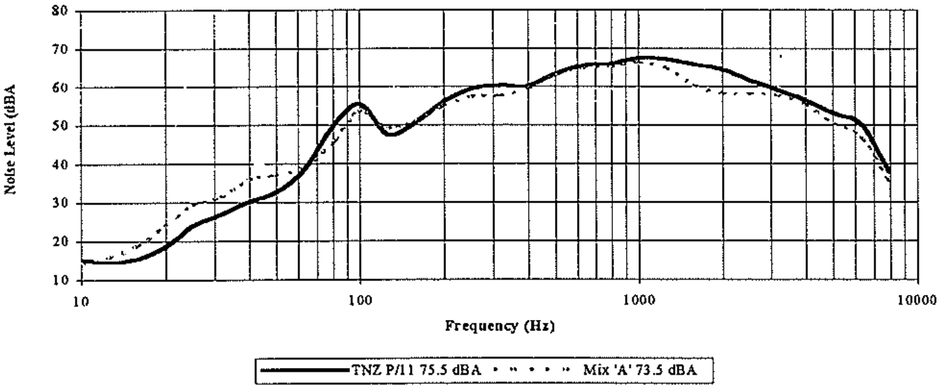


Figure 4.6 Third octave band analysis for TNZ P/11 (north) mix and Mix "A" (for 2001).

Figure 4.5 shows that on one particular surface the most significant changes with time occurred during the first year after the surface was laid down, and that these changes occurred for frequencies below 1000Hz. Comparing the standard TNZ P/11 mix and the Mix "A" data for 2001, the differences are more subtle, with Mix "A" producing slightly higher noise levels below about 60Hz, but lower levels at most frequencies above this, particularly between 1000 and 3000Hz.

4.3.3 Permeability Measurements

Measurements of the relative permeabilities of the different surfaces were carried out using a very simple process. A cylindrical ring, approximately 155 mm in diameter is placed onto the road surface, with a rubber sealing ring sandwiched between. The weight required to provide an effective seal is provided by someone standing on supporting flanges located on either side of the cylinder. Then 150 ml of water is poured into the ring, and the time taken for the water to drain is measured with a stopwatch.

On each of the four road sections, measurements were taken in each wheelpath, and between the wheelpaths, at selected locations spanning the length of each section. An average drainage time for each section for each of the yearly monitoring periods was calculated. The results of the measurements are plotted in Figure 4.7.

The plot in Figure 4.7 shows that the permeabilities of all of the surfaces decreased, i.e. the drainage times increased, over the first year, with this change slowing down by the end of the second year. The standard TNZ P/11 mix had by far the lowest permeability, with drainage times on averages 5-10 times longer than any of the other surfaces. The standard TNZ P/11 mix using high PSV chip performed better, but not as well as Mix "A" and Flexiphalt 150A mix, which gave very similar performances. Also shown on Figure 4.7 are bands of permeability performance (at 140s and 600s) taken from work performed on the 1980s on the Auckland Motorway (Somerville 1986).

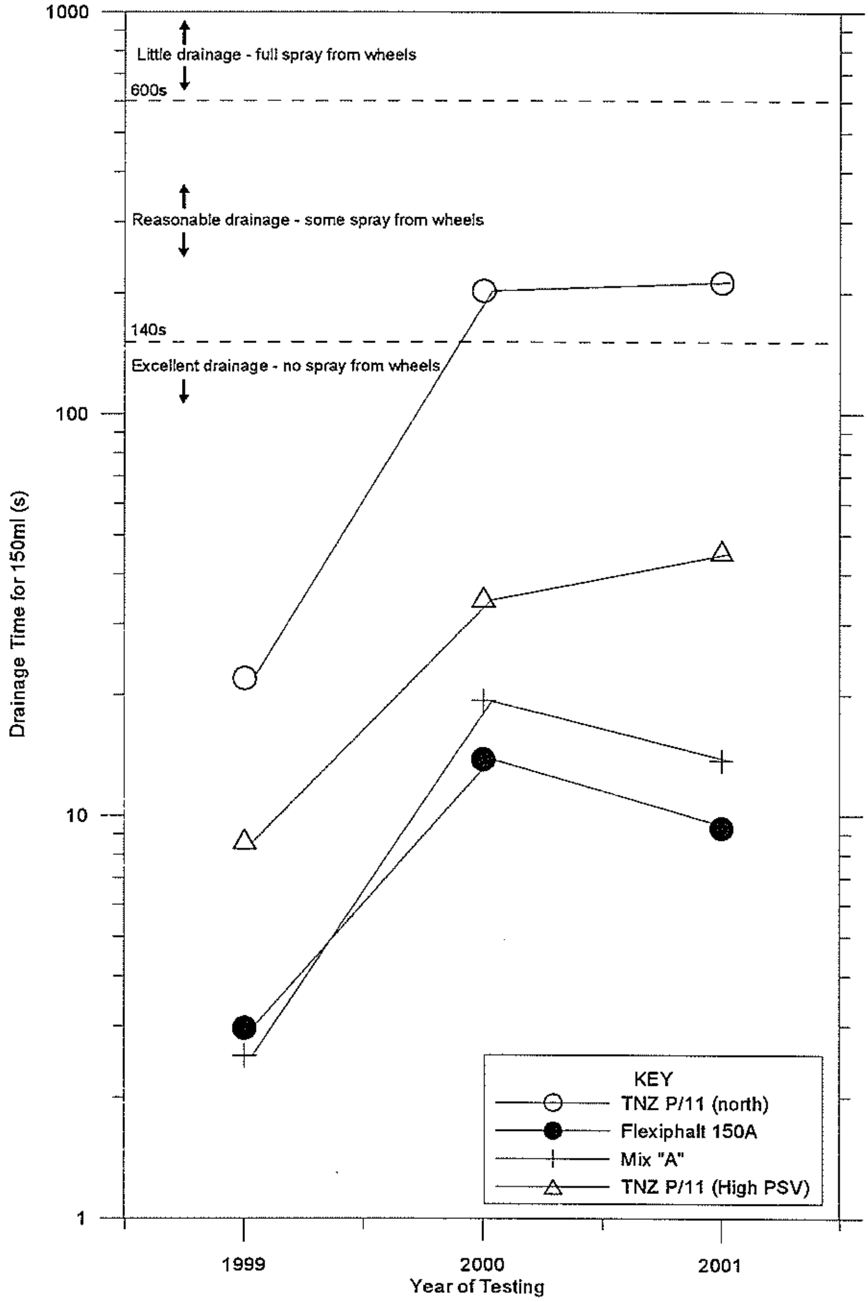
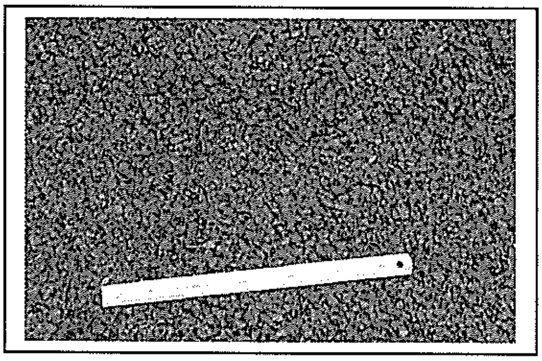


Figure 4.7 Permeability measurements for the test sections (from 1999 to 2001).

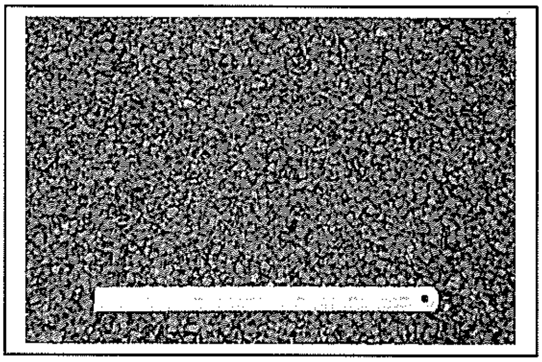
4.3.4 Road Surface Condition

Photographs showing the current state of each of the four surfaces, as well as the older TNZ P/11 mix to the south, are presented below in Figure 4.8. These show that, as expected, all the surfaces laid in 1999 are in much better condition than the older surface to the south. They also show that the surfaces of the three trial sections appear to be in better condition than the standard TNZ P/11 mix immediately to the north.

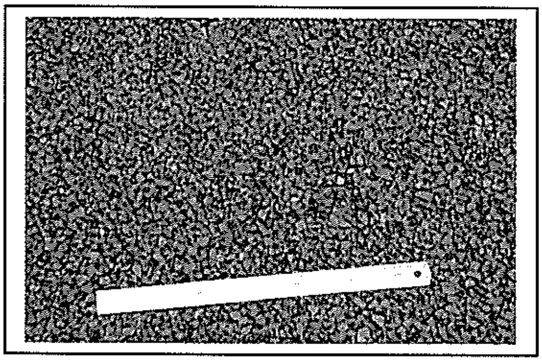
Figure 4.8 Photographs of the road surfaces of the four trial sections, and the adjacent older TNZ P/11 surface, as they appeared in 2001.



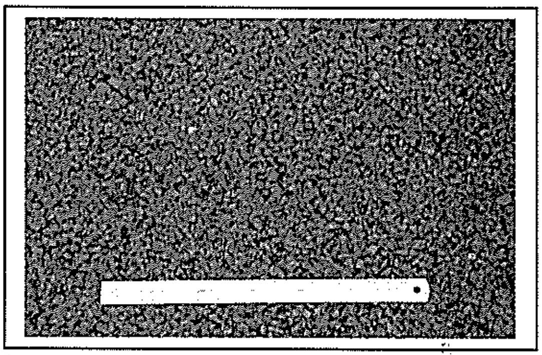
TNZ P/11 – north



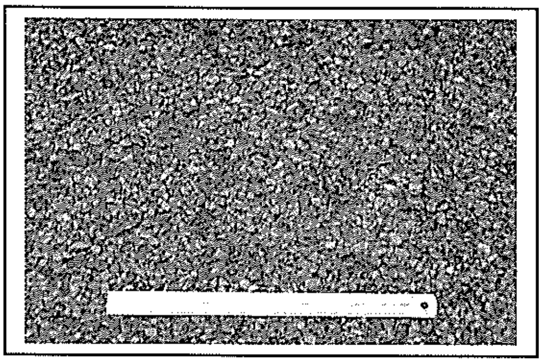
Mix “A”



Flexiphalt 150A



TNZ P/11 – high PSV



TNZ P/11 - south

5. Conclusions

This research project involved the development and field trialling of a mix design for porous asphalt that is more open than the current (1996) TNZ P/11 specification. The main conclusions of this study are:

- the more porous alternative mix that was developed utilising two different polymer-modified binders, and trialled, has stood up well to two years of heavy traffic,
- the skid resistance of these mixes has been at least as good over the trial period as the standard TNZ P/11 mix,
- their noise levels have been consistently lower than the standard TNZ P/11 mix, and
- their permeabilities have been much better than the standard TNZ P/11 mix.

6. Recommendations

Although the porous asphalt mix developed and trialled as part of this project appears to be performing well after just over two years of heavy traffic, there are still questions regarding its durability and performance over the longer term. Consequently, recommendations are that:

- monitoring of the skid resistance, permeability and noise is continued on a yearly basis until the surface fails, or until the performance/condition of the trial mix falls below that of the standard TNZ P/11 mix;
- the interconnected air voids content is considered as an alternative to the total air voids in the TNZ P/11 specification;
- the Cantabrian test is introduced into the TNZ P/11 specification.

7. References

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