Fine asphalt trials for low traffic volume urban roads in South Australia

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ABSTRACT: *Degradation of low traffic volume urban roads is due to oxidation of the binder and increased permeability affecting underlying layers whereas high traffic volume roads need to withstand traffic damage. As a result, a specific asphalt mix is required for low traffic volume urban roads to increase environmental sustainability and reduce whole of life costs. South Australian stakeholders collaborated in one set of trials to determine asphalt mixes which may achieve the required maximum air voids of 7% and then a subsequent trial to verify the attainment of the altered specification that minimises oxidation processes.*

Eleven trial sites were selected in 2013 and four asphalt mixes applied. From these trials, Fine AC10 asphalt was specified in DPTI's Master Specification for use on these low traffic roads. Twenty-five trial sites were selected in 2015 and verified that the asphalt mixes were not achieving the require air void content at the majority of sites. The complexities between mix design, construction practice and application conditions need to be understood to achieve the specification.

To improve the sustainability of low traffic volume urban roads it is necessary to ensure that the Road Owner, Contractors and Designer collaborate to remediate the site conditions which result in higher air void content and then enforce techniques and practices to achieve this goal. Further investigations are needed to refine the technical specification for these roads and consider other asphalt mixes and to prepare a cost-benefit analysis.

KEYWORDS: Fine asphalt trials, low traffic volume, urban roads, South Australia.

1 Introduction

Asphalt pavement specifications are predominantly designed for heavy traffic loads and to withstand traffic damage. Local councils in South Australia have many sealed roads with low traffic volumes where the design objective is to withstand environmental effects and achieve longer life to reduce maintenance costs. These low volume traffic roads are defined as urban streets carrying traffic that falls within the lowest category of Table A 2 of the Austroads 'Guide to Pavement Technology Part 4B: Asphalt' [1], i.e.:

- A street that carries less than 100 commercial vehicles per lane per day
- The structural design level for the street should be less than 5 x 10^5 ESAs (Equivalent Standard Axles)
- Light free flowing traffic.

APRG defines the desirable aims for asphalt mixes for low traffic volume urban applications [2] as:

- Low air voids (density)
- High bitumen content (impermeability).

A long-term performance study of asphalt mixes on lightly trafficked Australian streets showed that aging of the binder is reduced for mixes compacted to 6% air voids or less [3]. The study showed these mixes to be more durable in terms of cracking resistance. As the air voids increase beyond 7% it becomes increasingly easy for water and oxygen to penetrate the asphalt, which leads to an increased rate of oxidation aging and a risk of stripping. Linden *et al.* [4] found a 10% reduction in an asphalt pavement's life for each percent increase in air void content above 7%. This finding may be expected to be exacerbated for thin surfacing layers. McLeod [5] concluded that "compacting a well-designed paving mixture to low air voids retards the rate of hardening of the asphalt binder, and results in longer pavement life, lower pavement maintenance, and better all-around pavement performance."

In 2012, a South Australian industry group formed from local government Works Managers met with the Department of Planning Transport and Infrastructure (DPTI) to discuss the appropriateness of DPTI's specified asphalt mixes used on local streets, primarily in the greater Adelaide area. From these discussions, City of Salisbury and Tonkin gained funding from the Local Government Association (LGA) Research and Development Fund in early 2013 supplemented by co-funding from 10 local councils. A reference group was formed for oversight of the project including the Department of Planning Transport and Infrastructure (DPTI), Australian Road Research Board (ARRB), Institute of Public Works Engineering Australasia South Australian division, Tonkin and Australian Asphalt Pavement Association (AAPA). The reference group established the objectives, protocols for trials and helped to facilitate the engagement with the local asphalt industry to deliver asphalt trials in collaboration with the contributing Councils that provided streets for trials.

In 2013, trials were focussed on understanding and assessing asphalt mixes currently used on residential roads, with these results presented at the 2014 IPWEA SA Conference in Adelaide [7]. The learnings from the trial helped to influence DPTI to include a new asphalt mix in its standard specification, known as Fine Dense Mix Asphalt (Fine AC10) [8][9].

During the remainder of 2014 and into 2015 the Fine AC10 was used by local government. In 2015 IPWEA SA took a leadership role and negotiated additional funding from 10 Councils to verify the Fine AC10 was delivering the required lower air voids in the field. The report was completed in September 2018.

This paper presents the findings of the 2013 and 2015 trials, i.e. 6 years of trial work, and presents recommendations for on-going improvements to the specification and placement of asphalt wearing coarse on pavements constructed for low traffic volume urban roads. Both reports can be found on the IPWEA SA website:

- Low Volume Road Asphalt Trial in SA (2014) https://www.ipwea.org/southaustralia/viewdocument/low-volume-road-asphalt-trial-in-sa?CommunityKey=2150c4e3-0255-4e84-9161-97c40f823da7&tab=librarydocuments [6]
- Fine AC10 Asphalt Trial in SA (2018) https://www.ipwea.org/southaustralia/viewdocument/fine-ac10-asphalt-trial-in-sa?CommunityKey=2150c4e3-0255-4e84-9161-97c40f823da7&tab=librarydocuments [7]

2 Aims and objectives

The aim of the low traffic volume road trial project was to specify asphalt mixes that are specifically intended to achieve longer service life on urban streets carrying limited numbers of heavy vehicles. The mixes would also be suitable for use in pedestrian areas and for maintenance patching. By achieving longer-life, these asphalt mixes would also be more environmentally sustainable and minimise whole-of-life cost.

The objectives of the 2013 trials were to:

- Select asphalt mixes which are easy to compact and have high flexibility and lower viscosity
- Develop a technical placement specification for asphalt used for low-volume traffic roads.

Ease of compaction was important to remedy the rapid cooling that takes place when mixes are constructed in thin layers and the influence of other compaction challenges such as stiffness of underlying pavement, irregular shape of underlying pavement, access for full size paving and compaction equipment. Mixes were to be constructed to a low *in situ* air voids to reduce permeability, which helps to protect the underlying granular layers and limits oxidation aging of the binder. The high flexibility/low viscosity of the mixes accommodates the relatively high deflections experienced in residential street pavements under commercial vehicle loading.

The objectives of the 2015 trials were to:

- Demonstrate whether the Specification adopted by DPTI because of the 2013 trials could be met;
- Support increased scrutiny of asphalt supply and placement by local governments
- Identify activities for focus and improvement

3 Methodology

3.1 Trial Set Up

The technical characteristics of the asphalt mix designs include a fine, dense, graded aggregate in combination with high binder content.

In 2013, a total of 11 trials sites were selected on residential streets in the Adelaide area. Each site had four sub-sections where four different types of mixes were placed. For all four mixes placed on a site, each Contractor was to develop and keep the mix design the same for each street in terms of aggregate grading and binder content. The variations between the mixes were in the binder type used and the addition of warm mix asphalt (WMA) or reclaimed asphalt pavement (RAP), as follows:

- Mix A: class 320 bitumen
- Mix B: class 320 bitumen with WMA additive
- Mix C: class 170 bitumen with RAP
- Mix D: class 170 bitumen with RAP and WMA additive.

Class 170 bitumen (a softer grade bitumen) was included to potentially improve compatibility, durability and flexibility of the asphalt mix. Environmental sustainability is improved through the inclusion of WMA (lower energy production/manufacture) and RAP (reuse/recycling). It is also expected that WMA to further improve compactability and RAP to reduce cost.

From April 2015 to March 2017, 25 streets were assessed each with one or two mixes of asphalt. For these trials, the asphalt mixes were broadly grouped into the same four mixes as the 2013 trials; however, variations in the proportion of additives and aggregate grading were included. The mixes and placement were to be compliant with the DPTI specifications, being:

- Part R27 Supply of Asphalt https://www.dpti.sa.gov.au/__data/assets/pdf_file/0020/288110/Part_R27_Supply_of_Asphalt_MAY~_2017.pdf [8]
- Part R28 Construction of Asphalt Pavements https://www.dpti.sa.gov.au/__data/assets/pdf_file/0003/288111/Part_R28_Construction_of_Asphalt_Pavements_October_2016.pdf [9]

3.2 Monitoring Protocol

One of the key roles of the reference group was to establish monitoring requirements for each stage of the trial. The following aspects were recorded for all trial sites:

Site Condition

Prior to conducting work in the field Tonkin undertook a site inspection to take photographic records of the existing surface and to record the condition of the surface including extent/severity of cracks, potholes, rutting and other surface defects. At some sites, this data were supplemented with Falling Weight Deflectometer testing.

Mix Design

During mix production, grading, target binder and lime content together with binder type, warm mix addition type, bulk density, lab air voids, binder film thickness, indirect tensile strength, recycled asphalt planings (RAP) content were recorded.

Construction Records

Observations recorded during construction included ambient, surface and mix at auger and on the mat prior to compaction temperatures, compaction effort, field air voids and other general observations.

The obligation to provide this information fell with the contractors.

4 Outcomes of 2013 Trials

The results from the trial sections provided a good indication of the asphalt products being delivered to Metropolitan Local Government in South Australia in 2013.

4.1 Deflection

As shown in Figure 1, there was no direct link found between deflection of existing pavement prior to resurfacing and compaction of the AC wearing coarse (as measured by air void percentage) for deflections below 1.3 mm. The sample size was too small to provide comment when deflections are above 1.3 mm, and should be further explored in future trials.

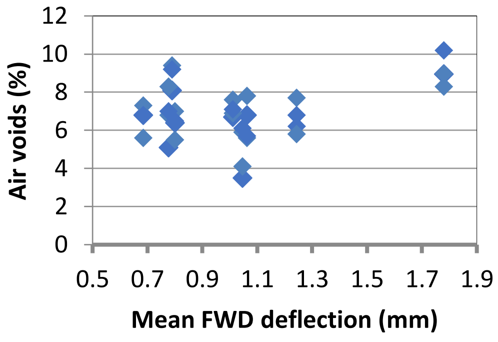

Figure 1: *In situ* Air Voids vs Mean FWD deflection

4.2 Air Voids

The trial was established with the intent to achieve 4-6% air voids in the field. The results of the trial indicate that the mixes used and work practices adopted need to further adapt in order to reduce field air voids to this target range.

The mean *in situ* air voids results were plotted in Figure 2 to graphically represent results with respect to the target range of 4% to 6% *in situ* air voids. 9 of the 44 trials (20%) resulted in a mean *in situ* air void results within the target range. It is worth noting that while some of the calculated mean results met the target band, not all samples that contributed to that mean value fell within the target band, nor did the characteristic values that were calculated.

It is also worth noting that 18 of the 44 trials (40%) resulted in a mean *in situ* air voids result above 7.0% (see dashed line in Figure 2). Based on other research, air voids above 7% will result in increased permeability for oxygen and water and will accelerate ageing of the binder.

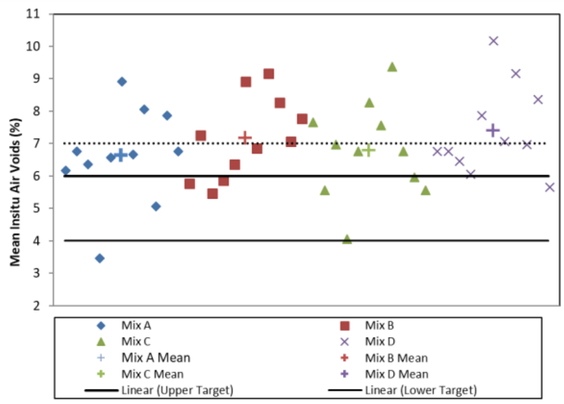

Figure 2: *In situ* Air Voids with means and target limits

4.3 Binder Content

The trial provided some confidence that increasing binder content above 5.5% is a cost effective way to help reduce field air voids. Mixes with binder contents less than 5.8 that corresponded with binder film thickness 60% absorption less than 8.5 did not perform well with field compaction. This is demonstrated Figure 3 below which presents the field void results with the binder film thickness values being adjusted for 60% absorption, represented in bands of field air voids.

Low field air void sites did not generally correspond with BFT < 8.2 and Binder < 5.8% or BFT > 9.5, but rather corresponded to binder > 5.8 or BFT (60%) above 8.5 but less than 9.5.

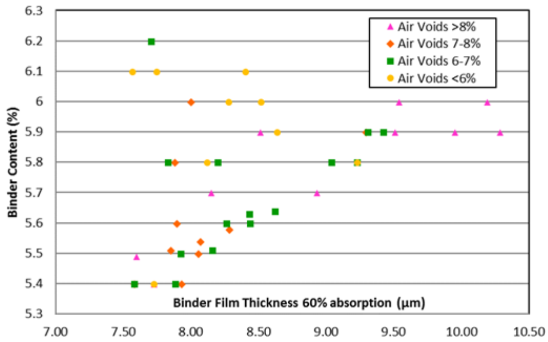

Figure 3: Plot of 60% absorption adjusted Binder Film Thickness against binder content grouped by field air voids

4.4 Filler

The trial indicates that filler binder ratio above 1 and mixes with 0.075 mm sieve (%) passing greater than 6 achieved lower field voids as shown in Figure 4.

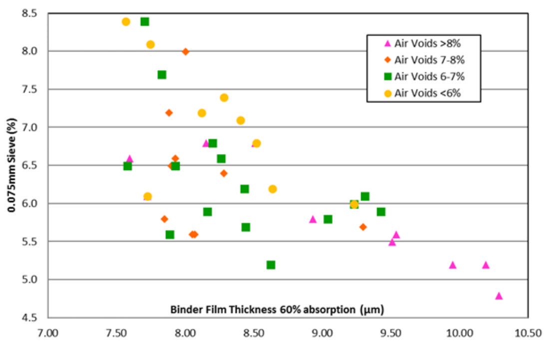

Figure 4: Plot of Binder Film Thickness (60% absorption) and % passing 0.075 mm sieve grouped by field air voids

A relationship with BFT 60% absorption revealed the higher the filler binder ratio (1 to 1.4) the lower the BFT 60% results (8.5-7.5) for low field air voids as shown in Figure 5. Filler binder ratio less than 1 and BFT 60% greater than 9.5%, despite high binder did not perform in terms of field voids.

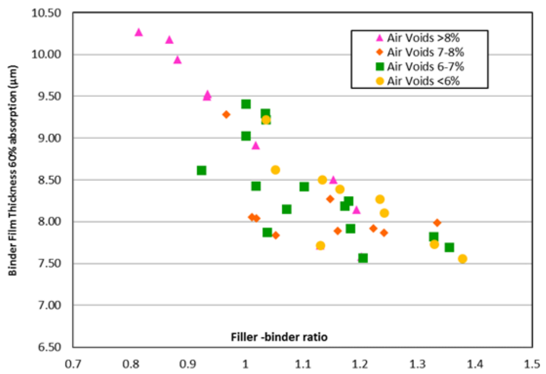

Figure 5: Plot of Binder Film Thickness vs Filler binder ratio grouped by field air voids

4.5 Binder Type

The trial provides some evidence [6], and confirms expectations, that C170 binder responds better than C320 binder in reducing field air voids with higher binder content. This needs to be tempered with risk of rutting; however higher density should mitigate this.

4.6 Laboratory Air Voids

The trial used a range of laboratory air void to maximise compaction in the field. It was recommended to lower laboratory air voids to 4% (50 cycles Gyproc AS 2891.2) as a result of the trial.

4.7 Warm Asphalt

The trial [6] indicated that warm asphalt compaction was less than traditional hot asphalt due to lower field density and higher aid void content. Industry needs to further develop mix designs recognising the higher offset between laboratory and field compaction and the increased workability with higher binder contents and compare with standard hot mix.

4.8 Indirect Tensile Strength (ITS)

The trial [6] provides evidence that increasing the binder reduces the Indirect Tensile Strength (ITS) of the asphalt. At this stage it is too early to observe any performance issues with lower ITS, however it is anticipated that ITS will not be a key criterion for testing for low volume roads.

4.10 Recommendation from the 2013 Trials

Overall, the trial showed promising results that an alternative asphalt mix may be developed for low volume roads. The following recommendations were made to improve longevity of asphalt mixes on low traffic volume roads:

1. Adopt 4% Laboratory air voids (50 cycles Gyropac – AS 2891.2.2) for mix designs to improve workability for low volume road asphalt. The specification will provide a suitable range.
2. Incorporate a minimum binder film thickness (60% absorption) of 8.0 micron recognising the trial results and monitoring with road authority's trends across the country.
3. At this stage the use of filler/binder ratio as a specification reference is not supported, however Figure 5 provides some reference for mix designers for referencing field void performance and relationships with BFT (60%) and filler/binder ratio when selecting filler content in mixes.
4. A minimum binder content of 5.7% should be specified.
5. Local Government should consider making density determination from the *in situ* asphalt part of the normal product acceptance process using characteristic values that are statistically analysed with a minimum of 4 samples per street.
6. Local Government and Industry should use the results of this trial to develop reasonable incentive/penalty clauses in contracts to reward Contractors for delivering low field air void mixes (4-6%) and penalise contractors for high air void mixes commensurate with the expected life reduction for every % above 7%.
7. Local Government should be aware of the potential for lower compaction with warm asphalt and industry should embrace more workable mixes to achieve compaction at lower field temperatures. This should occur with understanding of the offset between laboratory and field compaction and temperature.
8. Review density results for 'conventional' asphalt mixes used on low volume roads in SA and compare them to the results for the fine graded high binder content mix used in this study.
9. Review construction practices and compaction practices.
10. As a result of this trial local government should use the specification update through DPTI which includes the key recommendations from the trial.
11. LGA consider scope for continuation of a coordinated approach to funding research and to keeping abreast of national development.

These trial results were sufficient to provide direction to Local Government and industry to work together with DPTI to find ways to improve the manufacturing and placement of asphalt for low volume roads. The trials facilitated the development of a new specification for low traffic volume urban roads.

5 Outcomes of 2015 Trials

The following Table 1 provides an indication on the varying types of binders and additives used for the mixes in the trial. The higher number of C170 mixes is linked to the findings from the 2013 trial.

Table 1: DPTI Specification Compliance

Mix Type	No. of sites
C320 Hot mix	1
C320 WMA	5
C170 with RAP	11
C170 with RAP and WMA	8

The results of the 2015-2017 trials are summarised below.

5.1 Deflection

While deflection did not appear to be a dominant factor for the roads in this trial, it remains something for consideration, particularly if more roads above 1.3 mm deflection are included in future trials.

5.2 Air Voids

The Maximum Characteristic *In situ* Air Voids, referenced in Section 9 Properties of Finished Asphalt Pavement (Part R28) [9], results were plotted with comparison to the specified target range for 2.5 to 7%. This appraisal of the data indicates that 62% of the sites yielded maximum characteristic *in situ* air voids greater than 7%.

The average Maximum Characteristic *In situ* Air Voids for each of the four mix types has also been incorporated (colour crosses).

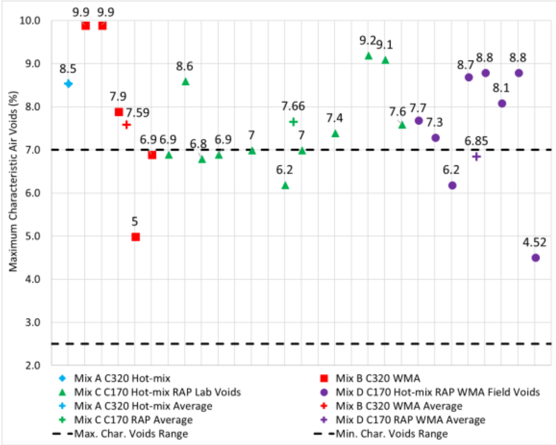

Figure 6: Maximum Characteristic Air Voids for the various Asphalt Mixes Installed

The following Table 2 was compiled to demonstrate the varying degrees of success for the various Fine AC10 mixes in satisfying the maximum characteristic air voids requirements of the DPTI specification.

Table 2: DPTI Specification Compliance

Mix Type	No. of sites	Percentage of sites achieving the required Max. Characteristic Air Voids
C320 Hot mix	1	0%
C320 WMA	5	40%
C170 with RAP	11	55%
C170 with RAP and WMA	8	25%

The trial was established with the intent to achieve characteristic air voids within the specified range of 2.5% - 7%. The results of this trial indicate that the mixes produced, and work practices, have improved since the last asphalt trials conducted in 2013. However, some refinement is required across the areas of asphalt mix design, production and construction in order to reduce field air voids to the specified target range. The results show the specification is not being met in 15 of the 25 sites (comprising of 4 sites over 9%, 6 over 8% and 5 over 7%).

To gain an appreciation of where the asphalt construction industry's confidence lies with respect to installing Fine AC10 asphalt, a simple comparison of the average air voids across the four pre-defined mix types have been compiled within Table 3.

Table 3: Comparison of Average Air Void – 2012 – 2013 Trials and 2015 – 2017

	Asphalt Trials 2012 – 2013		Asphalt Trials 2015 – 2017	
	Sample Size	**Average Air Voids**	**Sample Size**	**Average Air Voids**
Mix A C320 (Hot-mix)	11	6.64%	1	7.2%
Mix B C320 - WMA Additive	11	7.19%	5	6.66%
Mix C C170 – RAP (Hot-mix)	11	6.81%	11	6.61%
Mix D C170 - RAP and WMA Additive	11	7.43%	8	6.02%

By way of further explanation this table is presented to compare the average or mean results presented in Figure 2 in the 2013 trial and is not to be compared to Figure 6 which is characteristic values used for upper limit specification comparisons.

Due to the large difference in sample size for Mix A and Mix B; it is not possible to confidently perceive if these two mixes have improved within the asphalt industry. However, with the sample sizes for Mix C and Mix D being relatively similar, the results in Table 3 indicate that the use of warm mix additives does lead to improved compaction on site when used with C170 binder. This appears to show that since 2013 (the time of the previous asphalt trials), contractors have improved their understanding of how warm mix technology can be implemented both during production at the batching plant and installation on site.

5.3 Binder Content

The trial [7] provides some confidence that the specification requirement of a 5.7% minimum binder content is generally being met.

5.4 Binder Type

While the selection of the C170 binder was the more obvious choice of Local Government during these trials; the potential benefits or limitations of C320 binder remains something for consideration.

5.5 Laboratory Air Voids

The trial used a range of laboratory air void to maximise compaction in the field. The report recommended investigating the potential for lowering laboratory air voids to 2-3% (50 cycles Gyproc AS 2891.2).

5.6 Grading

The potential to extend the bandwidth of grading for fine particles contained with fine asphalt mixes should be considered. While this may contradict the requirements of AS 2150 it would provide an avenue for asphalt Contractors to “showcase” their expertise in asphalt mix design.

5.7 Wheel Tracking

Results for Wheel Track Testing were limited due to three out of the four participating contractors required to utilise specialist laboratory equipment interstate. The two samples tested did report results within the DPTI Master Specification requirements for medium duty asphalt mixes (Table 4).

Table 4: Wheel Track Testing Results

	Average Rut Depth (mm)	**Central Rut Depth (mm)**
C320 Hot mix	-	-
C320 WMA	3.7	-
C170 RAP	3.86	3.62
C170 RAP & WMA	-	-

Samples were subject to an applied load of 700N and terminated at 10,000 passes in accordance with the DPTI testing regime.

These two results comply with the wheel tracking test requirements of the DPTI specification Table R27B(a) – Nominated Mixes [8] for an asphalt mix consisting of AC10M 320 (which includes RAP and WMA) where the acceptable range in 3mm to 6mm.

While only 3 results were provided through these trials, it demonstrates that the wheel track test results are well within the specification limits for medium duty asphalt mixes

5.8 Warm Asphalt

Results for Fine AC10 mixes containing a Warm Mix Additive indicate that recent developments to this area of the specification is delivering improvements in field compaction compared to the previous asphalt trials undertaken from 2012 – 2013.

5.9 Recommendations

The results of the trial indicate that Fine AC10 specification will need modification; however, further research is required to determine the scope of these changes. The following recommendations were made from the 2015 report:

1 For future trials the potential exists for 2-3% Laboratory air voids (50 cycles Gyropac – AS 2891.2.2) including a review of design properties with respect to gradings of mix designs to improve workability for low volume road asphalt. Guidance from DPTI should be provided to confirm a suitable tolerance for this parameter together with mandating the requirements for wheel track testing.

2 Local Government should conduct in-situ field air void testing as part of contracts to better understand the achievement of improved asset life and reduce instances on high in-situ air voids above 8%

3 A minimum binder content of 5.7% should be maintained.

4 Future trials should consider the benefit of incorporating wheel track testing within the protocol requirements of future asphalt trials to establish a sample set that can provide the potential to draw sound conclusions on the long term durability of the Fine AC10 mix.

5 DPTI is encouraged to provide commentary on the acceptance criteria (refer below suggestion) within the current specification for the maximum characteristic air voids of the Fine AC10 asphalt mix.

6 Local Government needs to consider how to manage non-conformances associated with the maximum characteristic voids criteria of the current DPTI Specification.

7 The implementation of future asphalt trials should investigate the incorporation of greater flexibility in the current specification/governing protocol and aim to achieve a sample set for varying mix types that is more uniform.

8 Sponsors of future trials should consider scope for continuation of a coordinated approach to funding this research.

6 Conclusions

The work undertaken and led by the IPWEA SA division has:

- established a protocol and trial process that engages asphalt companies and local Councils with close involvement from the State Road Authority;
- developed a preliminary technical specification for placement of AC10 on pavements used for low traffic urban roads;
- verified that a large number of low traffic urban roads are not being constructed to the required standards;
- identified that improvements to the preliminary technical specification are required;
- highlighted areas for future investigations.

These trials have demonstrated that:

- Asphalt mixes need to contain a minimum binder content of 5.7% and be placed with a maximum *in situ* characteristic air voids of 7%.
- In winter conditions, the warm mix technology using C170 and Sasobit with 10-15% RAP and the higher binder content provided lower field air voids than fine hot bitumen mix with either C170 or 320. The average of the high characteristic field voids for both mix types remained over the specified limit of 7%.
- With average ambient temperatures of 13° C, warm mix technology placed with average temperatures above 147° C, delivered poor results with the average high characteristic field voids approaching 9%. These mixes were either C320 with Sasobit or C170 Foamed all with 20% RAP.
- In summer conditions, fine hotmix with C170 binder placed in all situations delivered the average of the high characteristic field voids below 7%. No warm mix technology was placed in this period.
- In summer conditions, sites with depths less than 25 mm and poor pavement conditions using C170 Hot Bitumen 20% RAP or using C170 Warm mix Foamed with 20% RAP resulted in average high characteristic field voids just over 7.5%.

The specified 7% upper characteristic air voids can be achieved. There are a number of site conditions which need to be addressed to ensure that this specification can be met, including:

- Weak pavements
- Variable pavement conditions

- Variable thicknesses of mixes placed
- Ambient temperatures below 25 °C
- Hand work
- Binder type, e.g. C170 may be more compactable
- Lack of preparation work prior to surfacing which does not address or remove weak pavement sections
- Selection of Warm mix additive and placing temperature may need to be higher when placed below ambient temperatures of 25 °C

7 Recommendation

Future trials should be ultimately led by the authorities responsible for managing local streets who are striving to deliver value to the communities through placing long life asphalt surfaces. Local Government and Industry need to continue with a coordinated approach to improve the level of testing and reporting and potentially share information.

This trial showed that improvements to the specification are required; however, does not provide definitive results to determine how the specification needs to change. It is anticipated further funding will be needed for further specification developments and the analysis of results for further trials.

IPWEA SA should approach contributing councils with a proposal to extend trials into the future to include mixes outside the bounds of this DPTI specification and to prepare a cost-benefit analysis. Environmental impacts should also be addressed for mixes used in the trials.

Acknowledgements

2013

This project was co-funded by the following organisations:

- Local Government Authority (Research and Development Fund)
- City of Salisbury
- West Torrens City Council
- City of Burnside
- City of Playford
- City of Port Adelaide Enfield
- Corporation of the City of Marion
- Corporation of the City of Adelaide
- Adelaide Hills Council
- City of Unley
- Light Regional Council
- IPWEA.

This project was supported by Australian Asphalt Pavement Association (AAPA) and its members with in kind support for trials and input into the protocol.

Tonkin, ARRB and DPTI provided in-kind support over and above available funding in order to complete the report.

2015

The delivery and oversight of this project was managed by IPWEA SA on behalf of the following co-funding organisations:

- City of Salisbury
- West Torrens City Council
- City of Burnside
- City of Playford
- City of Port Adelaide Enfield
- Corporation of the City of Marion
- Corporation of the City of Adelaide
- Adelaide Hills Council
- City of Unley
- Light Regional Council.

This project was supported by AAPA and its members with in kind support for trials, input into the protocol and providing feedback during reference group sessions.

DPTI provided valuable input to reviews and advising at reference group meetings at no cost.

Tonkin provided in-kind support over and above available funding to complete the report.

John Hutton provided oversight and reference group involvement for both trials initially representing the City of Salisbury and then IPWEA SA.

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