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ASPHALT ON AUSTRALIAN AIRPORTS

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SYNOPSIS

The paper reports on a survey of the performance of asphalt surfacings on airports by the Australian Airports Association. Problems were identified at certain airports with groove closure, groove edge breaking, and unsatisfactory surfacing performance. A national coring programme found stripping of asphalt on airport pavements was more widespread than previously thought. The focus moved to the binder with issues such as viscosity, temperature susceptibility, polymer modification, and quality control being considered. More detailed binder quality control was introduced on some major airport projects. An investigation was undertaken into how bitumens are produced and how polymer modified binders are manufactured around Australia, including the changes in production that have occurred over recent years. A project has been started to develop a new airport specification binder in close co-operation with the bitumen industry.

INTRODUCTION

Scope of project

Asphalt has been used extensively on Australian airports for decades with generally good performance. However members of the Australian Airports Association (AAA) have been concerned with the performance of some bituminous products (and predominantly asphalt) on their airfields. These perceptions have been reinforced by recent reports of occurrences of abnormal asphalt performance. This study was undertaken to provide the AAA Technical Committee with an overview of how bitumens and modified bitumens are produced in Australia and how they are performing on their airports.

The study was divided into three packages. Package A sought to ascertain what problems airports were facing with bituminous products by means of a survey and limited inspections. It sought information on closure of grooves in asphalt, groove edge breakage, premature aging of asphalts and soft behaviour of bituminous surfacings generally in hot weather. Package B covered project investigations into some aspects of bitumen and its performance, done in conjunction with actual construction projects. The concept of a new airport binder arose in this package. Package C was a survey of how bitumens and modified bitumens are produced for Australia, and how the products had changed over time.

The study relied upon inspection, survey, and previous test and investigation data (where available). Funding for in-depth research was not available. Some data, which could identify particular locations or processes, has been omitted in the discussion for reasons of confidentiality. The limitations mean that some of the findings are provisional and some are speculative, although the study findings have been extensively reviewed by AAA members. The problems discussed in this study need to be kept in perspective. Asphalt on Australian airports has a long history of good performance, PMB binders have been used for airports in other countries with reported success, and asphalt is widely used internationally as an airport surfacing. Asphalt and bituminous binders continue to be a product used by Australian airports, and the challenge ahead is to refine the system to improve performance.

Historical use of binder for asphalt on Australian airports

Asphalt used on pavements on Australian airports has been predominantly dense graded asphalt wearing courses. Open graded asphalt has been historically used for good wet weather friction, but the economics of grooving have proved more attractive in Australia since the 1980s. Asphalt is rarely used as a formally designed bituminous basecourse or in full-depth asphalt. It is usually used on civil pavements for medium to heavy aircraft pavements (from the Boeing 737/717 size upwards) and is widely used on military airports.

The binder used in asphalt has for many years been unmodified paving grade bitumen. Originally the then Commonwealth Department of Works had its own penetration based bitumen specification. After the Australian Standard AS A10 for penetration graded bitumen was introduced in 1967, the Commonwealth Department of Works moved across to that standard with the addition of their own 'vis-pen' requirement. The bitumen used on airports was the R90 grade. With the withdrawal of AS A10 and its replacement by the AS2008 viscosity based specification in the 1970s, Department of Works (or Housing and Construction as it became known) moved across to the AS2008 standard. It was found that there was a change in bitumen behaviour from the penetration to viscosity grades (essentially a change in temperature susceptibility or PI). Class 170 was too soft to be a suitable substitute for R90 bitumen in asphalt, and airports moved across the Class 320 for asphalt. Most stayed with Class 170 for seals.

Class 320 bitumen has given good service at many airports across Australia. Rutting of asphalt has generally not been a problem at airports, even with the heaviest aircraft. There have of course been rutting problems, but these were pavement associated not asphalt. There have been some airports in the hotter regions that have looked to stiffer mixes and used other binders. However the single factor that drove the introduction of polymer modified bitumens (PMB) on airports has been stripping.

Initially, some of the major airports found that asphalt made with Class 320 bitumen was stripping badly. The asphalt would degrade and loosen, leaving only a thin intact crust. This would fail, particularly in hot and wet weather, and significant and repeated patching was required. Asphalt made with the AB6/A10E grade of SBS polymer modified bitumen, for whatever reason, did not strip nearly as badly, and so this was adopted at several major airports. No other grades or polymers of PMB have been tried in large volumes. It should be noted that other airports are still using Class 320 bitumen in asphalt without experiencing serious problems. The evidence from the current AAA coring programme, running at the time of writing this paper, is that the incidence of stripping is more widely spread than previously realised.

After some years experience, it was apparent that asphalt made with A10E PMB bitumen gave other problems, such as groove closure and groove edge breaking. The problems were experienced with A10E supplied from different manufacturers and with different contractors. It raised the question of the "stiffness" or the "resistance to viscous flow" of the mix, since it seemed that the asphalt was viscously flowing. The asphalt specification (though not designed to be highly rut resistant) had not changed, and so the focus moved to the binder. Multigrade bitumen has now been used on some recent projects to get the benefit of higher viscosity at service temperatures. However the resistance to stripping of multigrade is something that the coring programme and experience is yet to fully assess.

Specification for asphalt on Australian airports

Asphalt mix design is done in accordance with the Marshall design method using 75 blows per face. The design is based on maximising the bitumen content consistent with achieving the specified design air voids content and the minimum Marshall stability. The philosophy is for good compactability, long durability given very low trafficking, and low permeability. In service, rutting of asphalt mix has not proved a problem. Stripping evaluation of the design mix is done using Austroads Method AST 02 – Stripping Potential of Asphalt – Tensile Strength Ratio. The optional freeze- thaw cycle is not conducted, and the Tensile Strength Ratio should not be less than 80%. A typical specification for asphalt used on runways and on (untrafficked) shoulders is shown in Table 1.

Table 1 Typical specification for Australian airport asphalt

Property	Runway	Shoulder
Nominal Mix Size	14mm	10mm
AS Sieve Size(mm)	Target % Passing (by volume)	
13.2	100	
9.5	82	100
6.7	70	82
4.75	60	70
2.36	44	50
1.18	33	37
0.600	25	27
0.300	16	17
0.150	10	10
0.075	5	5
Filler Content (% of aggregate by mass)	1.5% hydrated lime	
Bitumen Content (% total Mix by mass)	5.8	6.1
Marshall stability (min, kN)	12	8
Marshall flow (max, mm)	3	4
Marshall air voids target (%)	4	4
Voids filled with bitumen target (%)	75	80

The specifications used for asphalt for airports in Australia differ from the road arena in several respects. Firstly they have been written by only a handful of individuals, and they have been essentially unchanged for decades, apart from necessary updating. Second, they are Marshall based designs rather than the performance designs common in roads today. Third, the wheel loads during the period have been fairly constant, although are starting to increase with the latest Airbus models (Table 2). The number of loads (axles) has increased over time, but a busy airport still has much fewer loads in comparison to a busy road.

Table 2 Aircraft loads

Aircraft	Mass/tyre (tonnes)	Tyre pressure (kPa)	Period in Australian service
Boeing 727-200	22.6	1170	1960s onwards
Boeing 737-400	16.2	1440	1970s onwards
Boeing 747-400	23.6	1400	1980s onwards
Airbus A340-600	29.1	1610	2003 onwards (limited usage)
Airbus A380-800	26.6	1500	2007+

Fourth, if the airport mix specification was assessed for roads usage, it would raise real concerns over rutting. The airport mix has a high binder content, the grading is very close to the maximum density line, and the voids filled with binder are high. A void structure overfilled with binder will tend to lubricate aggregates (or even force them apart) thereby reducing frictional resistance with a resulting increase in rutting potential. From fundamental principles, the mix aspects related to rutting resistance are the viscosity of the mastic, packing characteristics of the mix, volumetric aspects, and aggregate characteristics. The airport mix design is relying more than usual on the viscosity of the mastic for its rut resistance.

An assessment of the rutting potential of the airport mix was made here using an expert system (a system from Jooste and Kong Kam, 2000) for a typical busy airport in a warm climate using Class 320 binder and the airport runway specification (Table 3). A model output value of -3 is indicative of a mix with a very high rut potential and a value of 3 is indicative of a mix with low rut potential. The calculated value of -0.35 suggests moderate rut potential for the airport runway mix. For the same airport mix used on a busy road with slow moving traffic, the calculated value was -0.95 which suggests high rut potential. This determination must be set against the experience on airports where rutting of asphalt mix has not proved a problem.

Table 3 Expert system assessment of rutting potential

TEST PARAMETER	SCORE	WEIGHT	TOTAL
Viscosity @ 60 °C after RTFOT	4	0.25	1
Softening Point after RTFOT	2	0.25	0.5
Indirect Tensile Strength	2	0.25	0.5
VFB	1	0.25	0.25
ENVIRONMENTAL	SCORE	WEIGHT	TOTAL
Temperature zone	3	-0.3	-0.9
Heavy vehicles/lane/day	1	-0.2	-0.2
Average heavy vehicle speed	2	-0.25	-0.5
Traffic Intensity	4	-0.25	-1
	TOTAL		-0.35

On some airport projects, mix design using gyratory methods has been run in parallel with the Marshall design to give an appreciation of the performance. Compaction to refusal has shown the airport mix to have air voids lower than the roads minimum, which is as expected for this mix. However this must be set off against the airport functional properties of low air permeability, good durability and compactability. Australian practice has been benchmarked against international airport practices in a separate exercise several years ago and found to be comparable. However the change in loads with the new Airbus aircraft, and the development in road authority mix design systems, mean that the airport asphalt mix specification will need review again in the future.

International use of asphalt on airports

Asphalt is widely used internationally for airports. A recent European survey (EAPA, 2003) resulted in the following data on its usage on European airfields (Table 4):

Table 4 Use of asphalt on European airports

Runways	Total of airports	Asphalt pavement	Concrete pavement	Others
All types	362	226	70	66
Runways > 3000 m	126	58	37	31

A range of binders is used in Europe. In Germany for runway, taxiways and aprons, both dense graded and stone mastic asphalts are used, often with bitumen of penetration 50-70 dmm. Polymer modified bitumen to their PMB 45 or 65 grade is also sometimes used (softening points >70 °C and >65 °C respectively, and elastic recoveries > 50%).

In France, the general standards for road construction are applied for the surface wearing course, but the following guidelines have been developed for airports (Table 5). Layer thickness ranges from 40 to 90 mm depending on the grading. The French make some use of the newly developed High Modulus Asphaltic Concrete, not yet considered in Australia, and rather different to any locally available product. This uses a hard bitumen, highly modified by polymers and additives, to give the mix mechanical characteristics significantly improved to those of high modulus asphalt. It has particularly high resistance to rutting and good resistance to shear and puncturing by static loads (Ballié, 2004). One such commercial binder (Colas Multicol) has a stiffness modulus in excess of 15,000 MPa at 15°C and 10 Hz.

Table 5 French wearing course guidelines

Application	Medium level performance	Heavy-duty performance
Runways	Airport asphalt concrete (improved stripping resistance, altered performance requirements)	High Modulus Asphaltic Concrete, or concrete or porous asphalt
Taxiways	Airport asphalt concrete or traditional asphalt concrete	High Modulus Asphaltic Concrete for wearing course, or airport asphalt concrete

In the United Kingdom, the general solution is to use dense graded asphalt for both basecourse and surface courses, generally using unmodified binder. PMBs are sometimes used in high stress areas. Porous friction course has been used extensively on runways in the UK for nearly 40 years.

In the USA, the general solution has been dense graded asphalt with unmodified bitumen (in their terminology, asphaltic concrete with asphalt cement). Asphalt is very widely used for wearing courses, and it is also used for basecourses, and sometimes as full-depth asphalt. Both grooving and porous asphalt are used for friction treatment. Their FAA has allowed the use of PG graded asphalts from 2000. The FAA has not addressed Superpave asphalt design yet in their airport asphalt P-401 specification, but they have issued preliminary guidance on its use (Herrin, 2004)

SURVEY OF AUSTRALIAN AIRPORTS

Survey and inspection

The Technical Working Group of the Australian Airports Association undertook a survey of the performance of runway surfacings on Australian airports in 2004. Returns from 38 civilian and military airports, covering 62 runways and the main Australian airports, were analysed (Kubu Australia, 2005a).

Of the runways and airports surveyed, two-thirds of the runways with asphalt surfacing and grooving have problems with groove closure (Table 6). Groove closure appears to be directly related to slow moving (and heavy) aircraft. As soon as the aircraft speed increased, the groove closure stopped. Where a taxiway crossed the runway, and the geometry was such that slow taxying would occur, there was groove closure right across the runway as the aircraft taxied across and directly in the wheeltracks.

Table 6 Survey of groove related asphalt problems

Grooving problems	Asphalt binder			
	PMB (A10E)	C320	Multigrade	HiPar
Yes	3	6	1	2
No	1	6		

A team of airport engineers then inspected certain airports where problems had been identified with groove closure and unsatisfactory surfacing performance.

Groove closure

The early stage of groove closure were plastic flow of the asphalt into the grooves, and sometimes stone at the edge of grooves had rotated slightly. The inspection and discussions with other airport engineers found that groove closure typically occurs in the first 1-3 years of a new surfacing, but not after that (for new surfacings, grooving is routinely delayed some weeks to allow initial hardening). It is logically related to a property of the surfacing that changes with time, and that is probably aging and hardening of the bitumen. This in turn is related to bitumen viscosity. It also found that groove closure occurred in the warmer months, and that must be related to a property of the surfacing that changes with temperature. Logically that is stiffness of the binder and asphalt, and again viscosity of the binder.

The mechanism of groove closure is thought to be viscous flow. Examination under the microscope of asphalt, which had been pushed/flowed into the groove, shows binder still covering stones and suggests a problem with stiffness/cohesion rather than adhesion. Given the pattern of occurrence, closure has to be related to a property of the surfacing that changes with aircraft speed (i.e. loading time). For bituminous surfacings, the stiffness modulus of the bitumen and the stiffness modulus of the asphalt are known to vary with loading time. Bitumen stiffness also depends on bitumen viscosity, which also varies with age. Since the airport mix specification has a moderate rut potential and is relying heavily on the viscosity of the mastic for its rut resistance, binder viscosity is a key issue.

Groove edge break

The inspections and survey also found groove breaking/crumbling, which is not the same as groove closure. Asphalt at the edges of grooves breaks off. Groove breaking is probably caused by horizontal stresses from aircraft tyres allied to insufficient cohesion. Research by De Beer et al (1999) on tyre/pavement contact stresses has shown significant horizontal stresses due to the tyres. De Beer used the Vehicle-Road Surface Pressure Transducer Array (VRSPTA) system to measure contact stresses under moving loads, i.e. Stress-In-Motion (SIM). An aircraft tyre for a Boeing 747-100 was tested as part of the research (46 x 16, 30 ply rating at 1448 kPa inflation; loaded in testing to 20-50 kN).

The VRSPTA, at right angles to the direction of travel for the free-rolling smooth tyre, clearly indicated *inward shear* towards the tyre centre. From this it was postulated that the pavement surface is experiencing a tensile stress *outside* the tyre edge and a state of compression towards the tyre centre. Other horizontal stresses were found in the direction of travel. For the Boeing 747 tyre, the measured maximum contact stresses were:

- transverse contact stresses of 261 - 502 kPa
- longitudinal contact stresses of 137 - 279 kPa
- vertical contact stresses of 2057 - 2240 kPa

These horizontal stresses are significant but less than the typical tensile strength of many asphalts, although low tensile strength cannot be discounted for some asphalts. Along the edge of a groove where the asphalt is unsupported, the horizontal stresses might be sufficient to cause edge breaking of some asphalts and especially those made with A10E PMB binder.

Stone loss

The inspections and survey also found stone loss, which could be due to the same horizontal forces causing groove edge break. Examination under the microscope of stones (5-10mm diameter) that had been freshly plucked from asphalt shows that they still have bitumen adhering to the stone. The asphalt was made with A10E SBS PMB and the failure/break appears to be in the binder. This suggests a problem with cohesion rather than adhesion.

The asphalt of another runway made with A10E was giving off "dust" or "grit" from the whole surface of the runway. This started shortly after construction and continues several years later. Runway sweeping currently picks up approximately 12kg of "dust" every two weeks. Examination of the dust under the microscope showed a mixture of binder coated and uncoated grains in the size range 0.3-1.5 mm.

Stone loss (and groove breakage) creates a significant foreign object damage (FOD) hazard. While part of the airport FOD risk management strategy is frequent inspection and sweeping, surfacings which generate FOD are unacceptable in an airport environment.

Jet blast erosion

There has been jet blast erosion of an asphalt runway surfacing (made with A10E) at one airport. Jet blast erosion occurs in a wide swath underneath each of the engines, which includes areas both inside and outside the wheeltracks. The pattern of erosion indicates that it is four engined aircraft causing most of it, and logically this is the Boeing 747 aircraft. The mechanism for this blast erosion is uncertain but might be related to cohesion of the asphalt at this airport.

Soft binder

At one airport, the asphalt runway surfacing (made with A10E) was reportedly unusually soft in hot weather (summer), and capable of being penetrated to over 25mm depth by a screwdriver pushed in by the groundsman. By contrast in cool weather it was hard. This is unusual behaviour. The use of a screwdriver like this is not a standard test, however it is not dissimilar to the common ball penetration test for sealed surfacing design. Typical ball penetration test values in dense graded asphalt would be 1-3mm, and it is a concern that the screwdriver penetrations were much higher. The groundsman monitored the penetration over time in an informal process. The screwdriver penetration remained very high in hot weather, although is decreasing some 3 years after construction. The full length of the runway was affected. Despite this softness, no rutting of the asphalt was observed or reported which meant that the softness has not led to the mix deforming. The penetration is related to the temperature of the surfacing (Figure 1). The slight lag between penetration and surfacing temperature is probably the result of temperature gradients within the asphalt layer.

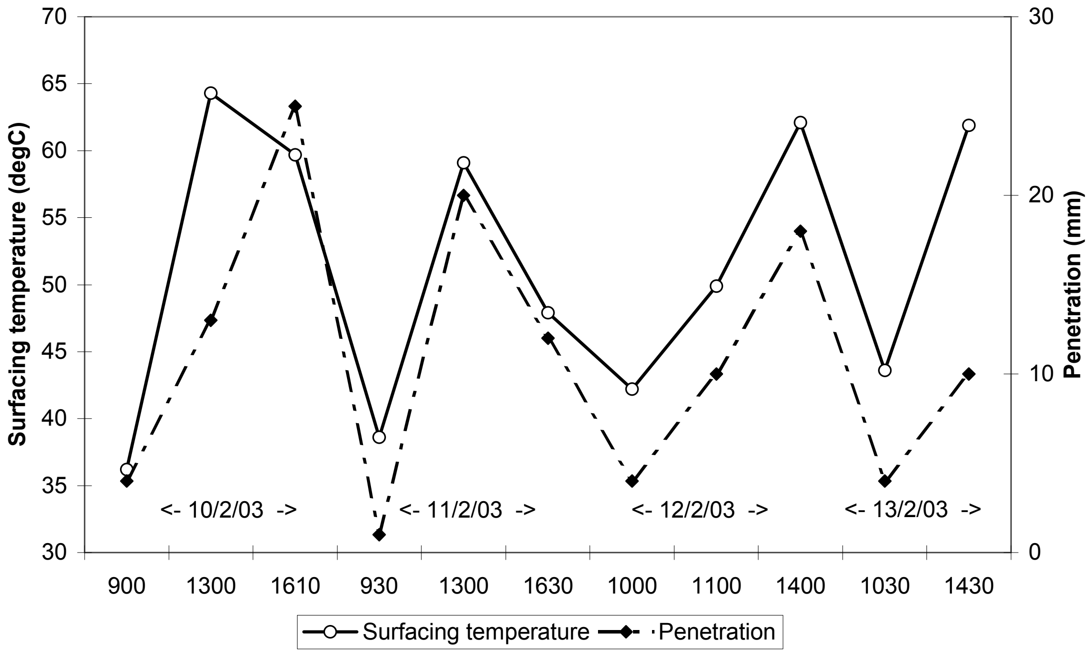

Figure 1 Airport M : screwdriver penetration vs surfacing temperature (Feb 03)

Discussion on asphalt made with various binders for Australian airports

The survey and inspection gave insights into the performance of asphalt made with the various binders. More insight on performance is expected after the coring research.

(a) The inspected asphalt made with multigrade C1000/320 bitumen (in a warmer climate) performed well with no groove damage linked to it. The groove closure linked to the single example of multigrade bitumen in asphalt was possibly a result of non-multigrade bitumen being used for the affected section.

(b) The inspections found that the asphalts made with Class 320 bitumen had performed reasonably. However the survey of airports found groove damage linked to half the asphalts made with C320 bitumen. One example of groove closure linked to Class 320 bitumen was very probably C170 bitumen being mischievously supplied for the affected sections. It should be noted that some airports have used bitumens other than Class 320, either because of high traffic levels or hot climatic areas. Some airports have also found stripping problems with asphalt made with Class 320 bitumen.

(c) Three of the four runways with polymer modified bitumens (made with SBS or SBS-blends) in the survey had problems with groove closure, groove edge breaking, jet-blast erosion, and/or softness in warm weather. On this very limited database, there were proportionately more problems reported with PMB than with Class 320. It may be that the Australian A10E grade of PMB bitumen has necessitated high polymer levels, and thus high levels of aromatic oils that have softened the bitumen phase. However some A10E products are reportedly made with lower levels of aromatic oils. The coring programme initially suggests that SBS polymer modification has improved the stripping resistance of asphalt.

(d) There seems little point in specifying a "good" bituminous binder if there is no assurance that the specified binder will actually be used. Some of the problems derive from the wrong bitumen being used. The quality control systems, which are allied to current Australian bituminous industry practice, are evidently not sufficient, and quality control needs to return to testing the product and its components.

Interestingly some overseas airport authorities are reportedly finding the need to do the same.

This discussion on binders is made within the framework of the airport mix specification having a moderate rut potential. The mix is relying heavily on the viscosity of the mastic for its rut resistance, and the binder viscosity is a key issue.

AIRPORT TESTING PROGRAMMES

Coring programme

A coring programme was undertaken to determine the extent of the “stripping” problem around Australian airports and the potential relationship to binders and traffic. Cores were taken from a number of asphalt pavements of different ages, different binder types, and different trafficking. The programme is close to completion, but the early results are clear that stripping is widespread.

Bitumen stripping occurs when the bitumen loses its adhesion to aggregates in the asphalt mix. Stripping usually occurs with the presence of moisture in the asphalt layer and is worsened when traffic loading causes high pore pressures within the asphalt surfacing. Under saturated conditions, all asphalt mixes may fail as a consequence of cyclical hydraulic stress physically scouring the asphalt binder from the aggregate (Kandhal and Rickards, 2001). This mechanism undoubtedly explains the stripping in some airport pavements.

However there is stripping on airports in areas where there is no traffic, although it is more severe in the wheeltracks (Table 7). In some cases, the water table is not near the surface. There are probably mechanisms present other than physical scouring, and investigations continue.

Table 7 Preliminary coring results

Stripping of coarse aggregate	Binder type		
	C320	Multigrade	A10E PMB
minimal	8%	25%	4%
moderate	70%	40%	93%
serious	22%	35%	4%
Total number of cores	54	20	28

Stripping of coarse aggregate	Location	
	In wheeltracks	Outside wheeltracks
minimal	9%	11%
moderate	66%	85%
serious	25%	4%

Note 1: Stripping was by RTA assessment.
Note 2: The same trend was evident for stripping of fine aggregate

Binder testing programme

The concerns over the contamination of binder used for asphalt (this phrase is used here to include the wrong grade or wrong binder being supplied) showed a need to revise the quality control systems in place. The AAA established a binder testing programme on selected projects in 2004/2005. Preliminary bitumen audit protocols were set out for sampling bitumen during construction. The programme is also gathering additional data for use in measuring temperature susceptibility and other parameters.

At this stage, protocols have only been applied to several projects, covering C320, multigrade, and A10E binders. The early results are supportive of the value of this testing.

BINDER AND MODIFIED BINDER PRODUCTION FOR AUSTRALIA

The survey and inspection raised concerns over properties of the binders being used on airports. Some of the main concerns were:

- Who are the polymer modified binder manufacturers in Australia?
- Is there a possible softness in the SBS polymer modified binder?
- What are the sources of [unmodified] bitumen sold in Australia?
- Has there been a change in the bitumen over time?

Polymer modified binder manufacturers in Australia

The producers of polymer modified bitumens in Australia at February 2005 were (in alphabetical order):

- Bituminous Products
- BP
- Pioneer Road Services (PRS)
- PMP
- Rubberised Bitumen Services
- SAMI
- Shell (through PRS)
- NT Rubberised Binders

This list is expected to vary over time as companies/plants open or close and as commercial arrangements change. A clear distinction should be drawn between the producer and seller of modified bitumen. It is common to buy modified bitumen from one company that has been manufactured in the plant of another. Some PMB manufacturers are toll producers. They will manufacture for anyone, but the recipes and process are usually controlled completely by the toll manufacturer.

Possible softness in the SBS polymer modified binder

The evidence from the airports survey and inspections suggests that there is a possible softness in the A10E SBS polymer modified binders used on airports, notwithstanding the moderate rutting potential of airport asphalt. This seems to run counter to the extensive evidence of improved fatigue life and rut resistance for SBS PMBs, and their high viscosity (and consistency) when tested at elevated service temperatures.

This issue stirred up intense debate over the Underlying Viscosity (UV) concept which was an attempt to quantify the viscous response of a PMB (slow speed loading) (the concept is discussed in Tredrea, 2003). A subsequent report by Phillips (2004) suggested that "underlying viscosity" had limitations that were not shared by some other binder rheological properties.

The exact nature of the so-called "softness" so far has not been able to be defined. There are indications that it exists from some complex modulus master curves, yet not from others. When tested by the dynamic shear rheometer, the phase angle (δ) of the SBS PMBs reduces at lower frequencies (slow loading, high temperatures), while that of Class 320 remains near 90 degrees. Splitting the complex modulus (G^*) into the loss modulus (viscous component, $G^* \sin \delta$), and storage modulus (elastic component, $G^* \cos \delta$), and studying the binders at lower frequencies gives some insight into the "softness". Groove closure is characterised by slow aircraft speed and hot weather. It is likely that for these conditions the loss modulus of some A10E SBS PMB formulations is lower than that of C320, which is sufficient to allow groove closure/breakage along the unsupported edges, at least for the first few years of service. Elsewhere in the asphalt surface, where there are no grooves, the strong SBS polymer network plays its part, and no deformation is seen. It is significant that the A10E asphalt in Figure 1 showed no rutting after 3 years service despite its softness in hot weather.

In general, a polymer modified bitumen can be considered a finely dispersed emulsion of a polymer-rich phase in a base bitumen-rich phase (Molenaar et al, 2004). The matching of the bitumen chemistry to the polymer requires that the two phases be compatible if a sufficiently stable mixture is to be obtained, free from a tendency to segregate during mixing or storage. For a highly modified SBS PMB, compatibility requires that bitumen should be low in asphaltenes and have sufficient oil of the correct aromatic content to react with the polymer. A typical A10E formulation of the sort currently used in Australia will have 6% SBS polymer and up to 6% aromatic oil (see for example Vonk and Hartemink, 2003), added to Class 170 bitumen. The base bitumen-rich phase is essentially a soft bitumen, and this might the reason for the so-called "softness" of the SBS polymer modified bitumen at groove edges. Under the horizontal forces at slow loading times, the cohesion of the binder in the asphalt is insufficient when fresh to stop the asphalt from "breaking" before the polymer network can react. These are speculative thoughts, and more work is needed to fully understand the mechanisms.

Unmodified bitumen sources

Unmodified paving grade bitumen sold in Australia is produced from several sources: refining of crude oil by Australian refineries, refining/processing of long and short residues supplied from local and overseas refineries to Australian refineries, and fully imported hot bitumen.

The Australian refineries are Kurnell (Sydney) Caltex; Clyde (Sydney) Shell; Lytton (Brisbane) Caltex (no bitumen production); Bulwer Island (Brisbane) BP; Altona (Melbourne) Mobil; Geelong, (Corio) Shell; *Port Stanvac (Adelaide) Mobil, closed in 2003*; and Kwinana (Perth) BP. The refineries at Clyde, Altona, and Geelong use imported long and short residue feedstock supplied from local and overseas refineries (predominantly Singapore).

Fully imported hot bitumen is supplied from refineries in Asia, Africa, Middle East, and New Zealand to Western Australia, Northern Territory and soon to Victoria, South Australia and Queensland. The quantities of hot bitumen imports are small but are likely to grow substantially. There are many refineries that are able to export hot bitumen to Australia. A separate study of the economics of importation by the author addressed production changes to meet the Australian AS2008 specification, refinery loading, shipping economics, quality control, demand in the refinery's local country, and pricing. A key determinant are the transport economics, and the modelling of these showed some surprising answers - it is not only the closest refinery that can compete in the Australian market. The list of potential and commercially feasible refineries for the export of bitumen to Australia is enormous (Kubu Australia, 2005b). Imported hot bitumen can meet the AS 2008 specification and there is no reason to not use it on the grounds of importation alone.

Change in the bitumen over time

It is sometimes held that bitumen in Australia has changed little over the years. Certainly the bitumen production circuits in Australian refineries are little changed, and since they were optimised for a particular crude diet at design, there should be some basis for continuity. However this picture is misleading. The source of crude oils, other refining circuits, and refinery operating practices have changed over time.

The sources of crude oil for bitumen manufactured in Australia were fairly constant for many years. The latest oil import data suggests that the crudes imported specifically for bitumen have changed in the last few years for some refineries (Table 8), probably as a result of their recent circuit changes. Furthermore the source of crude oils used by overseas refineries supplying residues and hot bitumen to Australia has undoubtedly changed.

Table 8 Changing Middle East imports of crude for bitumen manufacture in Australia

Crude source	2000-01	2003-04
Saudi Arabia	8%	6.5%
UAE	6%	9.4%
Qatar	1%	0.1%
Other	3%	0.2%

There have been a number of changes to refining circuits in Australia. The most significant in terms of bitumen production has been the closure of the lube oil plants at BP Kwinana, Mobil Stanvac (closure of the whole refinery), and Shell Geelong. Others have been the latest round of investment to upgrade refineries to produce low sulphur fuels (diesel). Some changes - taken in isolation - do not appear to directly affect bitumen production. However there are indirect effects because supply chain management means that the crude oil diet, refinery production settings, and economic optimisation of products have changed.

A spin-off from lube oil plant closures is that the aromatic process or combining oils that are used to make SBS and bitumen compatible are no longer locally available. Mobil Stanvac was a major supplier of these oils, and when that closed, they were typically sourced from BP Kwinana and Shell Geelong. Now these lube oil plants have closed, the oils are fully imported. This affects SBS/bitumen production.

Refinery operating practices have changed. The amount of heavy ends that can be drawn out of the crude oils has been affected by changes to refining processes over time. These include running the vacuum distillation column at higher temperatures, an increase in by-products from other (non-bitumen) refinery circuits that can be used to blend with heavy ends, and the use of additional circuitry to get more out of the oil bottoms. Bitumen and the blending components for bitumen have been affected by these operational changes.

Comparison of the current yield from crude oils used for bitumen (or supplying blend components for bitumen), with those from the early 1980s is instructive (Platt's, 1999 and Dickinson, 1984 respectively) (Table 9). The crude yield data was generated using Bonner & Moore's proprietary linear programming system - Refining and Petrochemical Modelling System, and is optimised for topping yield Singapore which is relevant to Australian refinery yields. It is modelled in terms of HSFO content (high sulphur fuel oil) which includes both ship bunkers and bitumen, and so the two sets of data in Table 9 are not directly comparable. However the trend is unmistakable. While the specific gravity of these crude oils is almost unchanged over time, the assay (or yield) has changed quite a bit over time.

Table 9 Changing yield of crude oils used for bitumens in Australia

Country of origin	Name of Crude	Specific gravity	1980s bitumen content (% mass)	Current HSFO 180cst content (% mass) - topping yield
Iraq	Basrah light	0.857	23	57
Kuwait	Kuwait Export	0.869	29	79
	Khafji	0.884	35	89
	Wafra Burgan	0.913	33	79
Saudi Arabia	Arabian Heavy (Safaniyah)	0.888	35	88
	Arabian Light	0.858	14	50
Iran	Iranian Light (includes Agha Jari)	0.856	20	43
	Iranian Heavy (includes Gach Saran)	0.871	25	33

The extent of change in the bitumen sold in Australia has been modelled by the author and others, who created a bitumen industry refining/sales model. It takes in account:

- refineries
  - geographical location
  - commercial supply arrangements
- bitumen production process
  - feedstocks
  - refinery circuit changes which affect bitumen (such as lube oil plant closures, but excluding hydrotreating and alkylation),
- sales
  - market (State by State)
  - hot bitumen imports

The model is based on published data, oil industry sources, and fundamental chemical engineering. The model is approximate. At the detail level, this model is commercially sensitive. It has not been released to the AAA, nor will it be published. At the aggregate level, it is not considered commercially sensitive, and it enables the complete scope of change to be seen.

The model showed that 61% of the bitumen sold in Australia in 2003/4 has come from production routes/sources that were not used in 1983/4 (Table 10).

Table 10 Changing process route used by bitumen sold in Australia

Process route	Bitumen sold in Australia	
	1983/4	2003/4
Crude oil	31%	20%
Long residue into straight run	31%	2%
Long residue into PPA/ Lube Oil circuit	38%	17%
New sources crude oil	-	6%
New sources long residue into PPA/ Lube Oil circuit	-	4%
New sources long residue into straight run	-	51%
Totals	100%	100%

DEVELOPMENTS IN AIRPORT ASPHALT

New airport binder

The concerns over binder led the AAA to consider the properties required for binders. The engineering properties for bituminous binders for airport asphalt were derived from discussions within the AAA Technical Working Group and a review of engineering fundamentals. The airport environment is characterised by:

- Much less traffic over the design period compared to highways,
- Generally stiff pavements,
- Some longer and slower loading times than highways,
- Higher tyre pressures (typically 2x highway) and wheel loads (typically 10x highway wheel loads),
- Night construction work requiring easy compaction of asphalt at the lower end of the temperature limits.

Some of these attributes are found on roads as well, but it is the particular combination that characterises airports. The engineering properties for bituminous binders for airport asphalt, relative to Class 320 bitumen, are the following:

- Good asphalt mixture stiffness at slow loading times and across the service temperature range
- Higher mixture resistance to viscous deformation
- Higher resistance to stripping
- Constructible
- Robust and reliable

These requirements apply to asphalt for trafficked areas. Other parts of the airport such as runway edges, shoulders and blast areas will have different requirements, eg. durability, oxidation of bitumen, erosion of surface.

The AAA then embarked on a co-operative approach, with industry, to jointly develop a suitable solution. Expressions of interest were sought in mid-2005 from those existing modified binder manufacturers likely to be able to service all of Australia. Manufacturers were asked to submit one or more products, which may be products that are currently available and/or new products specially developed to meet the assessment criteria. The product could be a binder or an additive to the asphalt mix. A preliminary evaluation of these products has just been completed, and several will be selected for further investigation and likely large scale trials.

Future airport asphalt specification

Although the experience of airports is that rutting of asphalt mix has not proved a problem, there are changes coming in individual loads with the new Airbus aircraft, and an increase in numbers of loads (axles) as traffic/aircraft increases. Surfacing problems have a number of causes, and binder is only one of them. The changes to binder cannot be made in isolation, and other aspects of surfacing will need attention in the future including the asphalt mix design/specification.

The move of road authority mix design systems to performance based and gyratory designs means that the local asphalt suppliers will focus on these methods, and the future airport asphalt specification needs to be adjusted lest it become an orphan. Overseas, some airports are doing performance testing of mixes for major projects using an advanced testing machine such as the MMLS (Molenaar et al, 2004). These are available in some laboratories and accessible to Australia, and should be considered for major project asphalt designs.

Bitumen quality control

The AAA has established preliminary bitumen audit protocols for sampling bitumen during airport construction and maintenance projects. Eventually the bitumen audit protocols will cover all bitumen types. They do not require the full suite of specification tests, which would lead to excessive testing, but are aimed at reducing the probability of contamination/segregation. Contamination even can occur unintentionally due to industry standard working practices, and may be more prevalent than generally realised (Emery et al, 2004). A hypothetical example is an asphalt plant with a single bitumen tank, which is asked to manufacture polymer modified asphalt for an airport. In this example, the plant's 40,000 litre bitumen tank contains C320 bitumen, of which at least 10,000 litres must remain in the tank to cover the burner tubes. It is then loaded with a truck (up to 28,000 litres) of polymer modified bitumen ready for asphalt production, and as a result the bitumen is contaminated! Furthermore the C320 could upset the careful chemical balance of the polymer modified bitumen and cause further problems.

Education and training

The AAA binder research programme has shown a need for education and training in asphalt. Some of the senior people in airports engineering will be retiring in the next few years, and a mechanism is needed to capture their experience and disseminate it to others.

The cost of establishing and sustainably operating a suitable programme to do this is considerable. For the AAA, it makes logical sense to link in with AAPA as the existing provider of such programmes in the field. At the education level, the respected Centre for Pavement Engineering Education (CPEE) has a number of courses offered as part of a higher degree in pavement engineering. There is already an airport component as part of the existing Industrial & Heavy Duty Pavements course, although it is more focussed on structural design. At the training level, there is clear anecdotal evidence of the gap in terms of engineering airport bituminous surfacings. Training is needed to cover specification, design, construction, supervision and quality control. The gap is for both asphalt and seal surfacings. One solution is a 'live-in' short course offered to coincide with an airport construction project. This could offer classroom training in the day, and on the job training at night on the airport construction. Such a course could be developed under the auspices of the AAPA Training Centre, and would have international appeal as well as considerable commonality with training in the engineering of bituminous road surfacing construction.

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