Crumb Rubber In Asphalt Roads – Where The Rubber Hits The Road

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ABSTRACT: *Rubber tyres crushed and mixed into asphalt binder have been used for a number of years in the state of California in the USA, however it has seen limited uptake in Australia other than in spray seal applications. The addition of the crumb rubber particles to the asphalt binder have been shown to improve fatigue resistance and reduce cracking in asphalt, as well as the environmental benefits of reducing the quantity of bitumen binder required through the substitution of the rubber.*

South Australia is known for its reactive clay soils leading to premature asphalt failure, and the City of Mitcham to the south of Adelaide has some of the most reactive areas in the State.

In partnership with Tyre Stewardship Australia the City of Mitcham developed a crumb rubber asphalt mix for application in a local road test environment to demonstrate the improved crack resistance and longevity that could be achieved through the addition of waste tyres.

Extensive laboratory testing was undertaken of the crumb rubber binder mix to compare directly against a standard binder asphalt mix, and a polymer modified binder mix, while quantifying the savings that could be achieved as well as the quantity of tyres that could be removed from the waste stream.

During field application of the crumb rubber mix detailed field measurements and survey were undertaken including a high detail road seal assessment to allow ongoing monitoring of the trial road over time against control standard mixes installed at the same time.

The results of the laboratory testing, field installation and monitoring, and lessons learnt will be presented, including ideas for further progression and application of the use of waste tyres in asphalt binder in Local Government roads

KEYWORDS: crumb rubber asphalt, city of Mitcham, tyre stewardship Australia, residential road.

1 Introduction

The City of Mitcham in South Australia has large areas of extremely reactive clay soils with low structural strength, both of which lead to premature failure and excessive deformation in roads. The use of crumbed tyre rubber in asphalt overseas has shown improved performance and asset life, and the intent of the trial in Stanlake Ave is to document and report on the improvements possible in a local setting so they can be applied throughout South Australia, and Australia.

Laboratory based testing of the terminal wet blend crumb rubber asphalt mix has shown that significant benefits to fatigue, crack resistance, and rut resistance can be achieved. Over time the trial will be able to report on any observed benefits in the field through the collection of data related to cracking and rutting as well as the overall asphalt deterioration and useful life increases.

The initial test results both in the lab and in the field would demonstrate that at the very least, crumb rubber can be utilised successfully as a substitute within a bitumen binder mix to provide an opportunity to re-use the tyres while adding improvements to the asphalt performance.

2 Background

South Australia and in particular the Mitcham area is characterised by highly reactive clays (resulting soil heave when exposed to moisture is greater than 120mm) that have a low bearing strength capacity (CBR of 2 to 3) and even the most robustly constructed pavement and seal will present with cracks and failures within the first 12 months. Cracking in road seals is unfavourable, particularly in reactive soils as the resulting water ingress during rain events leads to further expansion of the underlying subgrade soils and faster deterioration.

Crumb rubber used extensively overseas in asphalt mixes, particularly in the USA (California) and Spain that have similar climates to South Australia and have demonstrated improved performance over time when compared to conventional asphalt mixes. In Australia there has historically been no significant uptake, and the use of crumb rubber has been confined to spray seal applications only.

Mitcham Council proposed to undertake a trial to place a crumb rubber asphalt mix on a road of known highly reactive soil and low subgrade strength, where adjoining streets recently constructed over the past 2-3 years have all suffered a large amount of cracking and failures and so improved performance was required. Stanlake Ave, St Marys was chosen as an ideal opportunity to compare against the adjoining streets and monitor over time.
The intent of the trial was to provide an alternative to polymer modified binder asphalt for use in reactive soils low strength pavements to prevent cracking, rutting, and fatigue in a local government environment, or to demonstrate that even in the most extreme circumstances crumb rubber asphalt would perform no worse than conventional asphalt.

3. Crumb Rubber Binder Bitumen Summary and Results

There have been various investigations historically in overseas publications for the optimum content of crumb rubber to be used in a bitumen binder, with the figure ranging anywhere between 10% and 20%. For the purpose of this trial a figure of 15% was adopted. The crumb rubber was mixed into the binder using a terminal blend wet mix process (the rubber completely dissolves into the binder) which allowed the product to be cooled, stored, and transported.

The trial asphalt mix contained 5.6% bitumen binder, and with 15% of the binder being crumb rubber, the 'net' bituminous binder required in the crumb rubber mix was then 4.76% (equates to 8.4 grams of crumb rubber per kilogram of asphalt mix) meaning in a raw materials sense the binder required was a lot less than the 5.5% required in conventional asphalt mixes and the control asphalt mix.

This reduction in the requirement for bitumen binder is important, as the cost of bituminous binder is approximately $900 per tonne, while the cost of the crumb rubber is approximately $600 tonne. Over time this cost saving is only expected to increase as the cost of crude oil increases and the cost to process the used rubber decreases through increased market uptake. Some of the savings of using less bituminous binder are offset during the asphalt manufacture due to the higher processing of mixing in the crumb rubber using a high shear blending process to depolymerise the rubber particles and dissolve into the binder.

For this trial the crumb rubber had to be sourced from Victoria, and so it was noted if localised processing of the crumb rubber was present in South Australia the cost may be reduced and the asphalt mix may potentially be much cheaper than a conventional C320 mix, particularly over time as the cost of bitumen only increases.

Based solely on 15% crumb rubber content in the binder (with no additional crumb rubber added to the dry aggregate mix) per square metre of asphalt at a depth of 50mm uses approximately 1kg of rubber tyre. If considering a local street of typical dimensions (500m long by 6m wide) this would mean the re-use of approximately 3,000kg of rubber, or the equivalent of 430 passenger tyres. (however at the moment, only truck tyres are used, as they have a higher quantity of natural rubber, and less fibres.)

Testing of the bitumen binder itself demonstrated that a significant improvement over conventional C320 and C170 bitumen binder can be achieved with respect to the stress ratio, with the results demonstrating that the rubber mix achieved a significant increase in ductility (an indicator for crack resistance and flexural performance).

Table 1: Ductility Comparison

Bitumen Binder	Stress Ratio at 15ºC
C170/C320 *(normal)*	0.92
S10E *(modified binder)*	1.69
Trial CRB Binder	1.52

4. Asphalt Production Mix Testing Results

Laboratory testing was undertaken on the asphalt sample both through the design stage and then on the production mix itself (the exact product that was placed in the field) to demonstrate how the crumb rubber mix compared to conventional asphalt over a number of standard test areas.

4.1 Fatigue Testing

Fatigue testing is based on the property that repeatedly applying a small load to a material (even though it is well below the material's ultimate strength) will cause gradual deterioration until failure is reached, which in the case of asphalt would be equivalent to the road receiving continual vehicle loading over a number of years until it begins to crack and disintegrate.

This mode of failure is exacerbated in cases where the underlying pavement and subgrades are poor, such as reactive clays with poor CBR bearing capacity which is the case in this trial. An asphalt mix resistant to fatigue would be favourable in these cases to prevent premature failure and early cracking in the road seal.

Table 2 below shows the comparative cycles to failure for both standard AC14 C320 and Crumb Rubber modified AC14.

Table 2: *Cycles to Failure*

Mix	Cycles to Failure
Conventional Asphalt Mix (C320)	116,868
Crumb Rubber Asphalt Mix	498,805

The results demonstrated outstanding properties with regards to fatigue failure through the addition of crumb rubber in the binder mix, with the CRB sample lasting close to 4 times longer than the C320 mix. The results are a good indicator that the CRB mix is more resilient to fatigue cracking in the field than a normal C320 mix, and is a significant increase in performance.

4.2 Moisture Sensitivity

Moisture sensitivity testing is undertaken to assess the susceptibility of an asphalt mix to degradation from water penetration. Although less of an issue in South Australia's climate, asphalt can be subject to premature failure through stripping, and cracking where the bond between aggregate and binder is weakened in the presence of water. Moisture sensitivity testing is undertaken by comparing the loss of tensile strength of the asphalt after saturating the sample with water, with the CRB asphalt demonstrating better cohesion and aggregate bonding properties than the standard C320 mix, and would be indicative of improved crack resistance and moisture performance over typical asphalt. Table 3 below shows and increase of over 1.1 times in Tensile Strength Ratio over conventional asphalt mix.

Table 3: *Tensile Strength Ratio (%)*

Mix	Tensile Strength Ratio (%)
Conventional Asphalt Mix (C320)	77
Crumb Rubber Asphalt Mix	87

4.3 Wheel Tracking

Predictions of the performance of an asphalt mix in the field with regards to rutting and repeated loading over time can be estimated using the wheel tracking test, where a set load is applied over the sample, which in this case was 10,000 times. The ability of the asphalt to resist rutting in service is highly desirable to maintain a smooth even road seal surface, particularly at intersections that are exposed to higher forces due to acceleration and braking. The CRB mix produced significantly better results and it could be expected that excellent performance could be achieved in a local road setting, as can be seen in table 4. This shows that conventional AC14 C320 mix deflect more than twice as much as CRB mix.

Table 4: *Wheel Tracking Deflection*

Mix	Deflection (mm)
Conventional Asphalt Mix (C320)	7.5
Crumb Rubber Asphalt Mix	3.6

5. Asphalt Production Mix Testing Results

Although there have been a number of studies regarding the hazards of volatiles released when heating crumb rubber asphalt mixes demonstrating that they remain at safe levels, it was acknowledged this may be an issue, as well as the potential for odours from the rubber. Through the inclusion of warm mix additives it was possible to lay the asphalt mix at 165°C which was below the temperature at which volatiles and odours are released.

5.1 Construction

The site was divided into 4 sections, with a different combination of asphalt mixes in each one. The design of each layer can be seen below:

1. AC10 C320
   AC14 C320

2. AC10 C320
   AC14 CRB

3. AC10 CRB
   AC14 C320

4. AC10 CRB
   AC14 CRB

By comparing in this manner we can potentially see which layer (in any in particular) of CRB provides a better road design.

During the placement of the asphalt it was necessary to roll the mix with a steel drum roller rather than the normal practice for conventional mixes using rubber multiple tyre rollers for compaction. It was found from the core tests of the in-situ placed asphalt that the air voids were slightly higher than expected however this was attributed to the different method for compaction and that it was a new and unfamiliar process for the contractor; however with further applications this would only improve.

5.2 Air Voids

The core test air voids can be seen below, making particular note that the conventional asphalt control section was compacted using the same process, and in this instance had higher air voids than the crumb rubber, which would help to demonstrate that product achieves compaction in the field and behaves in the same manner as conventional mixes.

Table 5: *Construction Air Voids*

Mix	Air Voids
AC14 C320	6.3%
AC14 CRB	6.3%
AC10 C320	8.2%
AC10 CRB	7.9%

5.3 Price

The price per tonne cost comparison for the construction of the road for both the conventional mix and the crumb rubber can be seen below, with the price for a polymer modified solution (to achieve the same performance benefits as crumb rubber) included for comparison also.
It must be noted that these figures are for this particular trial only and should only be used as a rough estimate of cost. This is entirely dependent on supplier, funding agreements, travel costs etc.

Table 6: Comparative Rates of Mix

Mix	$/Tonne	Comparison
AC10 C320	$ 166.42	
AC14 C320	$ 161.87	
AC10 CRB 15%	$ 172.98	+ $ 6.56 (4% higher)
AC14 CRB 15%	$ 174.77	+ $ 12.90 (8% higher)
AC10 A15E	*$191.00*	*+ $ 24.58 (15% higher)*

6. Performance Monitoring for First Six Months

The trial section of road will have a number of ongoing measures taken to assess the performance over time versus the conventional asphalt mix. At this stage there has been minimal change in environmental conditions due to an abnormal summer with no rain, however all the instrumentation or base line measurements have been done. The monitoring will occur quarterly for the first year and then every six months beyond that and will include:

Road and kerb survey benchmark monitoring
Benchmark survey levels were established prior to the road being constructed, and will be measured to observe the change in kerb and road levels due to seasonal variations (the expansion in the clay). This will help to establish how the road responds to small or

large adjustments over time and the corresponding failures.

Rut measurements
The test laboratory data indicated that the crumb rubber road should perform much better than conventional asphalt with respect to rutting, and so over time localised deformation due to rutting can be monitored and measured.

Road Roughness
The road is measured regularly to assess the IRI (International Roughness Index) and how this changes or progresses over time. The roughness measures the ride quality of the road, with higher roughness values indicating a road with a large amount of failures and deformation. Prior to reconstruction Stanlake Ave had an IRI value of 7.91 (extremely high). A roughness value of 1.9 is considered a suitable target for new construction, and for reference Julia Ave a street immediately adjacent was reconstructed three year earlier and has an IRI value of 2.51 already.

Crack measurements
A key measurement that will be monitored as part of this trial is the extent of cracking in the crumb rubber road versus the conventional asphalt section, on the basis that the test mix data and observations overseas would indicate that the road should be a lot more resilient to cracking.

Oxidation
Carbon black, a key chemical compound used in rubber tyres to prevent oxidation and deterioration has been shown to also provide a benefit to the road surface through being present in the tyres used in the mix. Over time the level of oxidation in-situ will be monitored and reported on.

8 Conclusions and recommendations

As discussed, the initial mix results show that Crumb Rubber Modified Binder is a superior mix to the standard C320 council mix.

The binder itself is more ductile, while the mix is:

- more resistant to fatigue
- has a higher tensile strength ratio
- lower deformation due to wheel tracking
- Can achieve the same, if not lower, air voids

We are still undertaking tests to see how it reacts to its environment, however we are already investigating prices to undertake significant asphalt works with Crumb Rubber into the future as a replacement for standard council mix on local roads.

All the results above are purely in regard to its performance as an asphalt mix. This mix is also proven to reduce waste, a point that is highly complimented by both our residents and Elected Members. Large amounts of public engagement were undertaken to promote the trial and inform the public about how roads can use recycled products, eliminating them from landfill.

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