Overlay Testing and Surface Mixes

Glynn Holleran Technical Divisional Manager NI Fulton Hogan Ltd New Zealand

Irina Holleran Technical Services Manager Fulton Hogan Auckland New Zealand

Chapa Jayalath R&D Supervisor Auckland Fulton Hogan New Zealand

ABSTRACT

In New Zealand the use of full depth asphalt pavements is limited to major infrastructure projects and some rehabilitation work. In general thin overlays are used and these are placed on a wide range of pavement types. Economic circumstance has encouraged the industry to optimise use of RAP percentages at as high as possible a level with some success. However many pavements do have issues with curvature (> 0.3 mm) and deflection. Often sub optimum layer thicknesses are laid with attendant issues of segregation, roller checking and surface slippage. This leads to shortened life of overlays. Use of polymers has been suggested and successfully trialled. However the cost of polymer addition is an impediment. This work adapts the RAP work reported in AAPA in 2011 (1) and extends it to include design using the IPC/ Asphalt Mixture Performance Tester (AMPT) apparatus with the overlay jig. Originally designed in Texas to examine reflective cracking potential this approach may be able to rank surfacing mixes for resistance to cracking when placed under repetitive load and greater strains as produced in higher deflections and curvatures. This work discusses AC14 mixes that have failed in thinner layers in 4-6 years and looks at different RAP percentages and different polymer systems. Flow number is also measured using the AMPT to compare deformation resistance and Wheel tracking results also compared. The aim is to provide good overall performance at the lowest price by using an engineered binder and appropriate grading.

1. INTRODUCTION

Thin overlays are the primary work horse for urban arterial roads in many cities of New Zealand. Due to economic considerations these layers are often thinner than minimums as recommended in the literature and specifications (2,3). Further, often designs of overlay thickness are still based on fatigue life as modelled using Shell and other models and tested using devices such as 4 point beam bending. This assumes that the end of life is a reduction in stiffness to 50% or other fatigue end point. However it is not usually observed that cracking begins at the bottom of the layer and this leads to the notion that top down cracking is more important in overlay failure (4) .This is also more consistent with the observation that surface defects can act as initiation of cracks. Mitigation of top down cracking using polymers is practiced (5) but the effect of combination of polymers with RAP mixes was pointed out as an issue in work at National Center of Asphalt Technology (NCAT), with more cracking reported with a PMB than non modified in high RAP mixes (6)**.**

Issues associated with mixing of RAP binder with virgin binder have been discussed (1, 7, and 8) and it seems that this does not occur to the level where a simple extracted blend blended with virgin binder can serve as a prediction of mix performances. Indeed recent NCAT work (9, 10) indicates that the recommendation of using softer binders is not as important as the actual volume of added virgin binder in mixes with RAP contents up to 25%. Warm mix additives can also boost performance. This effect also depends on the intermediate temperature properties of the binder.

Overlay testing was developed in Texas at University of Texas Austin (11) and looks at a thinner section of mix cut from a compacted core or block and flexed using a two part jig. This has several forms that include the IPC jig for the AMPT testing device; this appears to be a good relative measure of crack resistance.

In this paper the AMPT is used to characterise mixes and compare their properties in dynamic loading- dynamic modulus, flow number (with comparison to wheel tracking), fatigue and overlay testing. Only AC14 mixes are discussed in this paper but the work is being extended to finer mixes. These AC14 mixes included both polymer modified and performance bitumen mixes and with varying levels of RAP. Rejuvenation is used for some mixes to compare the effect on cracking using the Overlay testing method.

2. Overlay Testing Set Up

The test method is TXDOT DESIGNATION: TEX-248-F Revised 2013.
Samples are cut precisely from blocks manufactured using the Servopac, and then cored to sample dimensions.

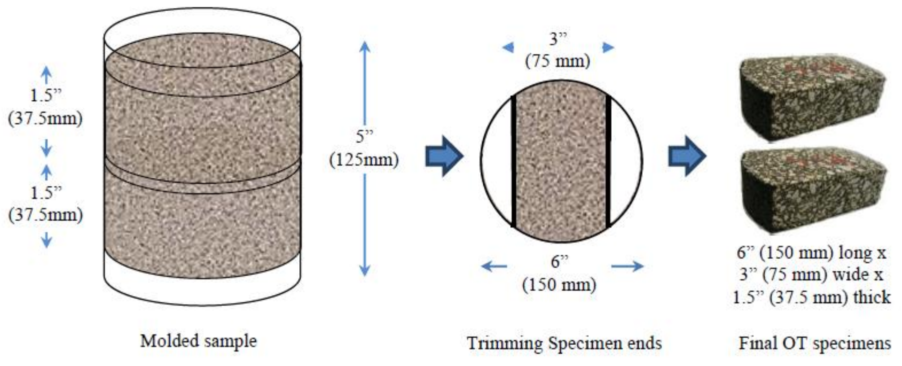

Figure 1 Overlay Test Samples

These samples are glued to a jig as shown with a special epoxy putty to prevent movement .

Figure 2 Test set up and mounted sample

The sample is conditioned for a minimum of 1 hour in the control cabinet. The test is terminated when the termination load is reached; this is 93% reduction of the initial load or 1200 cycles. Loading frequency is 0.1 Hz and displacement is 0.635 mm. Testing is carried out at a controlled 25 ^{0}C. This is plotted as tensile load versus loading cycles as shown in figure 3.

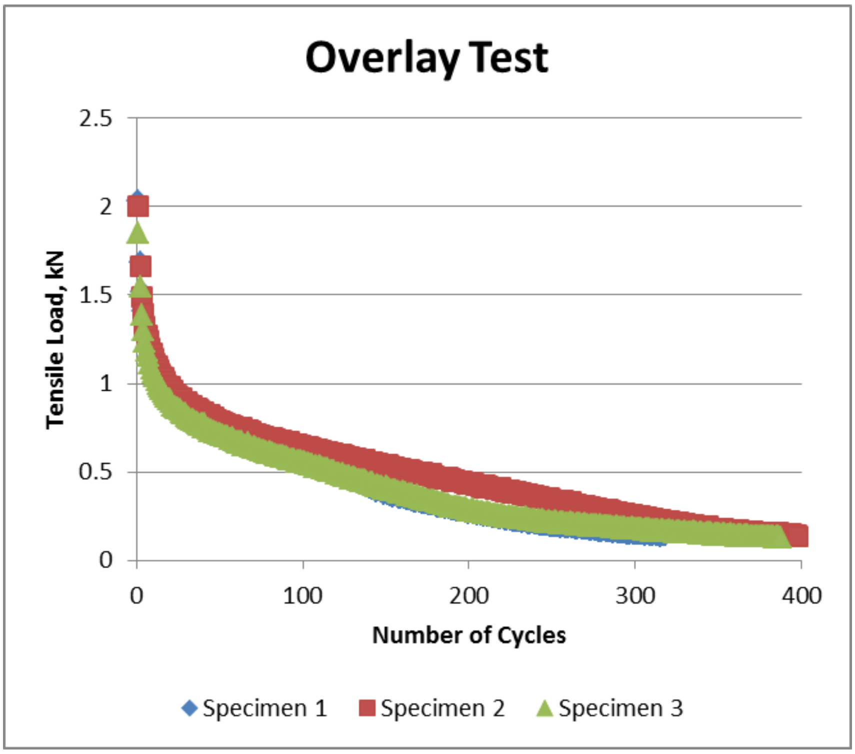

Figure 3 Plot of Test Result

Figure 4 Test Specimens failed

Other AMPT tests such as dynamic modulus, flow number and fatigue are described in the appropriate test methods and are based on AASHTO issued and draft methodology. VECD testing was to AASHTO current draft ex UNC Prof Richard Kim.

These were:
TXDOT DESIGNATION: TEX-248-F
AASHTO TP 79-09
Draft AASHTO “Determining the Damage Characteristic Curve of Asphalt Concrete from Direct Tension Cyclic Fatigue Tests” University NC.

3. Mix Designs

The mixes were made using NZTA specifications M/10 Draft 2010/2012. This was based on Servopac compaction and included performance testing to level 3. Binders used were Fulton Hogan performance grade PGT64 (12, 13), "Paveflex AX14" (Radial SBS), "Paveflex AXA H" (FH Proprietary elastomeric binder). RAP was a RAP 10 of a smooth grading and binder content (5.2%) (1), the rejuvenation oil was a maltenes napthenic fraction used commonly for rejuvenation. Mix design methodology for RAP mixes was according to FH practice as discussed previously (1).

4. Results

4.1 Overlay Test Results

The results are shown in figure 5 and table 2.

Main observations were:

- Cracking resistance depends on RAP level;
- PMB added to mixes with RAP levels of 15% or higher compromises crack resistance;
- Rejuvenation added into the virgin binder does not improve crack resistance;
- Polymer modified binders have better crack resistance than virgin binders in non rap mixes;
- Increasing volume of virgin binder to reclaimed improves crack resistance.

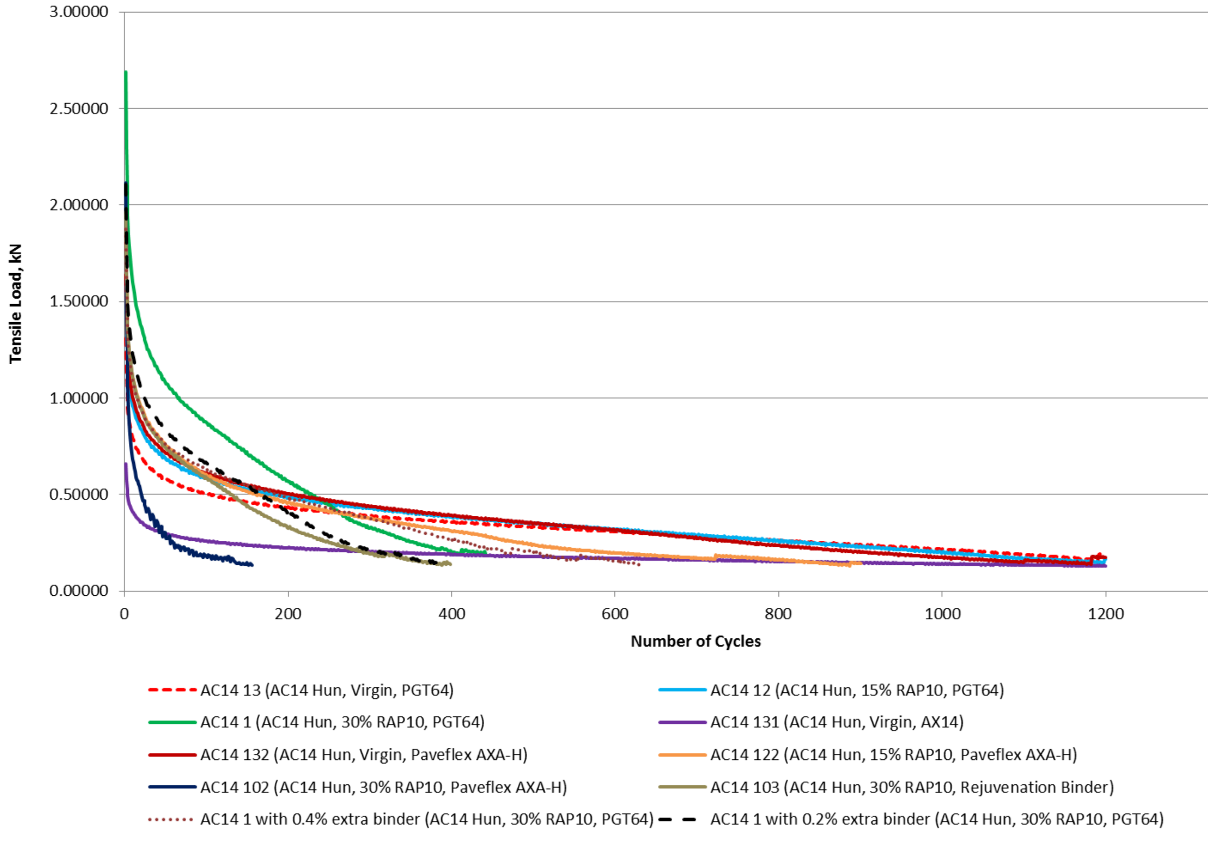

Figure 5 Overlay Test Results

Mix	Cycles to fail or termination	% Virgin Binder	RAP %	Binder Type
AC14 13	>1200	5.3	0	PGT64
AC14 12	>1200	4.6	15	PGT64
AC14 1	420	3.5	30	PGT64
AC14 131	>1200	5.3	0	AX14
AC14 132	>1200	5.3	0	AXA
AC14 122	900	4.6	15	AXA
AC14 102	190	3.5	30	AXA
AC14 1	400	3.5	30	PGT64 + Rejuvenator
AC14 1	413	3.7	30	Extra virgin binder
AC 14 1	613	3.9	30	Extra virgin binder

Table 2 Overlay Results AC14

In Holleran G&I 2011 (1) mixing effects in RAP binders were discussed, other researchers have also worked in this area and proposed that the RAP binder does not fully mix with the virgin binder, which makes the effect of the virgin binder more dependent on its volume than its rheology. Polymer binder added is of higher viscosity making mixing less likely. The work on rejuvenation shows that no aggregate effect appears to exist for softer added binder; it also opens up a potential deformation issue.

The effect of increasing volume of virgin binder was examined by adding extra virgin binder (PGT 64). This added binder gave improved crack resistance but not to the level desired.

4.2 Dynamic Modulus Test Results

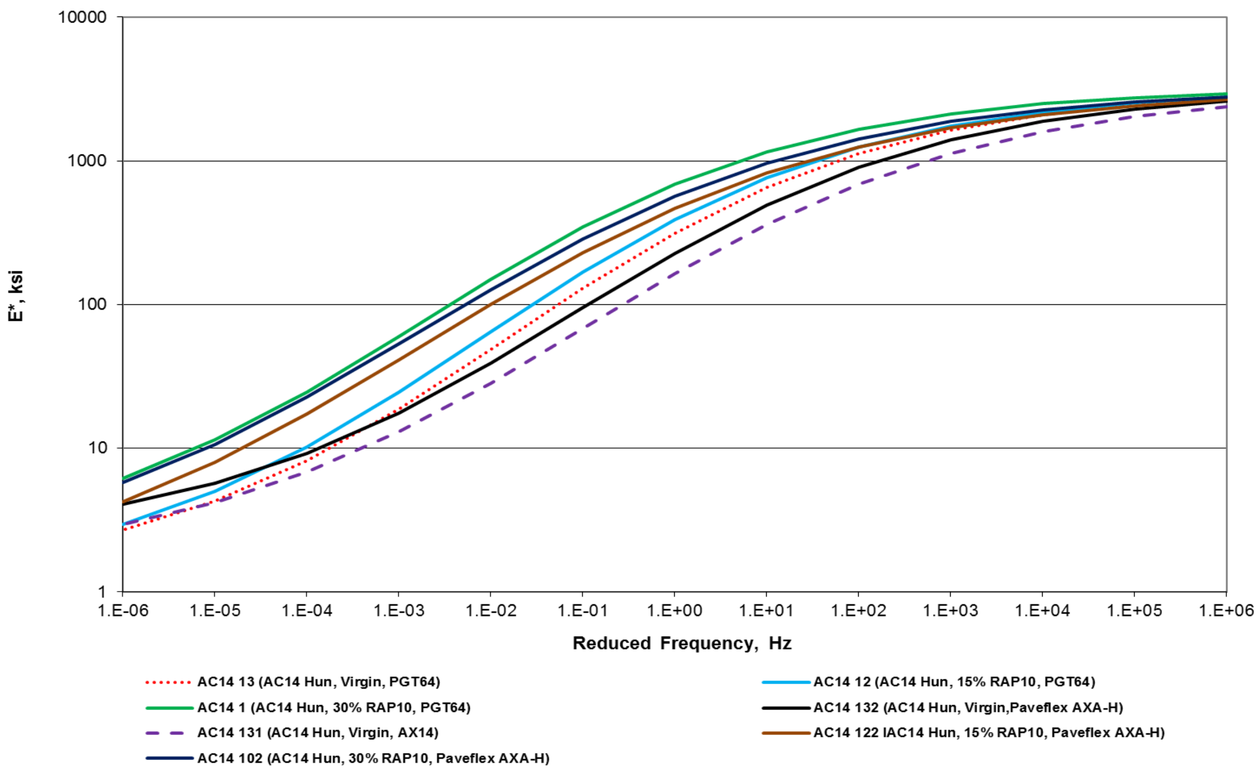

Figure 6 Dynamic Modulus Master Curves

The dynamic moduli of the AC14 mixes with varying RAP follow a predictable increase with frequency and RAP content. At lower and higher frequency the virgin mix and the 15% RAP have similar moduli. This would indicate at high shear and lower shear strain, response will be similar. 30% RAP mixes at higher frequency are also similar but at low frequency the modulus is much higher. This might suggest at lower temperature strain response might be similar and at high temperature, the 30% RAP mix will have more resistance to shear. The polymer modified system combines higher modulus at low frequency with similar response at high frequency. At intermediate frequency and temperature, 15% RAP is similar to virgin but polymer has a lower modulus. This covers an effective temperature range of -10 ^{0}C to 55 ^{0}C.

Table 3 shows the resilient modulus for these mixes at 25 ^{o}C using the Australian standard test AS. 2891.13.1-1995. These results are consistent with the dynamic modulus results. It does illustrate that the effect of the “Paveflex AXA H” polymer is to raise the resilient modulus but not to reduce crack resistance.

Mix	Resilient Modulus MPa	RAP %
AC14 13	3474	0
AC14 12	3570	15
AC14 1	4182	30
AC14 132	3885	0/ “Paveflex AXA H”

Table 3 Matta- Resilient Modulus results

4.3 Flow Number and Wheel Tracking Test Results

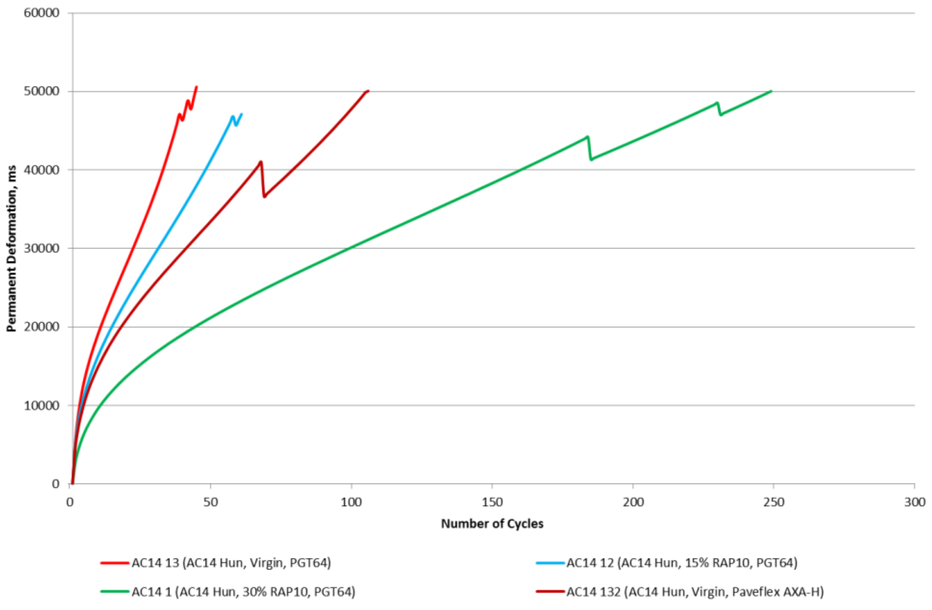

Figure 7 Flow Number Results - RAP Effect

This shows the hierarchy of deformation resistance. The highest level is 30% RAP mixes followed by polymer. This would appear to be a function of stiffness. Figure 8 shows the same mixes tested using wheel tracking (AG:PT/T231).

The tests give similar hierarchy except the flow number is not showing polymer modified as the best result. This maybe because in the test the recovery time of the specimen in the push pulls orientation is lower and it does not allow for aggregate interlock occurring and seems to be more related to stiffness and shear. In the wheel tracking test most of the energy is dissipated at the surface and some recovery is possible. In large stone mixes stones are pushed down to a stone on stone contact and interlock. The consistency is good for non modified binders.

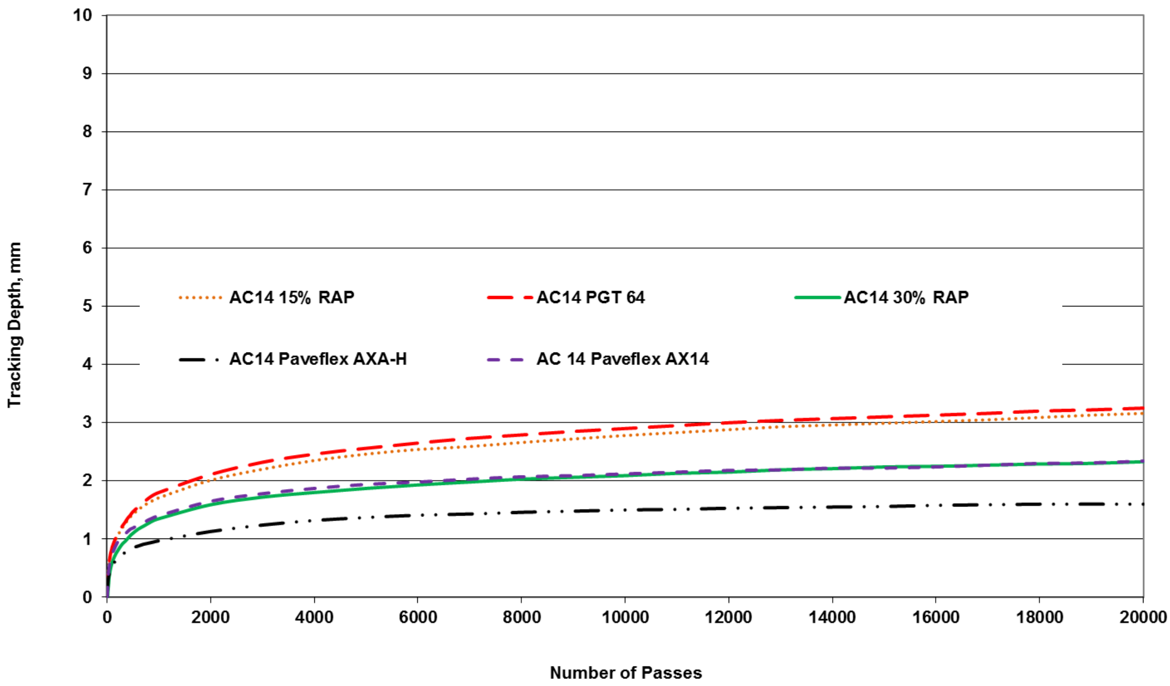

Figure 8 Wheel Tracking Results

4.4 Fatigue Results

Fatigue results using the AMPT give similar outcomes to those of 4 point bending. Figure 9 shows 4 point bending results for some of the mixes tested in the overlay tester.

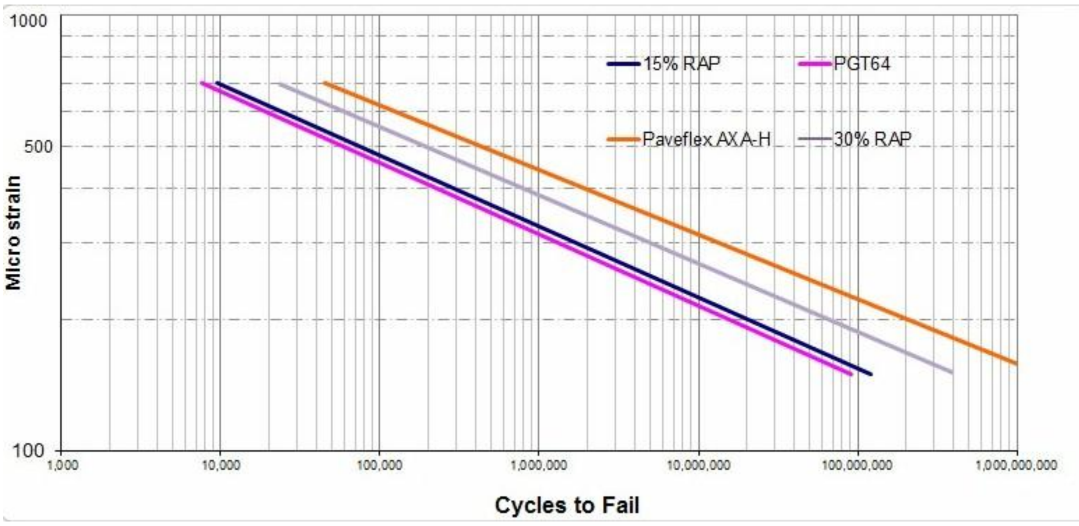

Figure 9   Four Point bending fatigue results

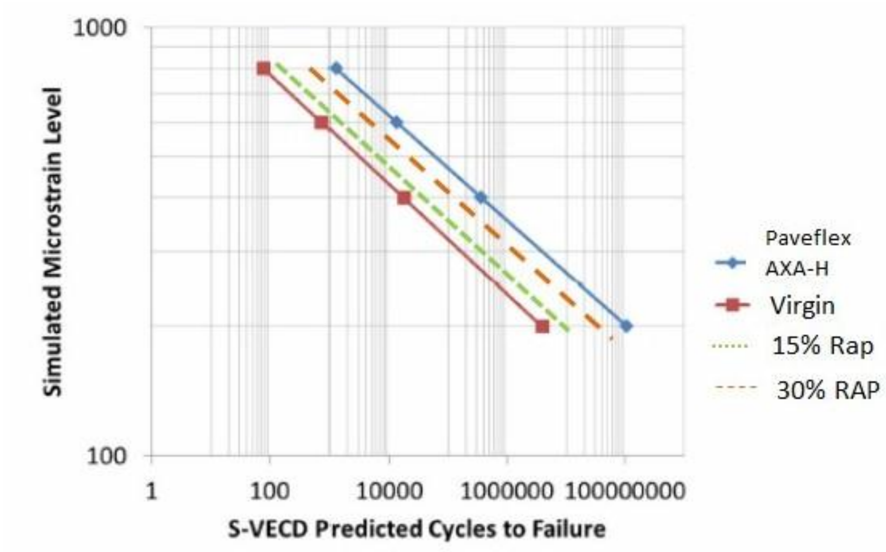

Figure 10 AMPT Fatigue Results

This shows that RAP effects on beam samples are to improve fatigue life. PMB (“Paveflex AXA H”) also improves fatigue life in virgin mixes. This is also consistent with AMPT results based on VECD in the limited testing done so far.

5. Field Results

Field results have shown that a 30% RAP mix in general requires higher volumes of added binder to maintain workability. Workability aids may be used to ensure volumetrics are achieved but thickness is a key variable. In AC14 30% RAP mixes in thicker sections, i.e. 80 mm and greater, the fatigue results are the best indicator of performance whereas in layers to 45 mm the overlay test is a better indicator. At levels less than this, the failure mode is often premature and consists of top down failure with water ingress into the base and subsequent fatigue failure by flexing. That is fatigue, although present, is not the primary failure mode. A typical failure over 5 years on a arterial heavily trafficked road is shown in figure 11. In thicker overlays with AC14 the issue is not as severe and 30% RAP surfaces do have good surface texture and appear to perform well. However these are of the order of 80 mm thick.

Fresh laid AC14 35mm

AC14 35mm 5 years old

AC14 35 mm 5 years old

AC14 35 mm 5 years old failed

Figure 11 Failure Progression

6. Continuing Work

To use high RAP level's in base mixes is not an issue based on our results. However for thin overlays the overlay tester and level 2 and three design are essential to ensure performance. This will also involve looking at the controlling features on mixing of binders in RAP mixes and methodology for modelling this. Rejuvenation of the RAP itself is possible as well as preheating RAP. This also needs to be more quantitatively related to field performance. The effect of mixture size needs to be assessed, it is known from USA work that finer mixes (9.5 mm) behave similarly but the level of virgin binder is generally higher for a given RAP content.

7. Conclusions

- Overlay testing is a good way of assessing crack resistance potential of overlays, especially on pavements of higher deflection and curvature;

- Overlay testing can rank performance of overlays and a tool in overlay design and optimisation of binder level and type;

- The AMPT tester provides a methodology that, while it does not replace performance related testing and volumetrics, can provide useful information for prediction of performance;
- Dynamic modulus measured using master curves gives much more information than a single standard temperature test such as resilient modulus;
- To improve in field cracking resistance of high RAP mixes in overlays there must be sufficient virgin binder added, this can be optimised using the Overlay Tester;
- PMB added to mixes with RAP levels of 15% or higher do not improve crack resistance indeed they appear to compromise crack resistance
- Rejuvenation oils added into the virgin binder does not improve crack resistance, that is softer binder added in insufficient amounts do not significantly improve crack resistance;
- Polymer modified binders in non RAP mixes have better crack resistance than virgin binders;
- Increasing volume of virgin binder to reclaimed binder improves crack resistance;
- Flow number can be related to wheel tracking for non modified systems;
- Fatigue failure and top down cracking are different modes of failure and not interchangeable. AMPT can be used for both measurements;
- Laying and binder layer thickness are important in practical and mechanical terms and minimums need to be observed.

8. References

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10. Authors

Glynn Holleran: Graduate of University of Melbourne with Master's Degree in Material Science spent 35 years working in polymers, bitumen and bituminous based materials. This has included, 7 years with ICI in polymer rheology, 3 years in adhesive dispersions, 11 years with Mobil in Australia as Technical Manager Bituminous products group covering all bitumen products. Established and directed Mobil's asphalt laboratory, Mobil's Technical Bitumen advisor for MRDI (specialist in Polymers, bitumen chemistry and refining). 11 Years in USA in Technology transfer in asphalt technology into Africa, Eastern Europe, Russia, Africa, China and South America (V.P Technology VSS and ITG - Responsible for a number of successful projects in Russia and China in Microsurfacing).Author of many papers and presentations on bitumen technology in NZ, USA, Australia, Asia, Europe, Middle East, and Africa. Currently Technical Manager Fulton Hogan Auckland NZ, directing Auckland laboratory, R&D, mixture design, bitumen technology and Technical Services.

Irina Holleran: Graduate of Vladimir State University in Civil Engineering with first class honours (red diploma) and Radio-Technical University in Ryazan in Electrical Engineering. 5 years in Agradorstroi Ryazan Russia laboratory in asphalt, two years Laboratory Manager in Centrkom Ryazan Russia in slurry and emulsions. Three years as Technical Manager VSS (Inc USA) Russia. 6 Years in Technical Support and R&D Fulton Hogan Auckland (Technical Services Manager Auckland) including two years as leader in asphalt mix design. She is the author or co-author of papers presented in conferences in Russia, USA, Australia, Singapore and NZ.

Chapa Jayalath: Research and Development Supervisor. Studied Engineering Science at Auckland University and has been working with Fulton Hogan in the areas of bitumen, PMB, emulsions and mixes. She is responsible for the AMPT testing device, its methodology and development.