Australian airport asphalt surface treatments

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ABSTRACT

Many airport surfaces in Australia are constructed of dense graded asphalt. These surfaces are generally replaced by asphalt overlay every 10-15 years. Airport asphalt surfaces are highly suited to sprayed surface preservation treatments.

There are a range of treatments to preserve and extend the life of asphalt surfaces. These generally replace lost binder and/or fine mineral material. These treatments generally create a temporary protective coating over the existing surface. A number of new materials have largely replaced the traditional coal-tar based and cutback bitumen products. These new materials are emulsion based and often include polymers.

This paper presents a summary of experience and new materials for treatment of asphalt surfaces at Australian airports. Oxidation retarders and surface filling treatments are explored, as well as fuel resistant membranes. A number of lessons learnt are presented and a whole of life approach is undertaken in considering future opportunities.

Keywords: Cutback, Emulsions, Friction, Rejuvenators, Whole life costing

1. INTRODUCTION

There are around 300 registered airports in Australia. Of these approximately 100 have asphalt surfaced runways [1]. Traditionally, airports have expected 15-20 years of life from a new asphalt surface. In recent years resurfacing frequency has increased to around 10-12 years. This is concerning for airport owners and likely reflects a combination of increased aircraft-related distress, as well as a reduction in bitumen quality.

To counter the impact of increased surface distress, life extending surface treatment is of increasing importance. These treatments reduce or retard the impact of oxidation and fuel related damage and can delay resurfacing by asphalt overlay by two to five years [2]. However, like all treatments, there are risks. The right treatment must be selected for the right application to prevent a good treatment from creating an adverse impact on the airport.

The aim of this paper is to summarise the factors that affect the success of sprayed asphalt surface treatments of airport pavements and to present common products and approaches available. A number of lessons learnt from twenty years of development and change are also provided. The treatments described address the environmental ageing and wearing of surfaces, as well as fuel expose damage.

2. BACKGROUND

2.1 Australian Airport Pavements

Australian airport pavements are routinely designed to comprise a thin (50-60 mm) asphalt surface on well compacted and high quality fine crushed rock base course [3]. Thick asphalt and bound base courses are not common for Australian flexible aircraft pavements. Further, Australia currently has no concrete aircraft pavements except at the runway ends, some taxiways and parking aprons at major airports. It follows that the majority of Australian airport pavements are asphalt surfaced and that asphalt surface treatment is a significant consideration for Australian airport owners. Australia has limited experience with open graded and stone mastic asphalt on airports. The vast majority of Australian airport asphalt surfaces remain Marshall-designed 14 mm nominal size dense graded mixtures with runway surfaces grooved to promote friction in wet weather [4-5].

2.2 Operational Requirements

Australia is a member-State of the International Civil Aviation Organisation (ICAO) and adopts or adapts the majority of the ICAO airport design and operational requirements [5]. Australian airport requirements are contained in the Civil Aviation Safety Authority (CASA) Manual of Standards Part 139 (MOS 139). Key aspects impacting on sprayed asphalt surface treatments include provisions relating to Foreign Object Debris (FOD) and surface texture/friction.

FOD is a significant risk to aircraft, particularly the engines. Common sources of FOD include aircraft parts, tools and loose stones from the surface. Surface treatments only impact FOD generated from loose stones, in the form of coarse aggregate coming from an asphalt surface. ICAO and CASA require FOD-free surfaces for all aircraft pavements. This requirement encourages the use of asphalt surface treatments that assist in the retention of coarse aggregate.

Regarding surface friction, aircraft landing speeds are not optional. A pilot does not have the ability to simply slow down when landing in wet weather in order to reduce the risk of skidding. It follows that maintaining a surface with good skid resistance, via surface macro-texture, are significant issues for ICAO and CASA. In Australia, many of the ICAO recommendations and guidelines have been made mandatory by CASA. Elements affecting asphalt surface treatments include [5]:

- **Surface texture**. A minimum surface texture of 1 mm (by sand patch test) is required to be maintained. New dense graded asphalt surfaces rarely exceed 0.6 mm. As a result, grooving is common in Australia. Some use of open graded asphalt and coarser asphalt mixtures (20 mm nominal size) have also been trialled but have been discontinued in Australia.
- **Friction levels**. The ICAO recommended maintenance planning and interventional levels for friction, measured by a self-wetting continuous friction measuring device, are mandatory in Australia where the surface texture requirement is not met.

The routine grooving of runway surfaces creates a challenge for the application of surface treatments as grooves can be filled with treatment product. Sprayed treatments also reduce surface texture and can adversely impact friction levels. These challenges must be balanced against the competing need to maintain a FOD-free surface by minimising the loss of coarse aggregate from the surface and the desire of the airport owner to minimise the period between resurfacing. It follows that sprayed asphalt surface intervention plays a significant role in airport surface whole-of-life considerations.

2.3 Surface Treatment Intervention

Sprayed surface treatments for asphalt are commonly used by airports in Australia. The main categories of treatment intervention are:

- **Oxidation retarders**. Commonly referred to as rejuvenation treatments or fog coats.
- **Surface fillers**. Commonly referred to as seal coats, polymer modified emulsions or fine slurry seals.
- **Fuel resistance membranes**. Also referred to as fuel resistant surfaces or fuel resistant treatments.

The first two categories are intended to preserve asphalt surfaces from age-related degradation [2]. The third is intended to protect asphalt from the damaging effects of fuel spills [6]. Many proprietary products have been developed and introduced by Australian suppliers, or imported into Australia in recent years. As a result the 'generic' specification of such products has become complex and there is limited opportunity for side-by-side performance comparison between products offered by different suppliers.

2.4 Associated Issues

Increasingly demanding aircraft

Since WWII aircraft have been developed to be more efficient [7]. This has resulted in incremental increases in individual wheel loads, tyre pressures and in some cases, the number of wheels on a single aircraft landing gear strut [7-10]. Wheel loads and tyre pressures have significant impact on asphalt surfaces. Demonstrative historical aircraft tyre pressures and wheel loads are shown in Table 1, showing an increase over time that has led to increased demand being placed on asphalt surfaces.

Table 1: Aircraft tyre pressure and wheel load evolution

Aircraft	First Service	Tyre Pressure (MPa)	Wheel Load (tonnes)
B727-100	1963	1.05	10.4
B767-300	1986	1.35	18.3
B737-800	1997	1.41	21.4
A340-600	2001	1.61	30.8
A350-900	2016	1.66	31.8

Due to the number of variants and configurations available for modern aircraft, some tyre pressures and wheel loads may not be exact.

Variability and performance of bitumen

There is a widely held perception that bitumen performance has decreased over the past 30 years. Certainly in Australia there has been a significant change in oil source and production refineries [5] that has led to measurable changes in bitumen properties over time [11-12]. A number of performance issues have also been reported, most commonly in high stress and high temperature environments, such as airports [13-14].

Proprietary products and expertise of specifiers

The divestment of airport ownership by the Australian Federal Government in the 1980s resulted in the closure of the various Roads and Aerodromes sections of the various Government departments. Subsequently, the aircraft pavement engineering expertise was decentralised and became embedded within the various professional services companies with airport design capability. Staff training, technical development, research and new product development and evaluation efforts were substantially reduced or discontinued [15].

The decline in professional design expertise within the clients and consultants resulted in a relative up-skilling of the suppliers and surfacing contractors. Australian airport surfacing contractors now retain in-house expertise and research and development teams focused on the evaluation and development of new proprietary products. Many of the products now used for asphalt surface treatment have transitioned from being generic materials specified by designers, to being proprietary products that are offered by surfacing and maintenance contractors. It follows that products have become diverse and while many products are similar in their intent and composition, comparison of equivalence and evaluation of field performance is challenging.

3. OXIDATION RETARDERS

3.1 Treatment and application

Oxidation retarders are light applications of bitumen without mineral filler or aggregate. The bitumen film protects the binder in the asphalt surface from oxidation and environmental exposure. Where the surface bitumen has been lost, the oxidation retarder may partly replace the lost binder. Oxidation retarders will not address segregated or coarse surface texture.

Oxidation treatments are most suited to surfaces that are early to mid-way through their lives by preventing further bitumen oxidation without replacing lost mastic. There is potential benefit in very early application where it does not adversely impact surface friction. An example of a suitable treated surface, before and after an oxidation treatment, is shown in Figure 1. Some report that additives or modifiers in the oxidation treatment can rejuvenate the asphalt binder by reversing the oxidation. However, it is likely that the measured reduction in binder brittleness is actually the dilution of the oxidised bitumen in the new bitumen from the surface treatment.

(a)

(b)

Figure 1: Suitable surface for oxidation retarder (a) before and (b) after treatment

Application rates are typically low to prevent excessive surface texture loss and to minimise curing time. From a whole-of-life perspective, it would be advantageous to increase the rate as high as possible, without adversely affecting curing time or friction. Rates depend on the surface condition and can be higher in un-trafficked areas. A runway application rate of 0.25 l/m^2 of residual bitumen is common.

3.2 Experience

Traditionally, cutback bitumen was used as the primary oxidation retarder in Australia and these treatments were commonly termed Surface Enrichment Sprayed Treatment (SEST). When airports were less busy and less commercially focused, closure for a few days to allow treatment and curing was possible. However, a reduction in the willingness to accept medium-term runway closures reduced this opportunity. A number of treatments also failed to cure in a 'normal' period of time, with taxiways closed for up to three weeks. This was likely the result of changes in the properties of imported bitumen in Australia. As a result, such treatments became restricted to smaller airports, where pavements could be completely closed indefinitely. Shoulders and other un-trafficked areas remain able to be treated with cutback bitumen. To mitigate the curing-time risk, faster evaporating 'power' cutters were introduced. With significantly lower flash points, these lost favour due to safety concerns.

Coal-tar based products were also common. These products allowed faster curing more safely because the product was emulsified (in petroleum products) rather than cut back. Coal-tar based products were also fuel resistant which was advantageous. However, coal-tar is carcinogenic at elevated temperatures. Although able to be safely applied at ambient temperatures, coal-tar products lost favour due to concerns during future resurfacing works. During cold planing prior to resurfacing, the friction associated with the profiling teeth heated the surface. Despite the risk being demonstrated to be low, the odour of coal-tar was deemed unacceptable by paving crews. Disposal or reuse of millings contaminated with coal-tar was also problematic due to environmental concerns.

Conventional bitumen emulsion provides a safe and rapid curing bitumen-based alternate treatment. It quickly became favoured by contractors for its safety benefits and clients for its rapid curing. Engineers questioned its ability to penetrate into asphalt surfaces given the higher viscosity of freshly broken emulsion compared to cutback bitumen.

3.3 Future opportunities

As an improvement on conventional bitumen emulsion, without introducing safety or environmental concerns, a number of suppliers developed proprietary modified bitumen emulsions (Table 2). These have been developed to provide increased adhesion to the existing surface, higher softening point, rapid curing time and increased penetration into the existing surface binder by the addition of oils. For example, Fulton Hogan provides SERT [16] for this purpose. Most of these products are modified with a range of polymers. Some, such as GSB-88 are modified with naturally occurring bitumen, such as Gilsonite [17]. Some products recommend the application of a light dusting of sand to promote early trafficking and early-life friction.

Table 2: Oxidation retarder options

Product Type	Advantages	Disadvantages
Cutback bitumen	Good penetration into asphalt	Unreliable curing time Safety issue with fast cutters
Coal-tar emulsion	Good penetration into asphalt Fuel resistant Fast and reliable curing time	Carcinogenic at elevated temperatures Environmental concern for millings
Conventional bitumen emulsion	Applied at ambient temperatures Reliable moderate curing time	Poor penetration into asphalt surface Can remain tacky in hot climates
Modified bitumen emulsion	Applied at ambient temperatures Reliable moderate curing time Improved adhesion and penetration	Proprietary products without generic specification Moderate penetration into asphalt

4. SURFACE FILLERS

4.1 Treatment and application

Surface fillers consist of polymer modified bitumen emulsion with mineral fillers. The polymer modified bitumen is used to increases adhesion and to reduce tackiness of the treatment after the emulsion has broken. The mineral filler is incorporated into the emulsion on site and requires continual stirring to prevent settlement. The role of the mineral filler is to replace the fine aggregate in the mastic that has been lost from the asphalt surface by weathering, ageing and erosion. A typical surface suited to surface filler treatment is shown in Figure 2, before and after treatment.

Surface fillers have also been used in isolated areas of excessive built-in surface segregation. In small and isolated areas, hand application of manually spread product is practical. Where larger areas, or full runway surfaces are treated, a modified sprayer is more efficient.

(a)

(b)

Figure 2: Suitable surface for surface filler (a) before and (b) after treatment

4.2 Experience

Prior to the development of the current range of proprietary products in Australia, sand and conventional bitumen emulsion was used in this application. In isolated areas of built-in segregation the sand was hand-broomed into the surface prior to the emulsion being applied and hand-squeegeed into the sand. Any excess emulsion was countered with additional sand. In large areas, hand application was inefficient. Rather, the bitumen emulsion was sprayed onto the surface by conventional emulsion sprayer and the sand distributed by aggregate spreading trucks commonly used for spray sealing (also referred to as chip sealing or surface dressing). Typical sand and emulsion surface filling treatments are shown in Figure 3.

(a) (b)

Figure 3: (a) Sand over emulsion and (b) emulsion over sand surface filler treatments

4.3 Future opportunities

There are currently three main suppliers of proprietary surface filling products in Australia (Table 3). Fulton Hogan has developed a new purpose-built applicator with a squeegee fitted to the back, similar to a slurry box. Figure 4 shows an applicator with the squeegee and one without. This modification wipes excess product from the aggregate tops and pushes the product into the interstices between the coarse aggregate particles. Texture and friction reduction is minimised and less total product is used. This approach is recommended for all machine-applied surface filler applications. However, the squeegee system can leave a ‘pool’ of product at the end of each run which must be removed and refinement of the squeegee is required.

Table 3: Australian surface filling suppliers

Product	Supplier	Further information
Fulton Hogan	JetBlack	[18]
Downer EDI	Liquid Road*	[19]
SRS Road Servcices	SRS Sealcoat	[20]

* under licence from Seal Master of the USA.

(a) (b)

Figure 4: Surface filler applicator (a) with a squeegee and (b) without a squeegee

5. FUEL RESISTANT SURFACES

5.1 Treatment and application

Fuels, hydraulic oils and other petroleum products soften bitumen and erode asphalt surfaces. Airport parking aprons are frequently exposed to spillage of these materials during aircraft refuelling, cargo and passenger loading and due to venting of fuel from full tanks during hot weather. Although major airports adopt concrete pavements in the aircraft parking areas, regional and remote airports prefer asphalt surfaces. To protect these surfaces from the impact of fuel and other spills, a fuel resistant binder or a fuel resistant coating is required.

Prior to the realisation that coal-tar was carcinogenic at elevated temperatures, tar was often used as the binder for apron asphalt. This provided inherent fuel resistance in the surface. After the discontinuation of tar as an asphalt binder, tar was emulsified (in a low flash point petroleum product) and applied to the (bitumen bound) asphalt as a protective membrane. Following issues with the disposal of millings during subsequent resurfacing works, tar-based products lost favour.

5.2 Experience

Modified bitumen-based fuel resistance products were developed in preference to the tar based products. These bitumen based materials were reported to be very slippery and shrinkage resulted in significant top-down asphalt surface cracking [6] (Figure 5). At around the same time, a fuel resistant bitumen binder was developed. This was trialled at a number of parking aprons and evaluated in the laboratory with inconclusive results [6].

Some airports have returned to coal-tar based fuel resistant membranes regardless the complications during subsequent resurfacing. This short-term approach is questioned, as safety and environmental concerns are likely to increase, not decrease, in the future. The cost of contaminated waste disposal is also likely to increase.

(a) (b)

Figure 5: Examples of (a) slippery and (b) cracked fuel resistant membranes

5.3 Future opportunities

In 2014 a new generation of fuel resistant membrane called JetBloc was developed [21]. This membrane material is a blend of epoxy modified and cementitious polymers. This treatment had significantly improved abrasion resistant, crack resistance and adhesion compared to other available products. JetBloc is also available in any colour. When a light colour is selected, testing showed up to a 40% reduction in surface temperature during hot and sunny weather. A significant asphalt temperature reduction provides significantly reduced risk of asphalt shearing and rutting. A number of airports also appreciate the ability to customise and clearly delineate the aircraft parking positions.

A trial application was applied in 2014 at a military airfield in central Australia, where pavement surface temperatures often exceed 70°C. The application was performed by hand in two coats (Figure 6). Although more expensive than bitumen based products, with a ten-year maintenance-free period and no cracking of the underlying asphalt surface, JetBloc provides significant whole-of-life advantage.

(a)

(b)

Figure 6: JetBloc (a) application and (b) complete

6. EXECUTION AND OPERATIONS

6.1 Operational availability

The majority of Australian airports have a single runway. It follows that the majority of resurfacing and surface treatment application is required to be performed during periods of airport closure. For airports with regular public transport services, such works are often required to be performed at night and the airport reopened and available for full service each morning.

Work windows are often limited to just 6-8 hours and works may be performed during hot or cool weather. The selection of treatments that reliably cure and become trafficable within the available work shift is critical. Curing time is affected by product type, application rate, climatic conditions and existing surface condition. A trial conducted in a small and un-trafficked area is essential to ensure that the availability of the runway will not be compromised by an unexpectedly slow curing treatment. Treatments that require visual assessment and adjustment during application are challenging, even when the best available artificial lighting is employed [22].

6.2 Surface texture and friction

The application of surface treatments, such as oxidation retarders and surface fillers, reduces surface texture [23]. There have been reports of aircraft skidding off runways where the surface texture and fiction has been adversely impacted by surface treatment [23]. Where a surface has ample texture and friction, the reduction resulting from surface treatment is not concerning in light of the benefits associated with the improved retention of coarse aggregate and the minimisation of FOD. However, if the texture and friction are already marginal, then further reduction by the application of a surface treatment is unacceptable. A small trial in an un-trafficked area of the pavement is essential to verifying the impact of the treatment on texture and friction. It is recommended that friction is tested before and after a trial application, usually by a spot-tester such as the British pendulum. Post-treatment survey of treated runways by an ICAO-approved self-wetting continuous friction testing device is also recommended [24].

The application of sprayed surface treatments to grooved surfaces is a significant challenge. Some airports have trialled transverse application of treatments in combination with brooming the product out of the grooves prior to initial setting. Although successful at protecting the grooves, this approach is very inefficient and has significant direct cost and disruption cost implications. An alternate approach has been to spray multiple light applications of surface treatments to grooved runways in opposite directions. The light applications prevent product flow and minimises the impact on effective groove depth.

6.3 Rubber contamination

Rubber builds up on asphalt surfaces as a result of tyre ‘spin-up’ during aircraft landing [24]. Rubber contamination reduces asphalt texture and friction [23]. It also inhibits surface treatments from penetrating into asphalt surfaces. Rubber removal should be considered prior to surface treatment. The rubber removal process itself can erode the asphalt surface and ultra-high pressure water cutting is recommended over water blasting [25].

7. SUMMARY AND CONCLUSION

Over the last twenty years a number of issues have led to significant changes in sprayed treatments for airport asphalt, including:

- Cutback bitumen and tar-based oxidation retarders replaced by proprietary polymer modified bitumen emulsions.
- Sanded emulsion surface fillers replaced by proprietary mineral filled polymer modified bitumen emulsion.
- Coal tar-based fuel resistant membranes replaced by epoxy modified polymer membranes.

Treatment of asphalt surfaces to increase whole-of-life benefits have increased in importance and complexity. This reflects the increase in tyre pressures and wheel loads of aircraft and a decrease in bitumen reliability. The proprietary nature of new generation products reflects their development by suppliers, rather than clients or design consultants, and this complicates their specification.

The development of new generation surface treatments for airports must continue to recognise the work possession periods likely to be available, the impact on surface texture and friction and the likelihood of the existing surface to be contaminated by aircraft tyre rubber. Engineers and suppliers must be diligent to ensure that good products are not applied in inappropriate circumstances and inadvertently compromise runway surface friction and aircraft safety.

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