15th AAPA International Flexible Pavements Conference
22-25 September 2013
Brisbane, Queensland

Developing Warm Mix Asphalt for Airports

Greg White[1]

Abstract

Warm Mix Asphalt (WMA) provides a viable alternate to Hot Mix Asphalt (HMA) as an airport surfacing and/or structural layer. WMA provides a number of benefits over HMA. Reduced environmental impact (through reduced carbon emissions), increased health and safety (through reduced fume generation), and increased working time (due to reduced rates of cooling), being the primary advantages.

WMA can be generated through a number of technologies, which are broadly categorised as chemical and organic additive technologies, foaming technologies and a combination of both. Astec's Double Barrel Green foaming technology and Sasol Wax's Sasobit wax-based additive are the most commonly encountered processes in Australia.

While significant use of WMA has been made for airport surfacing in the USA and Europe, no consideration was found in Australian airports until Adelaide Airport in 2009. In 2012 and 2013, Barrow Island Airport and Adelaide Airport became Australia's first known airports to utilise WMA on their aircraft pavements, both initially as a means of allowing deep lift patching by reducing the time between compaction and a trafficable layer being achieved.

The Quality Assurance testing results for Barrow Island Airport and Adelaide Airport both show no significant difference between the WMA and HMA produced. There should therefore be no reason to delay trials of WMA as a runway and taxiway surfacing at Australian airports. Trials are currently being planned for a Defence airfield as part of a broader runway and taxiway resurfacing project.

Introduction

Based on published data (ERSA, 2013) there are around 100 airports in Australia with asphalt surfaces. These surfaces have traditionally been high quality, nominal 14 mm sized asphalt in layers of 50-60 mm thickness. For major airports, these surfaces are generally grooved to allow water to escape from under aircraft tyres.

Since 2000, the airport asphalt surfacing market has risen to around 100,000 tonnes per year. At the same time airport owners have become more focused on providing environmentally sustainable, technically sound solutions to their airfield infrastructure.

---

[1] Technical Manager Airports with Fulton Hogan, based in Brisbane, Australia.

The aim of this work is to demonstrate that WMA is a technically viable airport surface material. While this work is based on limited airport usage and data, the goal is to show that WMA is appropriate to be trialed as a grooved airport surface layer under heavy traffic in an aircraft turning area.

This aim is achieved through the description of the various WMA technologies and the advantages WMA offers Australian airports. A review of the international and domestic use follows, prior to detailing the limited use on airports in Australia to date. Data is analysed from two Australian airport projects and a grooved surface trial plan is described.

Warm Mix Asphalt Technologies

WMA is a type of asphalt mix requiring lower production temperatures compared to HMA, while aiming to maintain the desired constructability and post construction properties (Austroads, 2007). Originating in Europe, WMA is manufactured by temporarily lowering the viscosity of the binder. When the asphalt cools to its in-service temperature, the viscosity of the binder returns to that expected for a conventionally manufactured asphalt binder. Subsequent re-heating to the working temperature must not re-lower the binder's viscosity any further than would be the case for conventionally manufactured asphalt's binder. How this is achieved varies for different WMA technologies. **Figure 1** shows the typical binder viscosity (and therefore asphalt workability) versus temperature for WMA and HMA. The return of WMA binder to HMA viscosity (and therefore asphalt mix stability) occurs at around 100°C (215°F) which is well above Australia's maximum service temperatures.

Importantly, WMA generally utilises the same aggregates and binders, as well as the same composition and mix design, as HMA. The asphalt mix design process is not a function of the production temperature or the asphalt plant utilised in the manufacturing process and therefore there is generally no requirement for a different design process or outcome for WMA. WMA and HMA, as well as half-warm asphalt are generally defined by their manufacturing temperature as detailed in **Table 1**.

Table 1 Asphalt Types and Temperatures

Type	Manufacturing Temperature Range
Hot Mix Asphalt	Above 140°C
Warm Mix Asphalt	100°C-140°C
Half-Warm Mix Asphalt	80°C-100°C
Cold Mix Asphalt	Essentially ambient

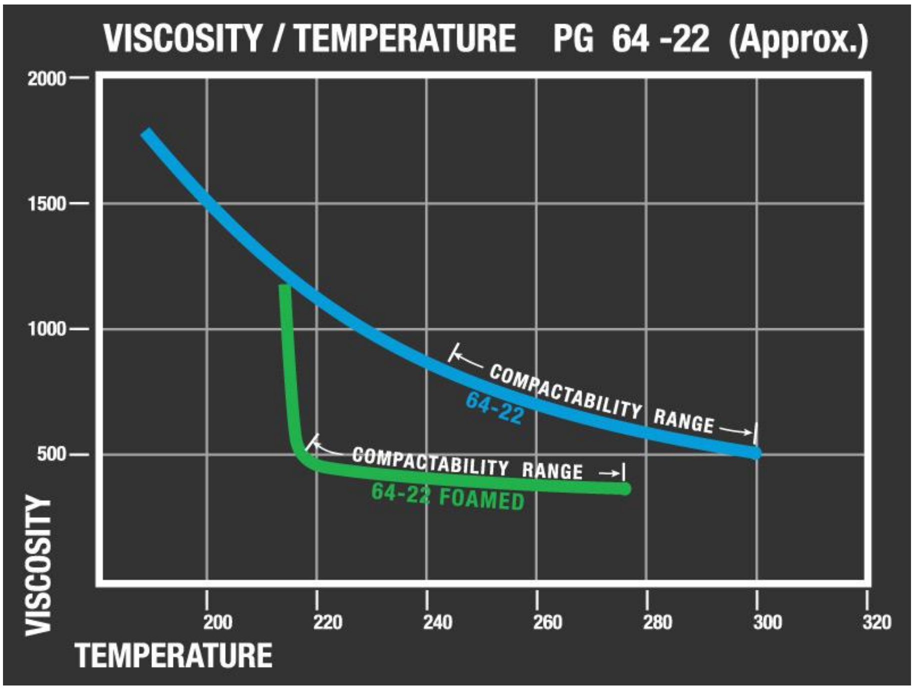

Figure 1 Viscosity versus Temperature

Methods and Products

There are a large number of proprietary products and technologies that can be utilised in the manufacture of WMA. These can, however, be generally categorised into a number of groups or technology types:

- **Chemical Additives**. Surfactants such as Cecabase.
- **Organic Additives**. Such as Fischer-Tropsch Waxes like Sasobit, fatty acid amines like Licomont BS 100 and Montan Wax.
- **Foamed Bitumen processes**. Using synthetic zeolite (Aspha-min) and the Astec Double Barrel Green technology.
- **Two Stage processes**. Using a combination of processes such as Low Energy Asphalt (LEA) technology and Warm Asphalt Mixture (WAM) Foam (by Shell).

Table 2 provides a summary of common technologies (Middleton and Forfylow, 2008).

Table 2 **Common Warm Mix Asphalt Technologies**

Process	Company	Additive	Production Temp (°C)
Sasobit	Sasol	Yes	20-30°C reduction
Aspha-min	Eurovia, PQ	Yes	20-30°C reduction
Evotherm	Mead-Westvaco	Yes	85-115°C
Low Energy Asphalt	LEACO	None	< 100°C
WAM-Foam	Kolo Veidekke	Soft Binder	110-120°C
Double Barrel Green	Astec	None	116-135°C

Due to their popularity in Australia, Sasobit and the Astec Double Barrel Green technologies are described in more detail in **Appendix A**.

Advantages and Benefits

WMA has numerous advantages over traditional HMA and no known disadvantages. Demonstrated performance over 20 years (EAPA, 2009) shows that these advantages are available to Australian airports with little or no performance risk. While there are related and associated advantages to the use of WMA, the primary advantages are:

- **Reduced environmental impact**. As demonstrated by reduced Equivalent CO2 (ECO2) generation at reduced production temperatures, illustrated in **Figure 2**.
- **Workplace safety**. As demonstrated by the reduction in fumes generated by moderate changes in asphalt temperature, illustrated in **Figure 3**.
- **Improved quality**. Through reduced consumption of the binder's life, as a result of reduced aging during production at a reduced temperature.
- **Flexibility of application**. By allowing HMA (manufactured with WMA technology) to be transported significantly greater distances while remaining workable and compactable where HMA would not.

A more detailed description of these advantages is contained in **Appendix B**.

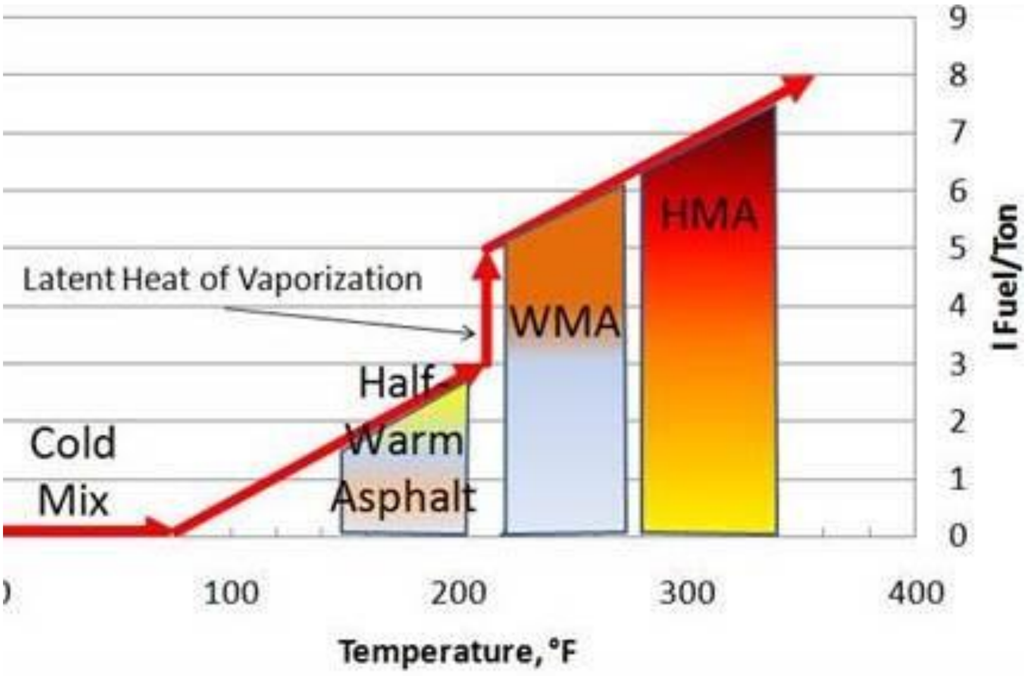

Figure 2 ECO2 Generation as a Function of Mixing Temperature

Figure 3 Fumes generation by WMA and HMA

Warm Mix Usage

While WMA has not yet been embraced by Australian Airports, it has a reasonable track history as an airport surfacing around the world.

International Airport Usage

While foamed bitumen technologies have existed since the 1950s, warm asphalt was first developed as a commercially viable surfacing option in the 1990s in Germany and Norway (EAPA, 2009).

In 2003, a number of production and laying trials were conducted in the USA (Michael, 2007) and these expanded to Canada in 2005 (Davidson, 2007). Since that time a number of airports in Europe and northern America have utilised various WMA technologies. Examples include Hamburg, Frankfurt and Munich Airports' runways in Germany, Cambridge Airport in the UK, a Defence airfield in Switzerland, Boston-Logan International Airport's runway in the USA, a US Air Force Base near Anchorage in Alaska and the taxiway and apron at Johannesburg Airport in South Africa.

Since 2008, Christchurch International Airport has been undertaking field trials of WMA on taxiway pavements. The initial trial totaled 141 tonnes to depths of 110 mm. Additional trials were conducted with and without RAP over a number of years with all reportedly performing similar or better than surrounding HMA (Hayward and Pidwerbesky, 2009).

Australian Non-Airport Usage

While Australia is yet to embrace WMA, trials of various technologies can be traced back to the start of the 21st century including (Austroads, 2007):

- Shell trials with WAM-Foam in 2001.
- RTA NSW trials of Sasobit additives in 2006.

Work performed by AAPA and Austroads between 2007 and 2013 has established a framework for the use of WMA in Australia and covered field and laboratory evaluation protocols as well as evaluating technologies and their environmental advantages. However, WMA remains far from 'main-stream' in this country.

Australian Airport Usage

Adelaide Airport was the first Australian airport known to consider the use of WMA on its aircraft pavements. The resurfacing both of Adelaide's runways and a number of taxiways in 2010 included the provision of a trial of RAP to be located on a taxiway. Fulton Hogan proposed to extend the RAP trial to also include WMA as well as a section of WMA with RAP. While this was seriously considered by Adelaide Airport, disagreement over warranty provisions during the Early Contractor Involvement phase of the project led to the decision to exclude the trial from the scope of work.

Brisbane and Melbourne Airports both expressed interest in trialing WMA on their aircraft pavement systems but neither had a suitable location for a trial that could be accessed as part of their runway overlay projects.

Any WMA trial, designed to demonstrate performance for potential use on the runway of an airport should be located in an area:

- Subject to regular traffic, preferably including turning.
- That can be grooved.
- That can be accessed for ongoing performance evaluations.
- Of reduced operational risk, such as a taxiway or apron.

In 2012, Barrow Island Airport's runway, taxiway and apron were resurfaced, which included a significant amount of full depth asphalt reconstruction. All works were performed between 2100 and 0600 and made serviceable for the daily Fly-In-Fly-Out (FIFO) operations. Barrow Island is located off the West Australian coast between Onslo and Karratha and provides the land-base for the Gorgon offshore LNG project (Chevron, 2013). All WMA was produced by the Astec Double Barrel Green system that is standard with all new Fulton Hogan asphalt plants.

The deep patching included 150 mm dense graded 14 mm asphalt in two layers, prior to a 75 mm structural asphalt overlay. The asphalt was a typical airport asphalt but utilised C320 binder with 5% Polybilt 101. WMA was suggested by Fulton Hogan and accepted by the client's designer in an effort to reduce the risk of rutting: as a result of heat retention in the thick asphalt preventing the paving of multiple layers in a single night shift and serviceability upon reopening to aircraft traffic. The resulting patches were of such high quality that the Double Barrel Green technology was adopted for significant portions of the surfacing layer. The project included a total of 14,000 tonnes of asphalt.

Adelaide Airport repaired a number of areas of distress in old asphalt surfaced taxiways in 2013. The design for the repairs included two 75 mm deep layers followed by a 50 mm wearing course. The asphalt utilised was a typical dense graded airport HMA with A35P polymer modified binder. The works included three patches which were performed between 2230 and 0430, on consecutive nights, prior to reopening to international and domestic aircraft at 0530 each morning. The first aircraft to use the area after the first night was an A330 and this caused 6 to 10 mm deformations (shoving and rutting) under a single operation.

During the day, the deformation was rectified between aircraft by rolling with a heavy steel drum. During the repair work, the pavement surface was noted as being warm to the touch, but not causing significant discomfort.

Two subsequent patches were performed the following nights with identical mix but using Double Barrel Green WMA from Fulton Hogan’s Adelaide asphalt plant and reduced manufacturing temperature. The thicknesses and timing was similar but the pavement surface was cool to the touch upon reopening to traffic and no deformation occurred.

Airport Performance

The slow acceptance of WMA within the Australian airport community is primarily due to perceived risk. The perceived risks relate to performance in both the short and long term, with the greatest perceived risks being:

- Marshall properties immediately after paving.
- Stiffness where the binder is less aged and hardened.
- Long term performance.
- Propensity for water damage or stripping due to the introduction of water used in the foaming process (where used) and at reduced mixing temperatures.
- Resistance to groove closure where the binder is less aged and hardened.

Barrow Island Airport

The work at Barrow Island Airport included 10, 14 and 20 mm nominal sized asphalt mixes constructed in varying thicknesses. HMA and WMA were utilised for both the 10 mm and 20 mm sized mixes. The intermittent use of HMA and WMA allowed for normal process control parameters (grading, stability, flow, density, air voids and binder content) to be tracked for both WMA and HMA over the duration of the works. Because the foaming head remained on during all of the final surface layer production, no comparison of 14 mm HMA and WMA properties could be made.

These was no significant difference between the HMA and WMA for the various parameters measured. For example, **Table 3** shows the moisture content immediately after asphalt production of 10 mm and 20 mm nominal sized asphalt's used at Barrow Island Airport. **Table 4** shows the average of the average densities achieved for each Lot. **Figure 4** and **Figure 5** show the Flow and Stability results for each Lot of 10 mm and 14 mm nominal sized asphalts respectively.

Table 3 Moisture Contents for Barrow Island Airport

Mixing Temperature	Mean Moisture Content of Asphalt at Production	
	10 mm Nominal	**20 mm Nominal**
Hot	0.027%	0.045%
Warm	0.031%	0.034%
Specification (Maximum)	0.150%	0.150%

Table 4 Relative Densities for Barrow Island Airport

Mixing Temperature	Mean Moisture Content of Asphalt at Production	
	10 mm Nominal	**20 mm Nominal**
Hot	98.3%	98.1%
Warm	98.1%	98.0%
Specification (Minimum)	97%	97%

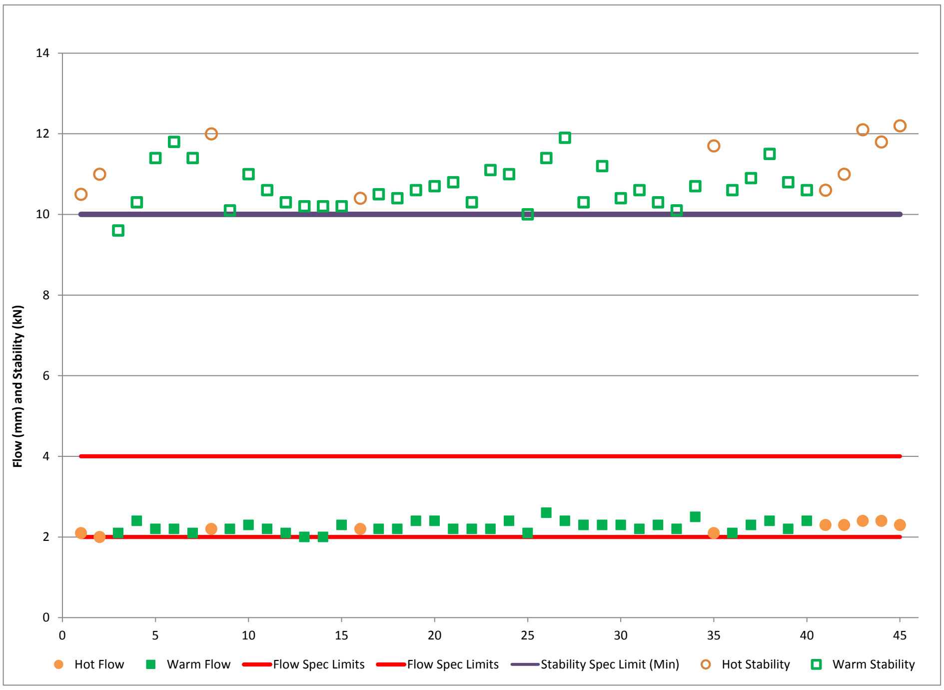

Figure 4 10 mm Flow and Stability for Barrow Island Airport

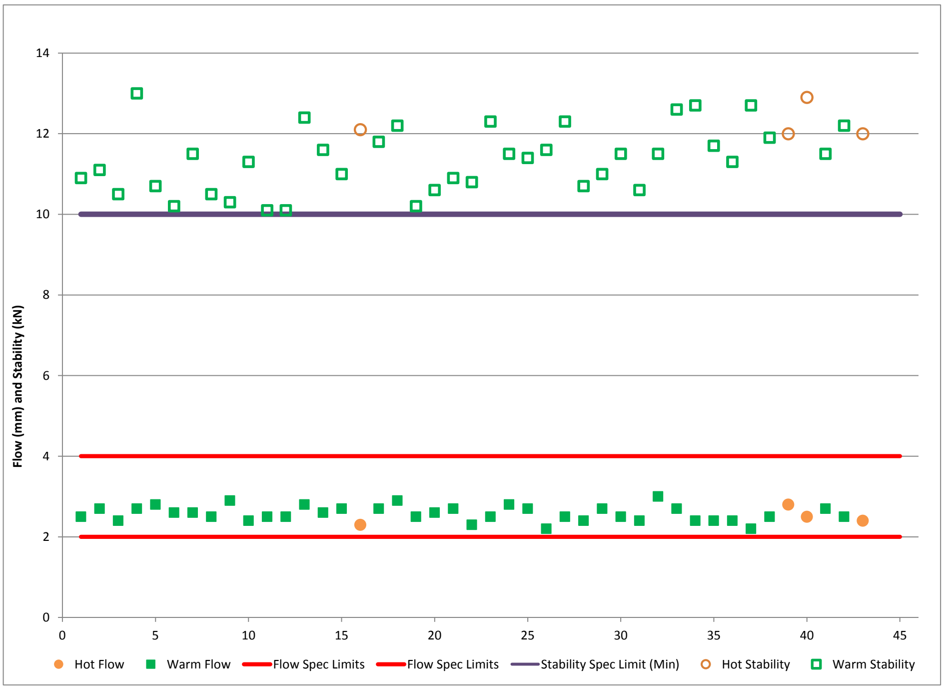

Figure 5 20 mm Flow and Stability for Barrow Island Airport

From **Table 3** it can be seen that there was no statistically significant difference between the Moisture Contents of the HMA and WMA as the time of product and that both the HMA and WMA Moisture Contents were at all times well below the specified maximum of 0.15%. This is despite a small amount of water being added to the bitumen to create the foaming in the Double Barrel Green system. **Table 4** shows that the Relative Densities achieved in the field were well above the specified minimum and were virtually identical for both the WMA and the HMA. **Figure 4** and **Figure 5** demonstrate no statistically significant difference in the Flow and Stability achieved by WMA and HMA for both 10 mm and 20 mm nominal sized asphalts. Inspection of the HMA and WMA surfaces during construction showed no identifiable difference between the two.

Adelaide Airport Patching

The patching work at Adelaide Airport provided limited production data for otherwise identical HMA and WMA produced by bitumen foaming as summarised in **Table 5**.

Table 5 **Comparison of production properties from Adelaide Airport**

Property	Hot Mix	Warm Mix	
Binder Content	5.5%	5.5%	5.3 – 5.9%
Flow	2.2 - 2.4 mm	2.3 – 2.4 mm	< 3 mm
Stability	12.8 - 13.7 kN	13.4 – 13.9 kN	> 11.5
Voids	4.0 - 4.3%	3.7 – 4.1%	3 – 5%
Relative Density	99.6 - 99.9%	99.4-99.6%	95%

It can be seen from **Table 5** that the WMA utilised had virtually indistinguishable Marshall properties to that of HMA. The WMA did not suffer from rutting resulting from the inability of the multiple-thick layers to dissipate heat as the HMA did. The surface was inspected some weeks after the work and the only visual difference between the patches was that resulting from the re-rolling of the surface to correct the HMA deformation of the first patch.

Despite these uses, the risk relating to groove closure has not yet been tested in Australia due to the lack of a runway wearing course trial. While good performance has been reported for airports in the USA and Europe, these airports use inherently different binders, aggregates and mix compositions and therefore this good performance can not necessarily be extrapolated to Australian conditions without undertaking a grooved surface layer trial.

The Future

Prior to the acceptance of a WMA as a reliable surface for Australian airport use, a trial that assess performance of a grooved WMA surface under turning traffic is required. This trial must be documented and the performance of the WMA monitored to provide increased confidence in its capability.

A significant trial is currently being planned with the Department of Defence. The trial is planned to be conducted in conjunction with runway resurfacing works. The trial will include all mix design and production testing as well as additional wheel tracking and resilient modulus measurement at the time of construction. A monitoring and future testing program is also being developed.

Once a trial is performed and additional confidence in WMA as an airport surfacing is gained, the Australian airport asphalt specification can be reviewed to allow WMA where appropriate. The only changes that would be required to the current specification is the reduction of the production, paving and rolling temperature limits.

Conclusions

The advantages of WMA in terms of environmental impact, workplace safety, quality outcomes and flexibility of application are well documented and accepted. A number of leading WMA technologies are commonly available around Australia. Despite this availability, only limited use of WMA has been made by Australian airports.

International airports have made good use of WMA in resurfacing projects across Europe and the USA. Experience with and comparison of WMA and HMA quality assurance data at both Barrow Island Airport and Adelaide Airport identifies no significant difference between the two materials, for otherwise identical asphalt mixes. This clearly demonstrates that grooved WMA surface construction trials should be undertaken with confidence as the final step to acceptance of WMA as a viable alternate airport asphalt surface material in Australia.

Trials are currently being planned to be conducted at a Defence airfield as part of runway resurfacing works. This trial would incorporate comparative asphalt mix testing as well as a long-term performance monitoring program.

The only element of the current Australian Airport asphalt specification that requires amendment to allow the use of WMA are the mixing, paving and compaction temperature limits.

References

AAAP. Warm Mix Asphalt Validation Project. Australian Asphalt Pavements Association.

Astec. http://www.astecinc.com/index.php?option=com_content&view=article&id=790:200-double-barrel-green-systems-for-astec&catid=58:latest-news&Itemid=509 accessed 6 July 2013.

Austroads. Specification Framework for Polymer Modified Binders and Multigrade Bitumens. AP-T41/06. Austroads Project Number TT1133. 2006.

Austroads. Warm Mix Asphalt (WMA) Review. AP-T91/07. Austroads Project Number TT1220. November 2007.

Austroads. Review of Environmental Aspects of Warm Mix Asphalt. AP-T163/10. Austroads Project Number TT1454. July 2010.

Austroads. Field Evaluation of Warm Mix Pavements. AP-T214/12. Austroads Project Number TT1454. November 2012.

Austroads. Review of Overseas Trials of Warm Mix Asphalt Pavement and Current Usage by Austroads Members. AP-T215/12. Austroads Project Number TT1454. November 2012.

Austroads. Laboratory Evaluation of Warm Mix Asphalt Mixes. AP-T230/13. Austroads Project Number TT1454. March 2013.

Austroads. Evaluation Protocol for Warm Mix Asphalt. AP-T231/13. Austroads Project Number TT1454. March 2013.

Austroads. Evaluation Protocol for Warm Mix Asphalt. AP-T231/13. Austroads Project Number TT1454. March 2013.

Astec. The Double Drum. Product brochure. Accessed http://www.astecinc.com/index.php?option=com_content&view=article&id=109&Itemid=180. Accessed on 10 October 2013.

Chevron. http://www.chevronaustralia.com/ourbusinesses/gorgon.aspx. Accessed 10 July 2013.

ERSA. En Route Supplement Australia. Dated 30 May 2013. Accessed at http://www.airservices.gov.au/publications/aip.asp. Accessed on 02 August 2013.

Hayward, BJ & Pidwerbesky, B. ‘CoolPave with LEA: low energy asphalt, the future of asphalt paving’, In Proceedings 10th NZTA & NZIHT annual conference, Rotorua, New Zealand. New Zealand Transit Authority. Wellington, NZ. 2009.

Hurley, G. C. and Prowell, B. D. ‘Evaluation of Potential Processes for us in Warm Mix Asphalt’. Journal of the Association of Asphalt Paving Technologists. Volume 75. 2006. Pp 41-85.

Kristjandottir, O. Warm Mix Asphalt for Cold Weather Paving. A thesis submitted for the award of Master of Science in Civil Engineering. University of Washington. 2006.

Mejias-Santiago, M. and Brown, R. ‘Evaluation of Warm-Mix Asphalt Technologies for use on Military Airfield Pavements’. In Proceedings USACE Infrastructure Systems Conference. June 13-17 2011. Atlanta, USA.

Middleton, B. and Forfylow, R. W. ‘An Evaluation of Warm Mix Asphalt Produced with the Double Barrel Green Process’. In Proceedings 7th International Conference on Managing Pavement Assets. 15 April 2008. Calgary, Canada.

Ripoll, J.O. & Farré, C.M. ‘Evaluation of greenhouse gas emissions from the production of hot asphalt mixtures’. In Proceedings of the 4th Eurasphalt & Eurobitume Congress. Copenhagen, Denmark. 2008.

Sasolwax. http://www.sasolwax.us.com/sasobit.html accessed 10 July 2013.

Strantec. WMA Paving at Boston-Logan International Airport. Presented to the Federal Highway Administration WMA Working Group. May 15 2009. Dartmouth, USA.

Acknowledgement

The author would like to thank his employer, Fulton Hogan, for supporting the preparation of this paper and attendance at this conference. The contribution of Kevin Embleton and the provision of data from the Barrow Island project is also greatly appreciated.

The assistance of Chevron Australia and the Gorgon LNG Project, the owners of Barrow Island Airport, is acknowledges. As is the assistance of James Low of Adelaide Airport Limited.

Appendix A
Common Warm Mix Asphalt Technologies

Fischer Tropsch Wax (Sasobit)

Sasobit is a proprietary product developed by Sosol Wax in South Africa using the Fischer-Tropsch process. It is a long chain aliphatic hydrocarbon containing between 40 and 115 carbon atoms per molecule and having a melting point of 85-115°C (Sasol Wax, 2013). Sasobit is supplied in pellet form which can be added to the asphalt plant's hot bitumen storage via a purpose-designed feeder unit at relatively modest cost as shown in **Figure A.1**.

Once the asphalt has cooled to in-service temperatures, the wax molecules crystalise and will not re-soften the binder unless the asphalt temperature is increased to above the melting point (85-115°C) which is higher than all reported pavement temperatures in Australia (Austroads, 2006). Sasobit's crystalline network leads to improved structural stability of the asphalt at typical service temperatures.

Double Barrel Green

The Double Barrel Green technology utilises a manifold that includes a multi-nozzle water injection system to foam the binder just prior to its addition to the asphalt mixing drum as shown in **Figure A.2**. While this technology was originally developed for Astec Double Barrel asphalt plants, it can now be retrofitted to most models of asphalt plant. The foaming process requires around 1 litre (2% by mass of binder) of water per tonne of asphalt mix and some 90% of this water evaporates during the mixing process. Most of the remaining water is lost as vapour into the atmosphere during the paving and rolling process. The foaming process increases the surface area of the binder by some 18 fold, temporarily reducing its viscosity and allowing it to be mixed, paved and compacted at 30-40°C below that required for HMA (Astec, 2013).

Figure A1. Sasobit pellets

Following a modest initial investment for the addition of the manifold, pipework and water storage tank to a new or existing asphalt production plant, the only ongoing cost for the manufacture of foamed bitumen WMA is the small amount of water added to foam the binder as it enters the mixing drum. Since its introduction in 2007, over 200 Double Barrel Green systems have been installed to Astec and other asphalt plants.

Figure A.2 Double Barrel Green System

Appendix B
Advantages of Warm Mix Asphalt

Environmental

Airports, like all modern infrastructure, are under pressure from Governments, the community and their owners to reduce their carbon footprint. This stems from both an overarching desire to run the infrastructure in a sustainable manner as well as being known as an environmentally responsible corporation. WMA represents a significant contribution towards those goals during asphalt resurfacing works.

The standard measurement for generation of carbon emissions is Equivalent CO_2 (ECO2). The ECO2 associated with the manufacture and construction of asphalt is complex and varies with changes in (Austroads, 2010):

- The distances from aggregate source to the asphalt plant and to site.
- The moisture content of the aggregates.
- The use of hydrated lime in the asphalt mix.
- The binder content used in the asphalt mix.
- The fuel utilised by the asphalt production plant.
- The asphalt production temperature.
- The efficiency of the asphalt manufacturing plant.

The haulage distance is generally the shortest distance to a suitable aggregate source. The moisture content can be managed by good quarry practices. Hydrated lime is generally a requirement of the design and specification for the particular application and 1% hydrated lime is typical for airport asphalt in order to reduce the risk of binder stripping. Burner fuel is generally diesel for mobile asphalt plants where gas lines are not readily available, although fixed asphalt plants are often located adjacent to gas mains. Modern asphalt manufacturing plants are designed to be as efficient as possible given the limitations of current technology. These factors are generally fixed or beyond control. The production temperature therefore becomes the primary variable that can be managed to achieve environmental benefit.

The asphalt production temperature is a function of the post-production haul distance to the job site and whether HMA or WMA is being manufactured. HMA is generally manufactured at 160-180°C for airport asphalt. Comparable WMA would be manufactured at 130-140°C.

Pidwerbesky et al (2009) reported that WMA can return a reduction in ECO2 of 10-20%. However, half-warm asphalts can reduce ECO2 generation by up to 50% due to the step in ECO2 generation at around 100°C (215°F) representing the latent heat of vaporisation (ie. the energy required to turn liquid water into gas).

Various studies have found different ECO2 reductions association with WMA. Studies in Europe found a reduction in ECO2 of about 10% when the asphalt production temperature is reduced from 170°C to 130°C (Ripoll and Farre, 2008).

Where Recycled Asphalt Pavement (RAP) is included in the mix, significantly greater ECO2 reductions are possible. WMA and RAP are often considered as associated technologies as the ‘aged’ binder contained within the RAP and the ‘reduced age’ of the new binder (resulting from the reduced mixing temperature) combine to give an average binder age similar to that which would result from a 100% new binder exposed to typical HMA aging.

Safety

Working with hot products presents inherent risks. Bitumen, in particular, is a high burn risk material, especially when being transferred or stored under pressure. The reduction in burn risk associated with a reduced asphalt paving temperature from say 140°C to 100°C may be significant.

Fume generation is significantly reduced by even moderate reductions in asphalt temperature. The Emission Exposure Values experienced by staff working with asphalt were found to be reduced by 40-90°C when asphalt temperatures drop from 160to 130°C.

Quality

The finished WMA layer is virtually identical in appearance and performance to that of HMA. One of the key advantages is that despite the reduced cooling rate, the lower temperature allows a stable or trafficable temperature to be reached much more quickly. This allows WMA to be utilised in circumstances where thick layers and/or multiple layers of HMA would not cool adequately prior to the next layer being paved and compacted or the pavement being re-opened to traffic.

The other measurable difference between WMA and HMA is the binder aging. The reduced mixing temperature of WMA results in reduced aging and oxidation of the binder during the asphalt production process (Renegar, 2007). This reduces the viscosity and increases the penetration of the binder. As up to 60% of a binder’s whole-of-life aging can be experienced during asphalt production, any reduction in binder aging during the mixing process will result in an extended period until the same degree of aging is reached. If binder aging is the determining factor in an asphalt surface’s life (as is often the case for airport runway surfaces which experience very low traffic) then the life would be expected to be extended and the period between maintenance overlays increased.

All other typical measurable mix properties, usually using Marshall test methods, generally do not show any statistically significant difference to those achieved for otherwise identical HMA.

Flexibility

Asphalt paving is generally performed while the asphalt is between 140 and 160°C. This allows for adequate workability through the paver and the ability for typical construction equipment to adequately compact the layer prior to cooling below a temperature at which compaction is no longer achievable. The rate of cooling of the asphalt material is a function of the air temperature and the pavement temperature as well as the asphalt mix's own internal temperature. As the difference between the asphalt's temperature and the surrounding surface temperatures increases, so does the rate of asphalt cooling.

Warm mix asphalt is typically paved at between 110°C and 130°C to achieve the same workability and compactability as HMA. This directly reduces the difference in temperature between the pavement and the surrounding surfaces by around 30°C and significantly reduces the rate of cooling of the asphalt. This effectively increases the working and compaction time.

Similarly, when being transported long distances to remote sites, asphalt cools at a rate that is proportional to the difference between the asphalt and surrounding temperatures. Again, reducing this rate of cooling provides an increased working time over typically acceptable haul distances. Where longer transport times are required, warm mix technology can be utilised but the asphalt production temperature retained at around 160°C. This will allow increased cooling prior to paving without affecting workability or compactability. This flexibility is particularly useful in regional Australia where many airfields are located 4-6 hours from an established asphalt production plant. It is noted, however that once the minimum compactability temperature is reached, WMA compactability reverts very quickly to that of HMA. WMA provides for significantly less 'warning' that this temperature is approaching.