CHALLENGES FOR AUSTRALIAN FLEXIBLE AIRPORT PAVEMENTS

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ABSTRACT

Since the end of direct Commonwealth government management of Australian airports in the 1990s, there has been no coordinated up-keep of airport pavement technology and practice in this country. In contrast, aircraft technology has advanced significantly. To address significant risks, a number of construction contractors have introduced new products and methods. However, the risk-averse nature of the airport industry has sometimes resulted in good solutions being resisted. A number of challenges relating to flexible aircraft pavements have resulted, including aircraft with higher tyre pressure and wheel load combination than previously experienced and an associated inability to ‘prove’ the upper fine crushed rock base layers during construction. Also, a general reduction in bitumen reliability has resulted in the increased use of polymer modified bitumen for asphalt production, but these products are not readily available in regional areas. Moreover, airport asphalt was routinely rejuvenated to extend the period between resurfacing, but increased concern for the impact of surface treatments on skid resistance has resulted in some designers no longer recommending such maintenance. A reduction in the number of specialised airport pavement engineers has meant that expertise, particularly in spray seal design for airports, has become limited. The reduction in expertise has also seen the development of new methods for expedient airport pavement rehabilitation be substantially left to construction contractors. A collaborative, airport-industry-wide initiative is essential to addressing these challenges in the future.

1 INTRODUCTION

The technology, design and specification of Australian airport pavements dates from a practice developed by the Commonwealth Department of Works after the Second World War. This practice generally mirrored that developed by the US Army Corps of Engineers in the 1940s and 1950s. At that time, Australian airports were owned by the Commonwealth and were managed by teams of Commonwealth employees within the various Roads and Aerodromes branches. What had by then become the Department of Housing and Construction was disbanded in 1982 and direct management of airports by the Commonwealth ended in 1998 (Eames 1998). At that time private corporations, mining companies and local Government bodies (Councils) became the primary operators of airports in Australia.

The responsibility for managing, maintaining and developing airport infrastructure now rests with private airport owners and Councils. One exception is the 28 airfields managed by the Department of Defence, on behalf of the Commonwealth, for military aviation activity. The other exception is a small number of remote offshore airports that fall under the control of the Department of Regional Australia, as a service to isolated communities. Since the privatisation of the majority of the airports in Australia, engineering consultants have become the primary specifiers and designers of Australian airport pavements.

Competitive tendering and the ‘lowest-complying-bid’ philosophy maintained by some airport owners means that engineering consultants are not resourced to investigate, develop and implement new technology. That is not to suggest that the design consultants are not capable. Rather, they are simply not commissioned to do more than produce project-specific documentation. Similarly, airports do not retain technical expertise to significantly advance technology and practice. Construction contractors and material suppliers have evolved to partially fill some of the airport pavement technology void left by the demise of the various Commonwealth Roads and Aerodromes branches. However, contractors and suppliers are focused on developing proprietary products and processes with intellectual property that can protected in order to realise a return on their investment. Further, engineering consultants are not incentivised to adopt new technologies developed and offered by contractors and suppliers. Similarly, airport owners are generally keen for innovation and advancement, but only when solutions have been tried and proven on other airports. It follows that good solutions developed by industry remain limited in their application as designers and airport owners wait for others to validate the benefits.

As a result, the technology, practice and specification of airport pavement engineering solutions in Australia remains based on the practices developed by the various Commonwealth departments, with only minor changes to reflect challenges encountered. In some cases, designers have tended to adopt practice and tools developed by the Federal Aviation Administration of the USA. This often results in less economical solutions or pavement designs that are not suited to local conditions and materials. In contrast to stagnated design and technology practice, airport operations and aircraft technology have developed significantly over the same period. The aim of this paper is to highlight a number of key challenges resulting from the stagnation of flexible aircraft pavement design and specification technology. After
the evolution of aircraft is detailed, proof rolling of aircraft pavements, bitumen for asphalt, sprayed seal design and maintaining skid resistance during rejuvenation are all discussed. The growing requirement for expedient construction and rehabilitation methods is also addressed.

2 THE EVOLUTION OF AIRCRAFT

Since their first introduction in the early 1900s, aircraft have become progressively larger and heavier. Particularly since WWII, aircraft wheel loads and tyre pressures have increased significantly (Roginski 2007; Fabre et al., 2009). New aircraft, such as the A350-900, have tyre inflation pressures up to 1.66 MPa and wheel loads up to 31.8 tonnes. Further, the pavement strength rating system used by airports (known as ACN-PCN) was developed in 1981 to protect subgrades against pavement rutting due to overloading. The system was not developed to protect asphalt surfaces from higher tyre pressures or wheel loads as this was not an issue at that time. ACN-PCN has since been demonstrated to be unable to indicate to airport owners the increased risk of near-surface failures resulting from new, more demanding aircraft (White, 2015b).

It is inevitable that aircraft tyre pressures and wheel loads will continue to increase in the future. In 2008, increases in the tyre pressure limits contained in the ACN-PCN system were proposed by major aircraft manufacturers (Rodway, 2009). This proposal was approved in 2013 (Roginski, 2013) impacting around 40% of asphalt surfaced runways in the world (Shepson, 2009). The international group responsible for the ACN-PCN system is now considering a proposal to further modify the strength rating system. The impact of further changes on aircraft tyre pressures and wheel loads is not known. However, near-surface distress is triggered by shear stresses, which are affected by tyre pressure and wheel load combinations. As tyre pressures and wheel loads increase, distress of airport pavement asphalt surfaces can only become more likely. Further, ACN-PCN cannot identify this increased risk of surface distress.

3 PROOF ROLLING FOR AIRCRAFT LOADING

Unlike other countries in the world, Australia has made good use of high quality fine crushed rock in airport pavements. The high quality of Australian crushed aggregate has allowed relatively thin (typically only 50-60 mm) asphalt surfaces to be provided over crushed rock base course. Other countries, such as the USA, design at least 100 mm of asphalt at the surface, in recognition of a lower crushed aggregate quality. However, proving each crushed rock layer, as it is constructed, is essential to the Australian approach. In contrast, the USA requires a bound or stabilised based under the asphalt surface of pavements for substantial aircraft. Proving of each layer involves a number of coverages of a high tyre pressure ‘proof roller’ in order to induce a stress within the layer that slightly exceeds the level of stress expected at depth as an aircraft passes over at the finished surface level. As depth within the pavement increases, the required proof roller tyre pressure reduces (White, 2008). It follows that pavements with thick bound surfaces require lower maximum proof rolling tyre pressures than pavements with thin asphalt surfaces, such as those common in Australia.

It is essential that proof rolling be performed while the base course material is at or near optimum moisture content. This allows the compaction benefit to be realised and weak spots to be identified. Bound materials, such as cement treated base course, are not compactable once cured. However, prior to curing, the bound layer is likely to deform excessively under the high tyre pressures and wheel loads of the proof roller. The resulting ruts are impractical to correct without replacement of the cement treated material. It follows that it is only possible to proof roll cement treatment layers when they are cured, by which time the layer is essentially bound and no longer compactable. Further, bound materials rely on the tensile strength provided by the binder to resist deformation under wheel loads. Proof rolling of bound materials is not appropriate. Despite this, a number of projects have required bound layers to be proof rolled similar to that specified for granular layers.

3.1 PROOF ROLLING TYRE PRESSURES

In a summary on airport pavement practice in Australia, Emery (2015) states that a proof rolling tyre pressure of 700 kPa and wheel load of 2.3-4.5 tonnes is adequate for most airport pavements. The use of the Marco rollers, up to 1000 kPa and 12.5 tonnes per wheel is also recognised. The original heavy pneumatic tyred rollers, often referred to as Marco or Macro rollers, were designed and operated with tyre pressures up to 1,400 kPa. The over-inflation of earthmoving tyres (generally rated to 1,000 kPa) was necessary to replicate the high stresses in the upper basecourse layers resulting from aircraft with high tyre pressures on thin asphalt surfaces (White, 2014b). Further increases in aircraft tyre pressures have occurred since the rollers were developed.

For many years, the tyre manufacturers conditionally allowed over-inflation of earthmoving tyres subject to a number of operating constraints, including limiting roller speed and part-filling roller tyres with water. Around the year 2000, the conditional over-inflation permission was revoked by all earthmoving tyre manufacturers citing safety concerns. Since that time, 1,000 kPa has been adopted to reflect the rated maximum inflation pressure of earthmoving tyres fitted to the proof rollers.
The 1,000 kPa tyre pressure limit has left a proving ‘gap’ at the top of the pavement. The uppermost 100 mm of basecourse is often exposed to stresses exceeding 1,000 kPa when modern aircraft, including the common B737-800, are operated on pavements with thin asphalt or spray sealed surfaces (White, 2008). As aircraft wheel loads and tyre pressures increase, the gap between aircraft-induced stress and proof roller capability broadens. To further complicate the situation, most of the original Marco/Macro rollers are controlled by the Department of Defence. Many rollers are in poor condition and Defence no longer makes them available for use.

3.2 DESIGN OF PROOF ROLLING REGIMES

Proof rolling requirements are aircraft and pavement specific. Designers must determine the proof rolling regime on a project-by-project basis. In practice, this rarely occurs and standard or default regimes are left unchanged in specifications from one project to the next. White (2005) documented the use of the APSDS stress-with-depth function to compare aircraft-induced and roller-induced stresses. This formed the basis of an analytical method for proof rolling regime determination.

3.3 ALTERNATES TO PROOF ROLLING

Proving of granular sub-base and basecourse layers is an essential element for the construction of cost-effective flexible airport pavements in Australia. The process of proving each unbound layer underpins Australian airport pavement construction and design practice developed over many years. If the proving gap is not addressed, alternative options, which are likely to be unpalatable to airport owners, include:

- Adoption of concrete pavements. This is cost prohibitive in many circumstances.
- Increasing asphalt surface thickness. This is also cost prohibitive, although less so than concrete, in many circumstances.
- Use of bound basecourse layers under thin asphalt surfaces. Although less expensive than other options, this remains more expensive than granular basecourses and may introduce reflective cracking risks.

With a number of significant new runway developments scheduled in Australia in the coming ten years this is a significant issue. The replacement of the current fleet of Marco/Macro rollers with increased tyre pressure capability must be addressed. This would most logically be considered by airport owners on a national basis. Second-grade (and therefore economical) aircraft tyres, with inflation pressures exceeding 1,600 kPa, fitted to modernised proof rollers is one viable option worthy of further consideration.

4 BITUMEN FOR ASPHALT

There is a perception that the quality of bitumen has declined over many years. There is significant evidence to show that crude oil quality has reduced, oil refining processes have become more efficient and bitumen is extended by the addition of what would traditionally have been waste or by-products such as propane precipitated asphalt (White, 2016a; White, 2016b). Further, the majority of bitumen consumed in Australia is now imported from a diverse and ever-changing number of supply points. In the past, Australia refined its own bitumen from generally consistent sources of imported crude oil. Changes in bitumen supply have anecdotally been linked to a number of airport asphalt surface distresses, including early life shearing, premature ageing and early life top-down cracking (White and Embleton, 2015).

Traditionally C320 was the normal binder for airport asphalt across Australia and for many years provided good asphalt performance. However, stripping issues, horizontal deformation, groove closure and early ageing prompted many airports and designers to move to premium or modified binders around the year 2000. Between 2003 and 2014, Multigrade was the dominant airport asphalt bitumen in Australia. Some airports, particularly Sydney (NSW) prefer elastomeric PMBs, particularly A10E. This reflects a high level of comfort in the reliability of the supply and generally acceptable performance over many years. Outside of major population centres, risks associated with polymer segregation and degradation during transport resulted in PMBs being largely avoided.

In a summary of Australian airport practice (Emery, 2015) it is stated that airports in warmer parts of WA require PMB binders or Multigrade to improve rut resistance. However, airports in temperate climates of Australia, such as Hobart (TAS), Launceston (TAS), Canberra (ACT) and Melbourne (VIC) have recently used either Multigrade or PMB. It follows that differentiating the warmer from the cooler areas of WA for premium bitumen selection seems unjustified. Further, airport asphalt virtually cannot rut. Normal construction is 50-60 mm layers with a typical 80 mm maximum layer thickness in a single lift. Even at 80 mm, asphalt would need to increase in density by at least 6% to result in a 5 mm rut. Assuming 3% air voids at refusal density, that would require the asphalt to be constructed at 9% air voids. Such high air void content is unlikely to occur without being identified during construction. It follows that true asphalt rutting is extremely rare in airport pavements. Pavement rutting is more common, usually associated with base course densification or vertical subgrade deformation. Where the asphalt surface has failed, shear-related shoving is more
common. What is often confused for rutting is actually lateral shoving due to internal shear resistance failure. In heavy braking zones, horizontal (longitudinal) shear-related shoving has also occurred without vertical deformation (White, 2016c). The adoption of premium binders for airport asphalt is based on improved shear resistance and groove closure, rather than rut resistance.

Top down cracking of asphalt surfaces is now recognised as a life shortening failure mode in flexible pavements (Roque et al., 2004). Australian airports, particularly those containing Multigrade bitumen, have frequently experienced top-down cracking, sometimes constrained to the touch down zone, but in some cases extending the majority of the length of the runway. In the most severe cases, top-down cracking required surface removal and replacement when the surface was just five years old. Preliminary investigation has indicated that similar cracking has not occurred in other types of bitumen (such as PMBs) and rapid hardening and embrittlement of Multigrade bitumen, resulting from the acid used in its production, has been suggested as a potential factor (White, 2015d).

Top-down cracking and early life shearing risks associated with Multigrade binder, combined with durability concerns in PMB asphalt, have complicated the selection of bitumen for airport asphalt in the future. Some designers believe that selection should remain based on types and grades of bitumen that have provided good performance in the past. However, based on the significant changes in the bitumen industry and the performance of airport asphalt in recent years, it is likely that a bitumen of particular type and grade in 2016 is significantly different to bitumen of the same type and grade from 2006. It follows that good performance of a certain type and grade of bitumen from 2006 is not a sound indicator of similar performance in 2016. Rather, comparison of performance-based test results for currently available bitumen types and grades should form the basis of bitumen selection. The multiple stress creep recovery test has been recommended for performance-based comparison of bitumens for airport asphalt (White, 2015f).

To counter these issues, as well as asphalt groove closure, some Australian airports have moved to elasto-plastomeric modified bitumen for superior shear resistance (White and Embleton, 2015). Such products do not fit into the current grades of bitumen in Australia, which are unmodified, Multigrade, elastomeric or plastomeric. Examples of elastoplasticomeric binders include B380 (Emery et al., 2015) and JetBind (White and Embleton, 2015). Airports resurfaced (or currently being planned for resurfacing) with these products include Kununurra (WA), Broome (WA), Barimunya (WA), Gold Coast (QLD) and Devonport (TAS). Significant use has also been made in container terminals at various port facilities.

5 SPRAYED SEAL DESIGN

Sprayed sealing for airports is often seen as less challenging than asphalt resurfacing and is more commonly adopted by regional airports, where financial constraints often do not allow the involvement of specialist engineers. As a result, many sprayed seals on airports have been designed like road seals. Aggregate loss, resulting in aircraft engine damage, has occurred. Further, for a sprayed seal, the design is only an initial estimate. The actual bitumen application and aggregate spread rates must be trialled on site and adjusted by the designer. This requirement is often omitted by financially constrained or unaware airports. Resurfacing a runway with asphalt is considered very much a science, however, spray sealing airports is more of an art.

White (2010) summarises the requirements for spray sealing of airports and highlights the differences to road pavements. White (2013) detailed examples of how deviations from established practice can result in poor airport seal performance. A design guide and construction specification requirements were also developed by White (2015c). New seals on airports should be ‘double-double’ treatments with ‘single-single’ treatments acceptable for re-seals over existing surfaces in good condition. Premium binders are required to promote aggregate retention and resist bitumen flushing, at application rates that are significantly higher than for road seals of the same aggregate size.

5.1 AGGREGATE SIZE

Some designers believe that a 10 to 14 mm first coat should be followed by a 5 to 7 mm second coat (Emery, 2015). This is stated to reflect the need to prevent larger stone sizes from shredding tyres on wheel spin-up during aircraft touchdown. However, a 14 mm and 10 mm double-double seal is the most appropriate treatment, followed by a lock-down treatment. Resealing of existing seals in generally sound condition with a single 10 mm seal is also appropriate. A 14 mm and 7 mm initial or resel is sometimes used for airports utilised by smaller aircraft.

Firstly, 7 mm (or 5 mm) aggregate is often more flaky than 10 mm and larger aggregate (White, 2010; Austroads, 2006). The flakiness and reduced height of the smaller aggregate reduces the construction tolerance and increases the risk of ‘too much’ or ‘not enough’ bitumen being applied. Too much bitumen results in flushing and not enough bitumen leads to reduced seal life and loss of aggregate from the surface. As the aggregate size increases, the difference between ‘too much’ and ‘not enough’ bitumen increases commensurately. Natural variation in aggregate shape and existing surface texture requires a larger construction tolerance than is provided with 5 mm and 7 mm nominal sized aggregate seals.
Further, a 10 mm top layer of seal, with or without sand, will reliably achieve the minimum 1 mm surface texture required by CASA for a runway. As the aggregate size reduces, the risk of not achieving and maintaining this level of texture increases. Finally, steel drum rolling is a normal part of airport spray sealing construction. An appropriately constructed 10 mm seal, thoroughly steel drum rolled to remove the sharp edges, does not result in excessive aircraft tyre wear or shedding. As an example, the runway at Claris airfield (a small general aviation airport in NZ) was extended in 2005. During the construction it was noted that the general aviation aircraft preferred to land on the grass flanks rather than the existing sealed runway. This reflected the high rate of tyre wear experienced by regular aircraft operators. The existing runway aggregate was approximately 12 mm in size, was hard and sharp and did not include a lock-down treatment. There was no visual evidence of the surface having been rolled by a steel drum. As part of the runway extension, the existing runway surface was thoroughly rolled with multiple passes of a small steel drum roller. One year later, it was reported that pilots used the (then extended) runway without tyre wear concern.

An appropriately steel drum rolled 10 mm top seal layer does not cause excessive tyre wear and reduces the risk of flushing and loss of surface texture. The larger size of the 10 mm aggregate also allows a higher bitumen application rate, which increases expected seal life and reduces moisture ingress into the base course through the surface.

5.2 BITUMEN SELECTION

Traditionally spray sealing of airports utilised C320 bitumen. Not dissimilar to asphalt binder, a number of surface performance issues have developed over time, primarily the flushing of seals in hot weather (White, 2013). Likely causes include the decline and variability of bitumen quality (Oliver 2009), an increase in the frequency of sealing runways in winter time (White, 2015a) and a reduction in expertise and experience of airport pavement seal designers and supervisors. However, some designers maintain the appropriateness of C320 in warmer regions and C170 in cooler areas, as well as the use of cutter during cold-weather sealing to assist in ‘wetting the stone’ during rolling (Emery, 2015).

Cutter allows binder to remain at a viscosity that permits the cover aggregate to be adequately pushed into the binder film. This is referred to as ‘wetting the stone’. Without the cutter, the stone will not penetrate the hardened bitumen film, which cools rapidly after spraying in cold weather. Subsequent aggregate loss is likely during the cooler months of the year. This is avoided by adding cutter. However, cutter will remain in the bitumen and will not escape until the hotter period of the year when the residual cutter is volatilised. Prior to and during its volatilisation and evaporation into the atmosphere, the seal softens. As a result, flushing often occurs during the first summer after sealing. Australian bitumen appears to have become less tolerant of seasonal temperature fluctuations. As a result the frequency of flushing during the first summer after resealing has increased in both airports and roads. This was predicted by Oliver (2009) and White (2015c) recommends only sealing airports between October and February, to allow the complete avoidance of cutter.

Similar to asphalt, there is a trend towards premium bitumens for sealing. This reflects the increase in poor seal performance, likely resulting from reduced bitumen quality (White 2015a). Different approaches are common in different States. Class 450 conventional bitumen, sealing grade Multigrade and various PMBs (e.g. S20E, S10E and even A35P) have been utilised with varying success (White, 2015c).

5.3 LOCK-DOWN TREATMENTS

In a summary of airport practice in Australia, Emery (2015) states that sand seals are applied at runway ends and intersections to lock-in the hot bitumen sprayed seal. It is suggested that sand seals render the surface texture below the minimum 1 mm required in Australia (CASA, 2012). Further, it is stated that sand seal application should be delayed by 12 weeks or more to allow volatiles to escape and that severe flushing has resulted where this delay has not been observed.

As outlined above, a well designed and constructed 10 mm seal with a sanded-emulsion or proprietary lock-down treatment is the most appropriate airport seal for reducing the risk of surface texture falling below the minimum required by CASA. Further, experience indicates there is little basis for delaying the application of the lock-down treatment by 12 weeks. In many cases, the lock-down treatment has been applied the day after the hot bitumen seal without adverse impact. On the contrary, damage is most likely to occur early in the life of a new airport sprayed seal surface, when it is most susceptible to sluing under the impact of tightly turning aircraft. The weeks and months immediately after construction are periods when the lock-down treatment is most likely to reduce aggregate loss.

In summary, spray sealing is more an art than a science. The decline in number of experienced and specialist airport pavement engineers in Australia has seen significant loss of airport sealing expertise. In combination with decisions made by financially constrained clients and a decline in bitumen quality, distress in airport spray seals has increased, particularly in relation to hot weather bitumen flushing. If not addressed, sprayed sealing will not remain a viable surface treatment for Australian airports, requiring some regional airports to upgrade their surfaces to asphalt.
6  SKID RESISTANCE VERSUS REJUVENATION

Pilots of aircraft have no discretion with regard to landing speed. Large commercial aircraft land at 250 km/hr and decelerate at 2-4 m/s² until reaching a suitable taxiing speed (White, 2015e). It follows that safe airport operations depend on high-speed skid resistance provided by the runway surface texture. Asphalt surface macro-texture naturally increases over the life of a surface layer due to binder oxidation and erosion of the bituminous mastic. The time between resurfacing is often extended by rejuvenation of the surface, during which a fine application of bitumen, with or without fine aggregate, is applied to replace the lost mastic and assist in retaining the coarse aggregate in the surface.

Rejuvenation treatments partially fill the surface, thereby reducing both micro-texture and macro-texture (Emery 2015). The risk of reverted-rubber aquaplaning is considered to be high following runway rejuvenation (Emery et al., 2011) and some designers have discontinued the use of rejuvenation on runways (Emery, 2015).

Runway skid resistance is managed by maintaining a minimum 1 mm surface texture and/or by periodic measurement using a continuous friction measuring device (White, 2012; CASA, 2012). The 1 mm surface texture is not achievable from 14 mm sized dense graded asphalt, which generally provides 0.4-0.6 mm surface texture. Most Australian airports groove the runway surface to compensate for the lower than required surface texture and to promote wet-weather skid resistance. Although the continuous friction measuring devices provide a good indication of skid resistance, there are circumstances where inadequate friction to prevent aircraft skidding has not been identified (Emery et al., 2011). However, many cited examples were compounded by other factors, such as ungrooved dense-graded asphalt, over-application of rejuvenation product by inexperienced personnel, inappropriately timed treatment of a new microsurfacing in the runway wheel paths and landing on runways only marginally longer than the distance required to bring the aircraft to a stop (Emery et al., 2011). There are other examples where pilot error or mechanical failure likely contributed to incidents.

Treatments with or without sand have been used on runways and investigated in the USA since 1990. Incorporation of sand results in adequate high-speed skid resistance (Shoenberger and Newman, 2003). Extensive trials in New Zealand reported consistent results (Ridgely, 2015). Australian experience is similar, with few incidents attributable to loss of skid resistance resulting from runway rejuvenation.

Clearly, one avoidable aircraft skidding incident is one incident too many. However, appropriately selected and applied rejuvenation of runways contributes significantly to the minimisation of loose material from asphalt ravelling. Although it may appear simple to avoid rejuvenation in favour of more frequent asphalt resurfacing, this has significant impact on cost-effective whole of life maintenance of runway pavements in Australia. Rather than conclude that rejuvenation of runways is poor engineering, it is more appropriate to conclude that inappropriate rejuvenation represents a high risk. When the right treatment is suitably designed and applied to an appropriate surface, runway rejuvenation provides significant benefit at low risk. Experience, supported by sand-patch and friction testing after a small trial area, further reduces this risk.

7  EXPEDIENT CONSTRUCTION

In regional Australia, many airports now require existing pavements to be improved to cater for more damaging aircraft. The B737-800, Q400 and Embraer ERJ 190 are aircraft now regularly operating into regional airports and triggering pavement strength upgrades. However, the airport is critical infrastructure in regional areas, providing access to medical and other support. Therefore, extended closures to facilitate airport upgrades are not operationally acceptable. Similarly, at capital city airports, operational frequency and 24-hour flight schedules complicate access to runways for civil works, such as widening and strengthening. Resurfacing windows have also generally reduced and significant reconstruction programs are now required to be performed in short night shifts. This requires the nightly return of the surface to its existing level and strength, free of loose material and steps. A significant challenge results for civil engineering design and construction, which often relies on multiple layers of material, drying back of materials compacted at optimum moisture content and curing of cementitious binders.

An expedient construction material is often required for airport rehabilitation or upgrade work. Such materials must be rapid curing, near or at ambient temperature, fast to construct and able to be almost immediately covered by subsequent layers. Materials of high modulus are preferred to provide an equivalent level of structural strength with a reduced pavement thickness. This reduces both excavation and reconstruction effort. A number of materials have been used in expedient construction applications, including mass poured concrete, lean mix concrete, warm mix asphalt, rapid setting concrete and even self-cementing ground granulated blast furnace slag.

Foamed Bitumen Stabilisation (FBS) of crushed rock has recently seen an increase in use in such applications. FBS of crushed rock gravel (typically 3% bitumen and 0.5% cement) offers a similar level of structural contribution to that of asphalt, and exceeds that of many cement stabilised basecourses (White, 2014a). Cracking risk is negligible due to the low cement content. Further, the resulting material is more resistant to moisture damage and is almost immediately...
trafficable, which reflects its construction at ambient temperature. Like cement stabilisation, there are two design approaches to FBS:

- **Structural capacity.** Where a stiff layer is required for structural improvement, a lower bitumen content and new crushed rock is more economical. Similar structural capacity can often be achieved with marginal materials. However, the cost of the increased bitumen dosage is prohibitive.

- **Marginal materials.** Sub-standard locally available or existing basecourse materials are readily improved to achieve conventional airport-quality basecourse performance. This approach has been common in regional WA and Queensland, where materials that are suitable in dry conditions lose almost all cohesion and bearing strength when wet.

FBS of granular material has been performed both in situ and by pugmill operation. The pugmill allows increased control of the un-stabilised granular material. It also avoids the risk of a mechanical failure of in situ stabilisation equipment delaying reopening of a temporarily closed runway. In situ operations are more cost effective but rely on adequate existing pavement material characterisation and project-specific mix design (Collings and Thompson, 2007).

FBS was used at Sydney Airport in the 1970s for improved blast resistant of flanks required by the introduction of B747 aircraft. A recent return to popularity has resulted from improved equipment options and popularity in the road rehabilitation industry. Recent airport works using FBS include Barimunya Airport (WA), St George Airport (QLD), Melbourne Airport (VIC) and Darwin Airport (NT) (White, 2014a).

## 8 SUMMARY

Following the change in ownership of Australian airports from the Commonwealth to private corporations in the 1990s, airport pavement technology and practice has largely stagnated. At the same time aircraft technology has developed and airport operational tempo has increased significantly, combining to place increasing stress on airport pavements. It follows that flexible airport pavement technology has fallen behind the demands of aircraft and airport operations.

Key challenges include the proof rolling of crushed rock base and sub-base layers, bitumen for asphalt production, sprayed seal design and asphalt rejuvenation without impacting skid resistance. Further complication results from the increased requirement to perform upgrade work during short night shifts. New materials, suited to expedient pavement construction, are required. The loss of centralised expertise offered by the various Commonwealth Roads and Aerodromes branches has reduced the ability to develop and implement new technology for Australian airport pavements.

An airport-industry-wide initiative is essential to addressing these issues. Significant resources are required to address an agenda of agreed research priorities in a structured manner. Further, the various consulting engineers must be involved in order to gain acceptance of new technologies and airports must be willing to allow the validation and verification of new technologies on their airports. Critical to this initiative is the involvement of the construction contractors and materials suppliers, to ensure new technologies are economically viable and practical. A University-endorsed program of applied research is recommended to provide academic rigour and independence.

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