Trials of recycled asphalt and rubber materials in hot mix asphalt for New Zealand roads

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Contents

Executive summary

Introduction

This research, carried out in 2003-2004, aimed to facilitate the recycling of asphalt mix, recycled asphalt pavement (RAP), and crumb rubber (CR) from waste tyres into New Zealand roads. The objectives were to allow for the revision of the appropriate specifications to encourage recycling of these materials and to use field trials to prove the performance of recycled and crumb rubber modified mixes in practice.

The recycling of old asphalt is commonplace overseas but has not been attempted in any serious way in New Zealand. Asphalt millings containing large quantities of valuable (and finite) aggregate resources are instead used as clean fill. Recycling of used asphalt not only contributes to the long-term environmental sustainability of the roading network but also is becoming increasingly necessary as supplies of good quality aggregate are exhausted, particularly in the Auckland area.

In New Zealand about 2.5 million waste tyres are generated annually and most of these are disposed of in landfills. A 1993 Transit New Zealand Research review on the use of ground tyre rubber (GTR) in road construction concluded that the most promising use was in hot mix asphalt. Addition of GTR with the aggregate would require lower capital expense for plant modification than for the addition of the GTR to the bitumen. Although there would be an increase in cost, the enhanced flexibility of the mix would provide superior fatigue performance and therefore could make the material cost-effective on higher deflection pavements. If only 10% of current asphalt mix production contained GTR (at 3%) this would consume about 20% of the waste tyres produced annually. GTR has been used routinely in hot mix asphalt overseas for over 30 years but has not been used in New Zealand.

Method/results

The report gives the laboratory and field test results that have been used to revise the Transit New Zealand M/10 Asphaltic Concrete Specification to allow the use of 15% of recycled asphalt (RAP). Tests included Marshall Stability and Flow as well as Resilient Modulus tests with up to 40% of RAP.

Test results from the road trials of the material, laid in 2003 in Manukau City, are also given.

Results are also given of the properties of mixes incorporating ground tyre rubber (GTR). Results from road trials using 3% recycled rubber laid in Manukau City in 2004 are given. These results have been used to give examples of where the benefits of increased flexibility (fatigue resistance) could make this a cost-effective treatment.

Conclusions

- Field trials to demonstrate the practicality of adding RAP and GTR to asphalt have been performed.

- The results from the RAP trials have already been used by Transit New Zealand to modify their M/10 specification for asphaltic concrete to allow 15% of RAP in any mix without a specific design.
- Although the 25% RAP asphalt was found to have a higher viscosity binder, the pavement is still performing well.

Ground tyre rubber (GTR) has been less successfully added to asphalt and laid in Manukau City. It was expected that the addition of 3% of GTR would increase the fatigue resistance so that the material would be able to be laid on higher deflection pavements than traditional mixes. The initial crumb rubber asphalt mix laid appears to be performing well, but the subsequent mix laid failed within months of it being laid. It is unclear what the cause of this failure was, but mix variability has contributed. The fatigue test results on samples have confirmed the expected increases in fatigue life that would be obtained from the use of GTR.

Recommendations

- In contrast to the RAP trial where mix characteristics were very similar to traditional mixes, the GTR mix will require modifications to mixing and laying techniques to ensure that the desired properties are obtained. These modifications are expected to be learnt through more experience in handling this type of mix.
- The recommendation is that guidelines be developed for the manufacture and laying of GTR mixes to minimise the chance of early failure.

Abstract

This report gives the results of a Land Transport New Zealand (formerly Transfund New Zealand) funded Research Project carried out in 2003-2004 with the objective of facilitating the recycling of asphalt mix and ground tyre rubber (GTR) from waste tyres in New Zealand roads.

The report gives the laboratory and field test results that have been used to revise the Transit New Zealand M/10 Asphaltic Concrete Specification to allow the use of 15% of recycled asphalt (RAP). Tests included Marshall Stability and Flow as well as Resilient Modulus tests with up to 40% of RAP.

Test results from the road trials of the material, laid in 2003 in Manukau City, are also given.

Results are also given of the properties of mixes incorporating ground tyre rubber (GTR). Results from road trials using 3% recycled rubber laid in Manukau City in 2004 are given. These results have been used to give examples of where the benefits of increased flexibility (fatigue resistance) could make this a cost-effective treatment.

1. Introduction

Opus Central Laboratories was awarded funding by Transfund New Zealand (now part of Land Transport New Zealand) to carry out a research project to investigate the use of recycled materials into roads in New Zealand beginning in July 2002. This research was designed to facilitate the use of recycled asphalt pavement (RAP) and ground tyre rubber (GTR) from waste tyres in New Zealand roads. The project was expected to enable a revision of the appropriate specifications to encourage recycling and it used field trials to demonstrate in practice the performance of recycled and crumb rubber-modified mixes.

An industry-working group convened as part of the Transfund research project, *Recycling of materials for more sustainable road construction*, identified the main reasons for the failure of the roading industry to adopt these technologies. They were:

- a lack of clear direction in Transit New Zealand specifications,
- a lack of experience and confidence in the use and performance of the technologies in a New Zealand context.

Internationally the use of RAP and GTR were recognised to be well established techniques. The aim of this project was therefore to demonstrate that techniques could be used in New Zealand without major modifications to current practices.

Both techniques require a hot mix plant that has the capability to add the RAP or GTR outside the area of the flame used to heat the aggregate. New Zealand hot mix plants have had the capacity to add materials outside the area of the flame, where they are not damaged by the very high temperatures, only in the last few years and this has been one of the major reasons that the materials have not been trialled and accepted earlier. Even now a limited number of plants have the capability.

The research involved a laboratory investigation to establish limits and performance parameters for asphalt incorporating different levels of asphalt millings or crumbed rubber. This data will be used by Transit New Zealand to revise the M/10 asphalt specification (TNZ 1975) to allow (and provide suitable guidelines) for the use of recycled materials and crumb rubber. Incorporation into the specification will help to 'legitimise' the technologies and encourage their use. In addition the full scale field demonstration sites that were constructed and monitored provide validation of the laboratory work and prove the technologies in practice.

2. Background

2.1 Recycled asphalt pavement

Although asphalt has been recycled since the 1930s, recent improvements to materials technology, construction equipment, and techniques, together with an increased awareness of environmental responsibilities, have resulted in a growing interest in asphalt recycling. Today about 5% of the 250 million tonnes of asphalt produced annually in the USA is recycled. In Europe, significant amounts of asphalt are recycled, both by incorporation into plant mix and by recycling in-situ.

In Australia (where about 6.5 million tonnes of asphalt are produced annually), the use of recycled asphalt pavement (RAP) at hot mix plants has been a common practice for many years and, in 1990, about 5% of the total hot mix asphalt (HMA) production contained some RAP. Since that time, its use has increased to an estimated 10%. The proportion of RAP used has generally been less than 20% of the mix.

RAP is the milling or waste HMA obtained in the repair and replacement of existing pavements. The age of the material could range from days to many years. The material is stockpiled, mixed and crushed to obtain a consistent material normally of maximum particle size of 10 mm.

The *Asphalt Recycling Guide* (Austroads 1997) divides the use of RAP in HMA into two broad categories:

- mixes containing less than 20% RAP,
- mixes containing more than 20% RAP.

The basis for the distinction is that generally mixes with less than 20% RAP can have the RAP incorporated cold from a stockpile, without any special mixing provisions, except superheating of the aggregate to ensure adequate mix temperatures. These mixes are also frequently used without the addition of rejuvenating agents (Austroads 1997).

Generally for hot plant recycling, up to 20% RAP can be used without major changes in mix design (Austroads 1997).

For mixes containing more than 20% RAP, the *Asphalt Recycling Guide* (Austroads 1997) notes that, during full scale plant production, the RAP must be preheated before mixing with the new materials to ensure adequate uniformity of the final mix results, and to incorporate a rejuvenating agent. The rejuvenator could be a softer grade of bitumen than that normally used, or it could be rejuvenating oil.

When dealing with mixes containing high proportions of RAP, difficulties have been identified. These involve the need to know the design binder content in order to choose the rejuvenator grade. However, knowledge of the rejuvenator grade is necessary to determine the design binder content. The matter is complicated by the likelihood that the precision of measurement of the binder content and viscosity of the RAP binder is poor since only a very small sample of the potentially quite variable stockpile is tested. In addition, the method used to predict the viscosity of the binder in the recycled mix is likely to be quite imprecise. However, high precision may not be necessary in the determination of these values (although the binder content of the RAP needs to be fairly accurately known) since binder viscosity (provided it is within reasonable limits) is unlikely to have a major effect on the performance of recycled mixes.

In normal operation of a plant, the stack temperature must be adjusted to give the correct mix temperature (140-160°C). In practical terms, mix temperatures should exceed 150°C to ensure good mixing and a workable mix in the field. This stack temperature would be at about 220°C for 30% RAP and up to 260°C for 50%. There should be no difference between the laydown of recycled hot mix and the laydown of conventional hot mix. Conventional asphalt placing equipment and techniques are used with some variations in compaction procedures.

The determination of the long-term durability of binders has been a source of controversy in Australia for some time. As the application of existing laboratory tests has not been established, field information on the long-term durability of the recycled mixes is particularly important because, in the laboratory, the recovery of binder and subsequent blending with new bitumen does not simulate the field situation. Pavements using recycled asphalt have been visually monitored since the introduction of recycling in South Australia and their performance has been as good as that of new mixes.

The recycled mixes can exhibit lower permanent deformation than conventional mixtures. Januszke & Holleran (1992) found that the addition of 30% reclaimed material in the mix improved the resistance of the compacted specimens to permanent deformation.

Recycled asphalt-concrete mixes exhibited higher tensile failure stress, lower tensile failure strain, and higher stiffness than conventional mixes. This indicates less resistance to low temperature cracking.

Anderson et al. (1989) reported that performance to date of recycled asphalt-concrete pavements compared to virgin asphalt-concrete pavements in Alberta, Canada is similar, and hence the use of RAP is considered to be a viable option for rehabilitation of their asphalt pavements.

Detailed evaluation of recycled mixes in laboratory repeated load and indirect tensile testing shows that they are more resistant to permanent deformation, but are less resistant to low temperature cracking than comparable virgin mixes. For Alberta conditions, acceptable low temperature properties may be obtained by ensuring that the reclaimed material content does not exceed 50%.

Kandhal et al. (1995) have reported on five projects, each consisting of a recycled section and a control section, subjected to detailed evaluation. Ten additional virgin mix pavements and 13 additional recycled pavements were also evaluated as two independent groups. No statistically significant differences were found between the recovered asphalt properties (penetration and viscosity) of these virgin and recycled pavements in service.

Both virgin and recycled sections of the five projects are performing satisfactorily after 1.5 to 2.25 years in service with no significant rutting, ravelling and weathering, or fatigue cracking. No significant overall difference in the performance of virgin and recycled pavements was noted based on visual inspection.

A need exists to monitor closely the performance of recycled pavements and materials to gain objective whole-of-life cost and performance data at the earliest opportunity. The potentially large economic gains from these processes should justify the use of accelerated pavement loading to validate many of these processes.

2.2 Recycled rubber

Patrick & Logan (1996) reviewed the potential of rubber recycled from tyres for use in New Zealand pavements and discussed the two processes that can be used to incorporate rubber crumb into asphalt mixes. These are:

- wet process - where GTR is blended with hot bitumen in a tank and then added to the mix as a normal binder,
- dry process - where GTR is added as part of the aggregate fraction during hot mixing.

As the wet process requires special tanks and stirring facilities, they concluded that the simplest method for use in New Zealand was the dry process where appropriate plant was available.

New Zealand predominantly uses drum mixes where the aggregate is passed through a flame to dry and heat and then the binder is added further through the drum. In order that the GTR is not overheated in the mixing process, it has to be added outside the area of the flame and cannot be added directly to the cold aggregate feeds. The use of a recycling ring as used for the use of RAP is an appropriate method to add GTR.

The dry process mixes the crumb rubber with aggregate before incorporating the binder and about 3-5% by mass of coarse rubber particles is used.

Whether the asphalt containing a waste material can be effectively recycled in the future without any problems is not known in many instances. For example, asphalt containing significant amounts of ground tyre rubber has not been recycled as yet. Such recycling may pose air pollution problems.

3. Recycled Asphalt Pavement

3.1 Laboratory trial

3.1.1 Design of mixes

Job mix formulas were designed to be as close as possible to Blacktop Construction's standard mix 14 material, using their normal aggregate and recycled asphalt from their yard. The following tasks were performed:

- The RAP was tested to determine its binder content and aggregate grading.
- These values were used to derive an aggregate grading with the addition of new aggregate that closely matched the Blacktop standard mix.
- The binder content of the RAP was used to determine the extra binder that needed to be added to the blend to obtain the desired total binder content.

Several job mix formulas were designed, including a control and a range of percentages of recycled asphalt. Marshall mix design tests in accordance with the Transit New Zealand Specification TNZ M/10 properties were performed on each blend to determine the binder content of each mix design to give an air void content of 3.5%. Once the optimum binder content was determined, blocks were made using gyratory compaction (Servopac) in accordance with Australian Standard AS 2891 (Standards Australia 1995). The number of cycles of the Servopac was varied to obtain samples with approximately 3.5% air voids. These blocks were tested for indirect tensile resilient modulus in accordance with Australian Standard AS 2891.13.1 1995 by the Nelson laboratory of Fulton Hogan Ltd.

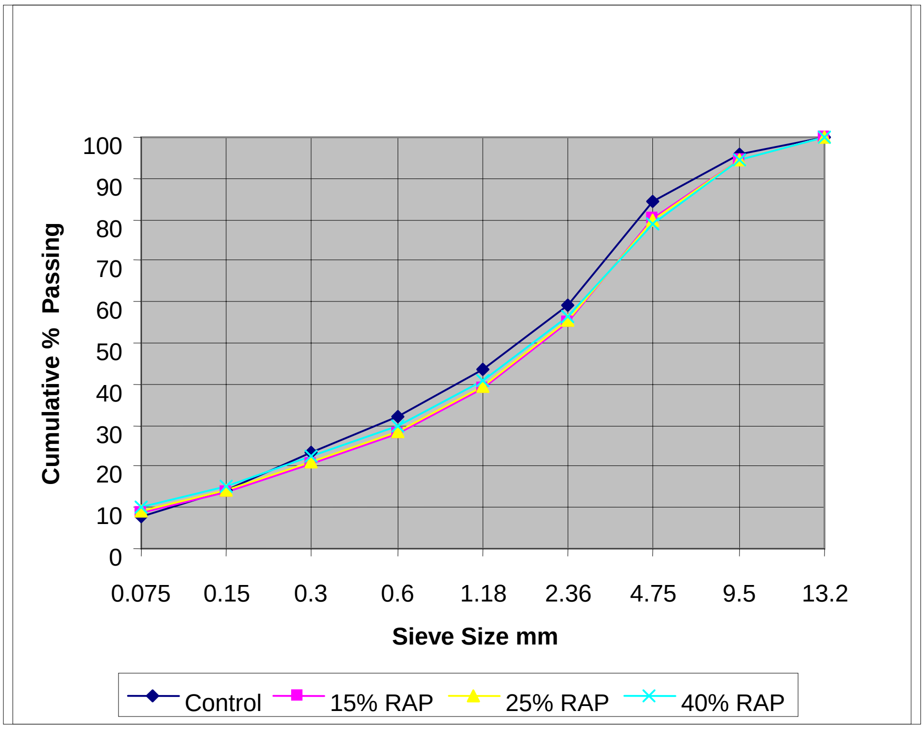

Figure 3.1 Aggregate grading by volume for RAP mixes.

3.1.2 Modulus testing of mixes

The indirect tensile modulus test is a method of testing the total mix and consists of applying a dynamic load to a sample and measuring the strain that is generated. The rate of loading in the standard test is similar to a vehicle travelling at about 20 km/h. The modulus gives an indication of the load-spreading ability of a material so that the higher the modulus the stiffer the material and the more it can spread the load. The test method is detailed in the Australian Standard AS 2891.13.1 1995. The test was performed at 25°C with a loading time of 0.1 sec.

Modulus is affected by binder hardness, binder content, air voids, temperature and loading time. As sample preparation technique can also affect the results, a gyratory compactor is required. In the tests performed in this study the binder content was 6%, air voids approximately 3.5%and therefore the main variable on the modulus value would be expected to be the binder hardness. Table 3.1 gives the results.

Table 3.1 Laboratory trials of a range of mixes.

Mix	Compaction Method	Binder Content %	Air Voids %	Stability kN	Flow mm	Modulus MPa
Control 0% RAP	Marshall	6.0	2.9	12.0	2.9	
	Servopac	6.0	3.8			1050
10% RAP	Marshall	6.0	3.6	14.5	3.4	
	Servo	6.0	3.6			1920
15% RAP	Marshall	6.0	3.9	16.6	3.0	
	Servo	6.0	3.2			2780
25% RAP	Marshall	6.0	3.9	13.3	3.9	
	Servo	6.0	3.3			3440
40% RAP 80/100	Marshall	6.0	3.6	12.8	4.1	
	Servo	6.0	2.8			2474
40% RAP 180/200	Servo	6.0	2.6			1384

Figure 3.2 shows the change of modulus as a function of RAP content together with the results from the field trial.

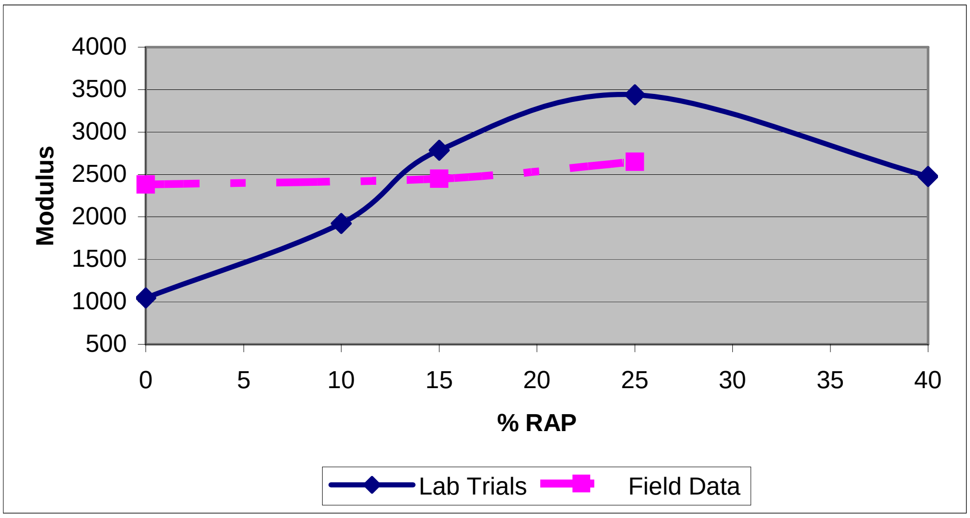

Figure 3.2 Resilient modulus results.

Figure 3.2 shows that the modulus increases as the percentage of RAP increases except for the 40% mix. We have no explanation for the drop in modulus.

A recent Transfund research project (Pidwerbesky 2002) tested 9 typical New Zealand mixes all using 80/100 bitumen and found modulus values ranging from 1375 MPa to 2540 MPa. This is a similar range to the 0 to 15% RAP values given in Table 3.1.

The conclusion is that the 15% RAP material, although having a higher modulus, is within the normal range of mixes used in New Zealand. This tends to confirm the current Australian practice of allowing 15% RAP mix to be used without special testing.

The intention of the trial was, if possible, to use a mix with a higher percentage of RAP and therefore factors that affect modulus were explored in greater detail.

In the Austroads Pavement Design Guide (Austroads 1992) a method to calculate modulus is given based on the material properties and proportions (Shell method). Although this method would not be expected to give exactly the same results as testing, it does allow the effect of varying properties to be assessed.

The method was used to back-calculate the expected softening point of the binder in the mix. The results are illustrated in Figure 3.3.

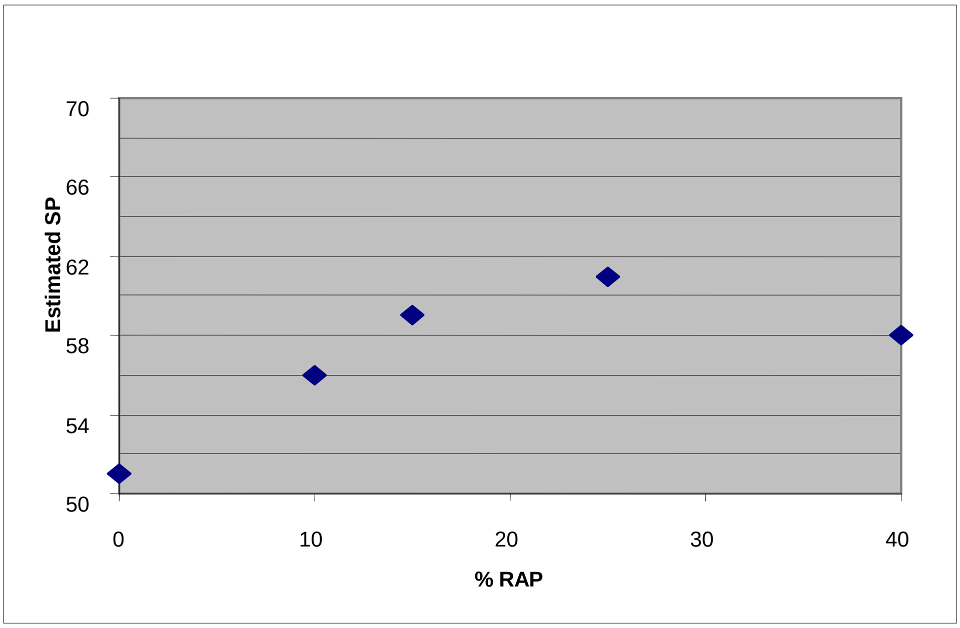

Figure 3.3 Estimated softening point (SP) of mixes.

Although the absolute values may not be exact the calculations do give an idea of the change in binder hardness that would account for the modulus change given in Table 3. The drop with the 40% blend cannot be explained.

The softening points would not be expected to be the same as a straight bitumen as hardening does occur in the mixing and transporting process (this is modelled in the laboratory by leaving the mix in an oven for one hour at 150ºC before compaction of the blocks).

The typical softening point of New Zealand bitumen in hot mix would be 55°C for 80/100 and 60°C for 60/70. It can be seen that the softening point of the 25% RAP is similar to that expected from a 60/70 bitumen.

3.2 Production trial

Trial sites were selected by Blacktop Construction with approval from Manukau City Council. The sites are suburban streets - Shirley Road (15% RAP), and Coronation Road (Control and 25% RAP). The trial sites were overlays on existing pavements. The concern on these sites was that failure could occur by shoving or rutting of the mix, not by fatigue cracking. The higher modulus obtained with the RAP would be expected to increase the resistance to a shoving type of failure. Therefore it was decided that the trial sites use both 15% and 25% RAP together with a control.

The recycled asphalt mix was made in a continuous drum asphalt plant with a recycling ring that feeds the RAP into the middle of the drum. The asphalt was constructed and laid using standard techniques and standard temperatures. The 15% RAP site on Shirley Road was laid on 19 June 2003, and the control and the 25% RAP site on Coronation Road were laid on 21 June 2003. Density measurements were taken using a thin lift Troxler Nuclear densometer on the 15% RAP site on the day of construction. Further monitoring was carried out one year after the trial sites had been down. Density measurements of the 15% RAP were done on the same sites, and cores were taken from each of the trial sites and tested for density and air voids. The binder was extracted and the viscosity was measured to ensure that significant hardening had not occurred.

Resilent modulus tests were also performed on samples compacted using a Servopac machine at two levels of compaction. Results are given in Table 3.2.

Table 3.2 Production trial test results for control and 2 RAP mixes.

Mix	Compaction Method	No. of cycles/blows	Binder Content (%)	Air Voids (%)	Stability (kN)	Flow (mm)	Modulus (MPa)	Viscosity 60°C (Pa.s)
Control	Marshall	75	6.1	4.2	16.2	2.8		856.1
	Servo	80		4.9			2300	
		120		3.7			2380	
15% RAP	Marshall	75	5.9	3.1	17.2	4.1		677
	Servo	80		4.1			2500	
		120		3.1			2450	
25% RAP	Marshall	75	6.0	3.2	15.0	3.4		
	Servo	80		3.1			2650	
		120		2.2			2700	

The construction of the trial is illustrated in Figures 3.4 to 3.7.

Figure 3.4 RAP stockpile.

Figure 3.5 15% RAP mix being laid in 2003.

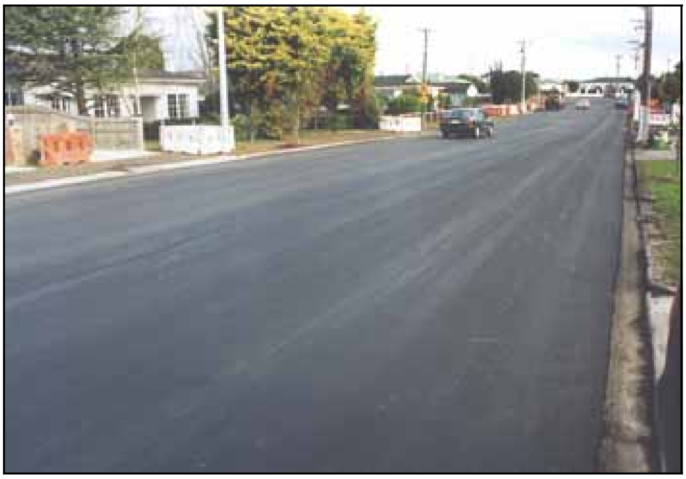

Figure 3.6 15% RAP surface completed in 2003.

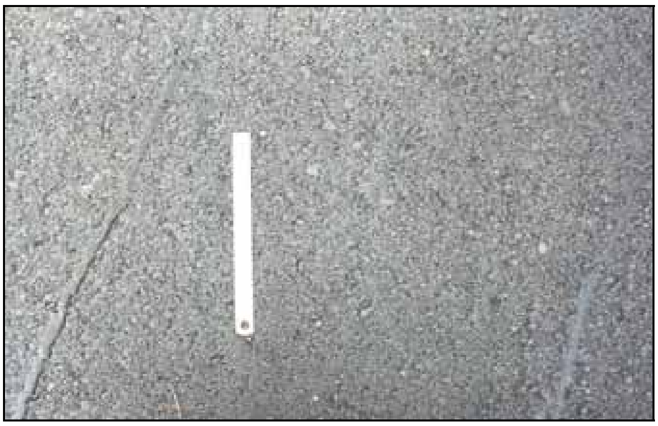

Figure 3.7 Surface finish of 15% RAP 2003 (30 cm ruler for scale).

3.3 Performance

Viscosity values were measured from the binder extracted from cores sampled one and two years after construction. The results are given in Table 3.3 and illustrated in Figure 3.8. The binder in the asphalt has hardened as shown in each of the asphalt types from the original production viscosity values. After two years all the mixes have a similar binder viscosity.

Table 3.3 Results of the monitoring test for the 3 mixes in the field.

Mix	Air Voids %	Bulk SG	TMSG*	2004 Viscosity Pa.s	2005 Viscosity Pa.s
Control	6.7	2.524	2.705	1092	5709
15% RAP	6.8	2.525	2.709	1958	5074
25% RAP	7.6	2.401	2.597	2933	5138

* TMSG = theoretical maximum specific gravity

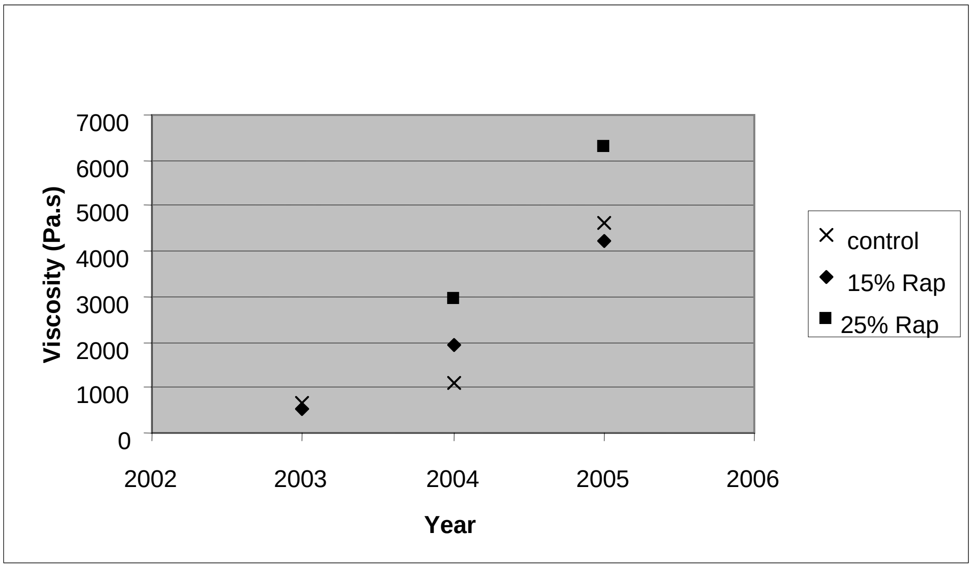

Figure 3.8 Change in viscosity of the binder over 2 years (2003-2005).

Inspections done after one and two years found that all the mixes were in good condition. The condition is shown in Figures 3.9 to 3.11.

Figure 3.9 Control after 2 years.

Figure 3.10 15% RAP after 2 years.

Figure 3.11 25% RAP after 2 years.

4. Ground tyre rubber

Oliver (2000) found a mix processed by the dry process had a fatigue life approximately eight times that of the control of identical composition. This will result in an increase in the allowable pavement deflection for equivalent traffic loading. Initial pavement design analysis has indicated, for example, that where the deflection criteria proposed by Sheppard (1989) is used, e.g. for a medium traffic pavement a maximum deflection of 1 mm with a minimum d250/d0 of 0.65 (ratio of deflection offset from the wheel load by 250 mm to the maximum deflection), the maximum deflection could increase to 1.5 mm to obtain a similar life. This should allow hot mix incorporating GTR to be used in areas that would now require pavement strengthening.

4.1 Laboratory trial

Job mix formulas were designed to be as close as possible to Blacktop Construction's standard mix 14 material, using aggregate obtained from Brookby Quarry, Manukau City. The GTR was obtained as crumb rubber from MATTA Products in Otaki and the particle size distribution is given in Table 4.1.

Table 4.1 Particle size distribution of GTR.

Sieve (mm)	Cumulative % Passing
1.18	100
0.600	90
0.300	36
0.150	10
0.075	1.5

The crumb rubber was included in the mix as a component of the aggregate. The combined aggregate gradings were designed by volume to allow for the variation in density of the aggregate and rubber components, with the GTR density assumed as 1.15. A series of job mix formulas were designed at varying rubber concentrations and binder contents. Marshall properties were tested to determine the optimum binder content of each mix design to give an average air void content of 3.5%. The particle size distribution in terms of volume is illustrated in Figure 4.1.

Table 4.2 Laboratory Marshall test results on GTR mixes.

Mix	Binder Content (%)	Air Voids (%)	Stability (kN)	Flow (mm)
Control	6.0	2.9	12.0	2.9
1% Rubber	6.0	3.6	14.5	3.4
3% Rubber	7.5	3.5	7.6	3.8

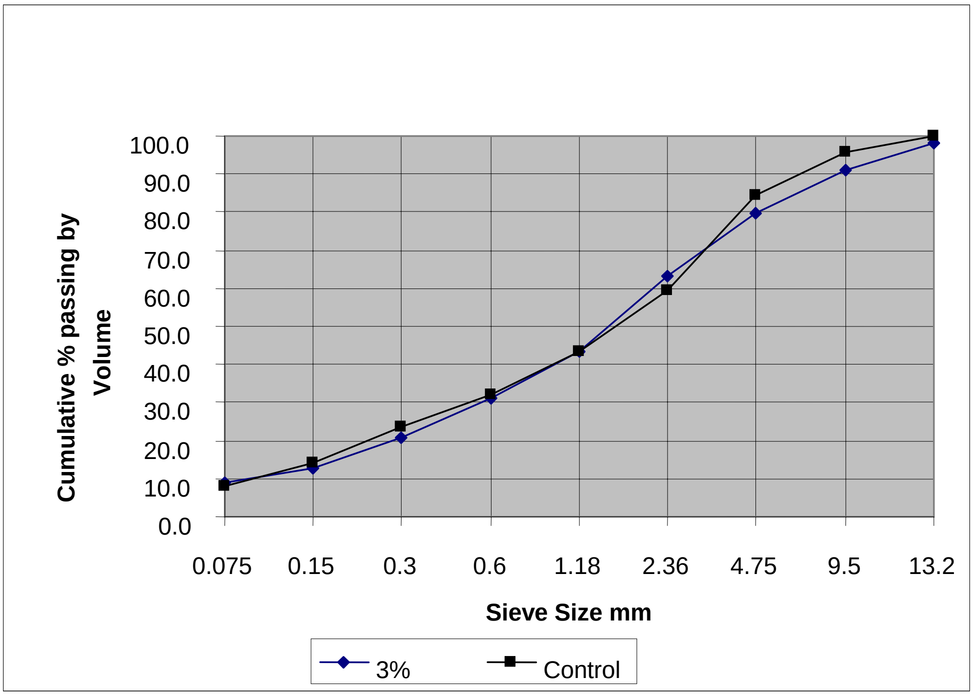

Figure 4.1 Aggregate grading (by volume) for GTR mixes.

4.2 Production trial

Trial sites were selected by John Smith from Roadnet in conjunction with the Manukau City Council. These sites were higher deflection sites that would normally not be regarded as suitable for laying hot mix asphalt. The sites were Friesian Drive and Imerie Ave, Manukau City, Auckland.

The recycled rubber mix was made in a continuous drum asphalt plant and the rubber was added as part of the aggregate fraction and initially fed in through the recycling belt. Because the recycling belt was unable to deliver enough rubber into the mix to meet the job mix formula, the rubber was then added into the mix through a Viatop® centrifugal pump. The mix was laid using conventional plant and methods, but the mix was compacted using steel-wheeled rollers only and not trafficked until the surface had cooled to below 40°C.

The mix was laid in two stages at the end of May 2004 after a lay-down trial in Blacktop's yard. The first paver run was supervised and constructed well. Difficulties were experienced in constructing the second two paver runs however.

Test results on samples taken during production had bitumen contents ranging from 7.5 to 8.8% and Marshall air voids from 3.2 to 8.9%.

The air voids in the field ranged from 8.7% to 17.6%.

In addition the modulus of the mix was determined on two samples compacted to 120 cycles gyratory giving results of 3,000 and 2550 MPa.

Six beams were prepared from the plant samples and compacted in the laboratory. The asphalt beams were tested in accordance with Austroads (2000) Test method AST03:2000 using Industrial Process Control's Fatigue Beam Apparatus. Test results are provided in Table 4.3, and plotted in Figure 4.2.

Table 4.3 Asphalt Beam Test results.

Beam	Voids (%)	Strain (με)	Flexural Life (cycles)	Initial Flexural Stiffness (MPa)	Cumulative Dissipated Energy (MPa)
1	8.3	500	1,815,700	3041	377.241
2	8.1	600	466,280	3094	148.849
3	9.6	450	1,473,410	2530	217.333
4	10.8	400	2,416,540	2444	279.377
5	9.9	350	187,440*	3127	26.363
6	10.7	350	2,960,020	2732	287.114
Average	**9.6**	**510**	**1,000,000**	**2828**	**–**

*Value considered as an outlier and not included in analysis of fatigue life.

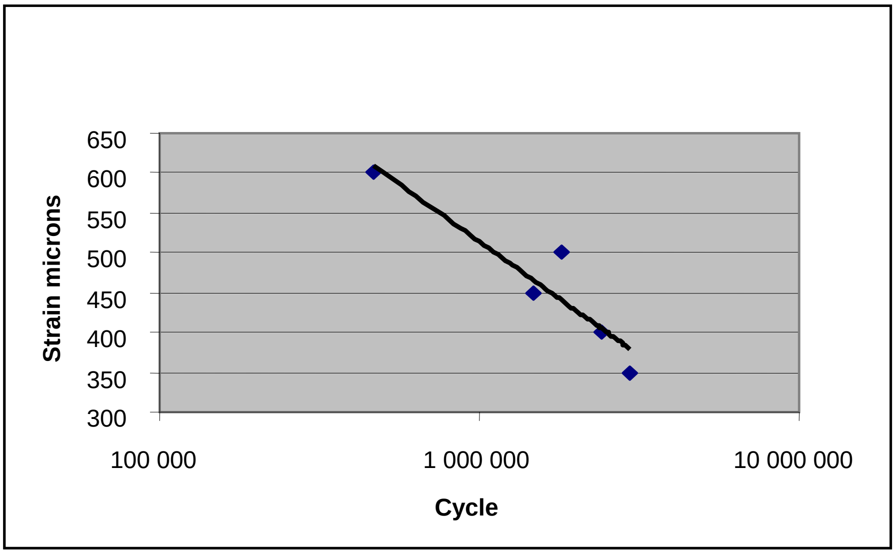

Figure 4.2 Plot of flexural cycles to fatigue of the sample beams versus controlled strain (microns).

The fatigue life is similar to those found by Oliver (2000). Crumb rubber mixes had lives at 600 µm strain of 400,000 to 600,000 cycles depending on the method of incorporation of the rubber. The results above indicate a life of approximately 500 000 cycles at a strain level of 600 µm. Oliver (2000) found that an unmodified mix had a fatigue life of approximately an eighth of the rubber-modified mix tested under the same conditions.

Using Oliver's factor of eight will result in an increase in the pavement deflection allowed for an equivalent traffic loading.

The mix and construction are shown in Figures 4.3 to 4.5.

Figure 4.3 Crumb rubber mix.

Figure 4.4 Crumb rubber mix laid 2004.

Figure 4.5 Crumb rubber mix laid in 2004.

4.3 Performance

The mix was inspected one year after it was laid. The first paver run is still performing well, but the subsequent two paver runs have disintegrated and the site has had to be relaid. The condition is shown in Figure 4.6.

Figure 4.6 Crumb rubber mix showing one good paver run on the right and the other two runs that failed.

5. Conclusions

This research aimed to facilitate the recycling of asphalt mix (RAP) and ground tyre rubber (GTR) from waste tyres into New Zealand roads. The objectives were to allow for the revision of the appropriate specifications to encourage recycling of these materials and use field trials to prove the performance of recycled and crumb rubber modified mixes in practice.

The recycling of old asphalt is commonplace overseas but has not been attempted in any serious way in New Zealand. Asphalt millings containing large quantities of valuable (and finite) aggregate resources are instead used as clean fill. Recycling of used asphalt not only contributes to the long-term environmental sustainability of the roading network but also is becoming increasingly necessary as supplies of good quality aggregate are exhausted, particularly in the Auckland area.

In New Zealand about 2.5 million waste tyres are generated annually and most of these are disposed of in landfills. A 1993 Transit New Zealand research review (Patrick & Logan 1996) on the use of GTR in road construction concluded that the most promising use was in hot mix asphalt. Addition of GTR to the aggregate would require lower capital expense for plant modification than for the addition of the GTR to the bitumen. Although the cost would increase, the enhanced flexibility of the mix would provide superior fatigue performance and therefore could make the material cost-effective on higher deflection pavements. If only 10% of current asphalt mix production contained GTR (at 3%) this would consume about 20% of waste tyres produced annually. GTR has been used routinely in hot mix asphalt overseas for over 30 years but has not been used in New Zealand.

Field trials to demonstrate the practicality of adding RAP and GTR to asphalt have been performed, that showed the following:

- The results from the RAP trials have already been used by Transit New Zealand to modify their M/10 specification for asphaltic concrete to allow 15% of RAP in any mix without a specific design.
- Although the 25% RAP asphalt has been found to have a higher viscosity binder, the pavement is still performing well.
- Ground tyre rubber (GTR) has been less successfully added to asphalt and laid in Manukau City. It was expected that the addition of 3% of GTR would increase the fatigue resistance such that the material would be able to be laid on higher deflection pavements than traditional mixes. The initial crumb rubber asphalt mix laid appears to be performing well, but the subsequent mix failed within months of it being laid. It is unclear what the cause of this failure was, but mix variability has contributed. The fatigue test results on samples have confirmed the expected increases in fatigue life which will allow the mix to be used in higher deflection areas without compromising the expected life.

- In contrast to the RAP trial where mix characteristics were very similar to traditional mixes, the GTR mix will require modifications to mixing and laying techniques to ensure that the desired properties are obtained. These modifications are expected to be learnt through more experience in handling this type of mix.
- The recommendation is that guidelines are developed for the manufacture and laying of GTR mixes to minimise the chance of early failure.

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