Australian Asphalt Pavement Association

Study Tour 2010

United States of America

California, Washington, DC, Tennessee, Alabama

7th to 21st August 2010

GROUP REPORT

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Australian Asphalt Pavement Association
Study Tour 2010 – United States of America
Group Report

Issued by:

AAPA

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Contents

This report is available on CD which contains links to all the 170 references and presentations.
Copies of the CD can be obtained through a request to info@aapa.asn.au

1. EXECUTIVE SUMMARY

Over the last 40 years the Australian Asphalt Pavement Association has undertaken a number of study tours across the world to learn and report back on new ideas, directions of research and technology changes which may have implications or advantages for Australia. These study tours included participants from a broad cross section of the road industry including staff of State Road & Local Government Authorities, contractors, consulting engineers, bitumen suppliers, researchers, academia and AAPA.

AAPA 2010 Study Tour to the United States of America

The 2010 tour was similarly composed, going to the United States of America to address four key topics. AAPA members and participant organisations were approached before the tour, to frame questions to be put to our USA hosts and contacts.

Hosts were contacted through the USA Asphalt Associations, NAPA, the FHWA, Departments of Transport, industry and academia. Four primary stops were selected: California, Washington DC, Tennessee and Alabama with primary hosts being Rita Leahy, David Newcomb, Don Brock and Randy West. The topics and questions were sent to our hosts in advance of the tour's departure allowing for the choice of suitable contacts to provide the valuable and targeted feedback.

The Key topics were:

- Perpetual Pavement Concepts
- Warm Mix Asphalt
- Recycled Asphalt Pavements (RAP)
- Accelerated Pavement Testing and Equipment
- General Issues (binders, sprayed sealing, surface friction)

This AAPA 2010 Study Tour Group Report answers the questions raised in detail, includes observations on the topics and makes recommendations for actions to benefit Australia.
The recommendations are highlighted as follows:

Perpetual Pavement Concepts

Support should be given to include Fatigue Endurance Limits into Australian pavement design through SRA/Austroads, ARRB, consultants & academia , remain in touch with the USA contacts, share experience on material performance, establish library of Australian material performance.

Warm Mix Asphalt

Pursue implementation of WMA, use USA treatment for TSR, acknowledge and confirm the lower laboratory test results and comparable field performance to HMA, redesign of WMA is not required although some extra sampling and conditioning may be required. USA information will minimise time and cost of introduction of WMA into Australia.

Recycled Asphalt Pavements (RAP)

Promote the sustainability advantages of RAP in all layers, propose usage guide for <15%, 15% to 30% and >30%, develop simplified procedure to evaluate inclusion of RAP >30%

Accelerated Pavement Testing and Equipment

Build strong relations with USA APT groups, test Australian materials at NCAT and link to local experience, expand APT in Australia for higher performance & higher mass vehicle loads, provide development opportunities to industry for innovative materials, embark on linking field and laboratory engineering properties through up-to-date equipment and data collection.

General Issues (binders, sprayed sealing, surface friction)

Promote NCAT & the Australian Industry partnerships for research and technology developments, consider the inclusion of more direct performance parameters in Australian binder specifications, and promote importance of tack coats and trackless tack coats.

Summary

The short 7 to 21 August 2010 study tour provided the 15 participants with an opportunity to directly address relevant Australian issues and to provide a joint feedback on the status in the USA on key topics of significant relevance to Australia. Apart from the contacts made in the USA, the participants have established good working relationships which will benefit the roads sector into the future.

The recommendations provide a path for the roads industry to move forward gaining benefit from the knowledge and understanding developed during the study tour.

Thanks & acknowledgements

The tour party extends its thanks to the Australian Asphalt Pavement Association Board and CEO for their support and facilitation of the tour including the partial sponsorship of some of the participants. The wonderful support, transport arrangements and fellowship given to us by our USA hosts, all the presenters and their support staff is acknowledged with great thanks. Without the organization and commitment of our hosts, the tour and the important learnings and recommendations that have arisen, would not have been possible.

2. INTRODUCTION

In the forty year history of the Australian Asphalt Pavement Association, a number of overseas study tours have taken place to facilitate a framework to learn from best practices and to ensure Australia has the opportunity to observe and implement world class technologies in highway engineering.

FHWA Turner-Fairbank Research Centre – the inspecting the APT site and two FHWA ALF's

This report summarises the observations and combined feedback of the personnel who participated in the study tour of the USA in August 2010. Prior to embarking on the tour, five topics of current interest to the Australian paving Industry were identified and for each of these American experience and perspective would be sought. The five topics were:

- Perpetual Pavement Concepts
- Warm Mix Asphalt
- Recycled Asphalt Pavements (RAP)
- Accelerated Pavement Testing and Equipment
- General Issues (binders, sprayed sealing, surface friction)

Chapter 3 of the report provides a concise overview of the observations for each topic and offers recommendations for actions that could be pursued in Australia following the tour with chapters 4 to 8 provide greater detail of the engagements with the Americans on each topic.

Chapter 9 contains a list of appendices covering the itinerary of the tour, the participants, the questions posed and a list of useful acronyms and abbreviations. The final appendix is a list of the 178 presentations, handouts and references presented during the tour. The electronic version of the report provides links to some of the referenced material.

Photographs of the tour visit can be obtained from: Tour Photos

3. OVERVIEW AND RECOMMENDATIONS

3.1 Perpetual Pavement Concepts

Observations

1. It is now evident that the Fatigue Endurance Limit (FEL) is an accepted concept
2. If the pavement structure is sufficiently thick so that the FEL is not exceeded and long life or so called “Perpetual Pavement” becomes a reality. “Perpetual Pavements” is a marketing term used in the USA to describe ‘long life flexible pavements”.
3. Thickness design methods in the USA are moving away from weighted Mean Annual Pavement Temperature toward dynamic modulus at a selected range of temperatures to match seasonal effects.
4. The USA Mechanistic Empirical Pavement Design Guide (MEPDG) has been updated and includes the FEL concept. The Auburn University NCAT developed PerRoad and PerRoad Express pavement design programs provide an approach to designing perpetual pavements. However, these programs currently do not form part of accepted deign practice in the USA.
5. Both Marshall and Superpave mix design methods are used, the number of Superpave Gyratory Compactor (SPG) cycles continue to be debated. Currently specified SPG cycles tend to produce dry and low durability mixes, binder contents are being increased with by reducing the number of cycles.

Recommendations

1. Australian flexible pavement design practice should investigate the opportunities for inclusion of Fatigue Endurance Limits into local practice.
2. Contact should be maintained between our US colleagues to facilitate the above through industry, State Road Authority, academia, consultants, ARRB personnel and the Austroad Pavement Structures Reference Group.
3. Existing laboratory tools in Australia should be used to facilitate comparison of local products to allow comparison with USA materials proven on their major highways and accelerated test facilities.
4. A “library” of the performance Australian pavement materials should be developed to provide input into local predictive models.
5. AAPA should include, as part of its technology development program, the conversion of PP / Long life design packages to SI units and, through partnerships with SRA / ARRB / consulting fraternity, the modification of Australian design methods of tools such as CIRCLY.

3.2 Warm Mix Asphalt

Observations

1. WMA is being used to provide improved quality of asphalt on many projects in the USA
2. The improvement in asphalt quality and interest in sustainability is driving WMA acceptance
3. The Road Agencies that have been able to investigate WMA with road projects and in conjunction with asphalt suppliers, and research facilities, are accepting WMA. Both FHWA and NCAT are providing major investigation for WMA, and distributing this information.
4. Schemes to allow WMA differ from State to State. Some specifications allow WMA at the supplier's discretion, while others have approval systems usually linked to local field sites. The placement of appropriate field sites for each Road Agency in Australia would be very costly.
5. TSR and Wheel Tracking laboratory results shown some sensitivity to WMA, which is not supported by field experience.

Recommendations

1. WMA implementation be pursued for Australia
2. Check WMA for TSR and follow USA treatment of this parameter
3. Acknowledge and confirm lab mix provides lower results in some lab tests
4. Acknowledge and confirm field performance of WMA meets HMA
5. Redesign for WMA is not required although some additional work is required to set asphalt sampling and conditioning in laboratories. Using USA information will minimize Australia's time and cost.

3.3 Recycled Asphalt Pavements

Observations

1. Sustainability requires that RAP is reused in the most optimal way without compromising the quality of the asphalt produced. Using RAP helps to reduce the cost of asphalt by preserving and reducing the demand for non renewable aggregates and bitumen.
2. There is scope to reconsider the criteria used to set limits to the maximum amount of RAP used in a particular mix.
3. RAP is considered a valuable material by most asphalt contractors with considerable investment on processing and monitoring of the quality.
4. The USA has the goal of 25% RAP on average in all mixes by 2013.

Recommendations

1. Promote the sustainability advantages in using RAP in all dense graded asphalt layers – surfacing and bases.
2. Propose usage guide for the inclusion of RAP <15%, 15 to 30% and >30% for different asphalts types in the various pavement layers.
3. Develop simplified procedure to evaluate actual RAP and binder properties when evaluating the inclusion of RAP above 30%.

3.4 Accelerated Pavement Testing

Observations

1. APT demonstrated that it is a valuable tool to obtain research results not possible to achieve within short time frames using other methods.
2. Provides a means for the rapid calibration of design models accommodating new concepts (fatigue endurance limits) and varying material types allows for early adoption of cost effective solutions.
3. Although the cost of the facility is significant to establish and operate, the results provide major financial benefits in the selection and design of expensive pavement structures.
4. Success of the research programs using APT is being achieved through collaborative research effort between industry, test equipment & product suppliers, road authorities, consultants and academia where funding is drawn from authorities and product developers.

Recommendations

1. Stronger relationship be established between Australia APT and the United States APT groups.
2. Materials should be tested by NCAT for Accelerated Pavement Testing to calibrate USA performance data to local pavements and environmental effects.
3. Expand accelerated pavement testing programs in Australia to better understand the performance of lighter pavement structures to accommodate higher performance & higher mass vehicles
4. Promote greater participation by industry by providing local benefits from APT in advanced materials development opportunities.
5. Embark on a program to link the field and laboratory engineering related performance data through the use of up-to-date test equipment.

3.5 General

Observations

1. Superpave Performance Graded Binder Specification is providing fit-for-purpose binders and appears to be accepted by the road authorities and asphalt suppliers alike. The temperature based system considers performance based on rheological characterisation of the binders and covers both conventional and modified binders. In the US there is little or no concern about binders made from different feedstocks with different chemical compositions.

2. Polyphosphoric Acid addition provides a stiffening effect on the binder, which appears to boost its PG classification. Usage was not determined as most agencies do not monitor the use of PPA addition.

3. Whilst sprayed sealing is undertaken in the USA, Australia is considered to have superior capabilities in sprayed sealing.

4. Whilst based on limited evidence there appears to have been substantial growth in the emulsion market and a reduction in cut-back binders.

5. Surface friction / Skid resistance appears to be managed to standard ASTM protocols with accident hot spots linked to pavement skid resistance properties and placed on improvement programs. Texture depth does not appear to be a requirement, however open graded and stone mastic asphalt is commonly used on their high speed interstate road network.

6. Increased attention is being paid to proper use of tack coats and development of trackless tack coats.

Recommendations

1. Partnerships should be formed between NCAT and Australian industry to share in their research and technology developments.

2. Consideration should be given to assessing how improved performance parameters can be included in the Australian binder specifications.

3. Increase awareness on the importance of tack and trackless tack coats

4. PERPETUAL PAVEMENT CONCEPTS

Working Group

Leader: Ian Rickards Group: Ian Rickards, Young Choi, Russell Clayton

The intention is that the views on the concepts and application in practice should be reported on the questions posed and responses when viewed from the three positions of Road Authority / State DOT, road construction industry and where relevant from advisors or researchers.

Tour scope

Perpetual pavement concepts - design, construction and performance – materials characterisation for improved design and construction, long term pavement performance and accelerated loading facility studies to assist calibration of material characterisation tests, environmental impacts on pavements layer selection.

It is accepted that the term “Perpetual Pavements” was derived in the USA for marketing the concept of asphalt pavements that are designed and built to last longer than 50 years without requiring major structural rehabilitation or reconstruction, needing only wearing course renewal as distress is limited to the top of the pavement. In some countries pavements displaying similar performance are termed “Long-Life Flexible Pavements”. For the purposes of this report which, arises from the tour of the USA, the term “Perpetual Pavements” (PP) will be used when describing these pavements.

Feedback from

- California – Caltrans / UC Davis & Berkley
- Washington, DC – FHWA / NAPA
- Virginia – VDOT / VAA
- Illinois – DOT & University
- Alabama - NCAT

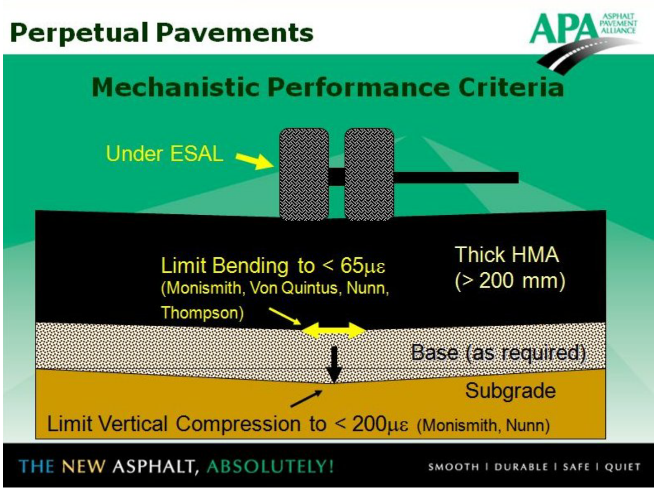
Observations

Fatigue Endurance Limit (FEL) and Perpetual Pavement (PP) design implications

From the group’s discussions with the US researchers and review of literature it is now evident that the asphalt Fatigue Endurance Limit (FEL) is an accepted concept. It follows then that by ensuring the asphalt pavement structure is sufficiently thick that the FEL is not exceeded and a pavement structure that has an indeterminate fatigue life or so called “Perpetual Pavement”, becomes a reality.

The FEL research is now focused on quantifying the limit rather than establishing its existence. There appears to be a growing consensus that the 70 $\mu\varepsilon$ (microstrain) FEL postulated as early as 1972 by Prof. Carl Monismith might be conservative for some mixes. The laboratory fatigue studies reported by Prof. Marshall Thompson and NCHRP illustrate the FEL is also mix dependent:

- Prof Marshall Thompson indicated his laboratory studies suggested the range is 90 to 300 $\mu\varepsilon$ and an average 125 $\mu\varepsilon$.
- NCHRP (Report 646) indicated that the laboratory fatigue endurance limit was in the range of 75 to 200 $\mu\varepsilon$ based on a 95% lower prediction limit. The higher values were associated with SBS polymer modified binders whereas the lower values were associated with straight bitumen binders.



From presentation by Rita Leahy, APA of California

The full scale field trials at NCAT (the National Centre for Asphalt Pavement Technology) provide evidence that a fatigue endurance limit exists in practice. These trials also confirm:

- the FEL is not a single value (i.e. a small percentage of stains over the FEL may not adversely affect the long, indeterminate, structural life of the pavement).
- the laboratory derived FEL may not necessary directly translate to the FEL in the field (i.e. the field endurance limit might be greater than that determined by the laboratory testing regime).

Researchers are divided on the occurrence of crack healing with perhaps a majority favouring its existence is straight run bitumen[1].

Pavement materials characterisation for thickness design

The determination of the appropriate asphalt modulus value for use in the thickness design of long life pavements is the subject of considerable research. The direction of the thickness design methods is away from the weighted Mean Annual Pavement Temperature (wMAPT) and toward the dynamic modulus at a selected number of temperature conditions that represent the seasonal range. Determination of the asphalt dynamic modulus using cyclic compression loading, with or without confining pressure, is gaining increasing acceptance with research institutions. Various research institutions including University of California, FHWA and NCAT were using the Asphalt Materials Performance Test (AMPT) apparatus[2] to characterise the dynamic modulus of asphalt mixes.

1 The research at the US Western Research Institute suggests that the polymer modification of bitumen may hinder the healing effects.

2 The AMPT device manufactured by Australia's IPC Global has gained a strong foothold in the US research institutions

For preliminary design analyses, a number of predictive models that estimate the asphalt dynamic modulus have been developed and are considered to provide a reasonable estimate of this property. The predictive models are based on the volumetric and bitumen binder properties of the asphalt. The Witczak models (in various iterations) estimate the asphalt dynamic modulus based on measured binder viscosity parameters. A number of researchers provided data indicating that the Hirsch predictive model provides an improved correlation with the dynamic modulus of asphalt measured in the laboratory[3]. The Hirsch model uses the bitumen complex shear modulus G* (measured in the Dynamic Shear Rheometer (DSR) to characterise the bitumen properties) and the volumetric properties of the mix to estimate the dynamic modulus of the asphalt.

From Harold Von Quintus, ARA / FHWA

Research undertaken by the University of Illinois indicated that the stress dependant behaviour of unbound granular base and subgrade materials is critical in modeling the underlying support conditions for long life pavement structures. Triaxial testing was considered to be an important component in determining the stiffness characteristics of the supporting materials.

PP Pavement Thickness Design methods

There are a number of pavement thickness design packages under development in the US. The AASHTO MEPDG (Mechanistic Empirical Pavement Design Guide) is the product of an extensive development program in the US. However, feedback from practitioners and researchers is that the MEPDG is quite complex and data intensive. At this stage, few DOT's have fully implemented the MEPDG while some states only intend on implementing/adopting sections of the guide that they consider relevant. Various researchers also indicated that field calibration of asphalt fatigue model may not be reliable (as 'top down' cracking may have been classified as fatigue cracking during the calibration phase).

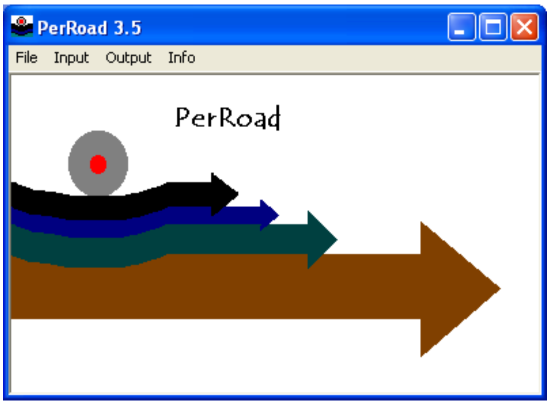
The MEPDG uses the Layer Elastic Analysis (LEA) program JULEA (Jacob Uzan LEA) as the analysis engine and the analysis is carried out based on the full pavement temperature spectrum. The MEPDG software has recently been modified to allow the designer to input a FEL for pavement thickness design calculations. The current MEPDG does not include specific guidelines for selecting the FEL.

The ILLI-PAVE software package from U Illinois uses a more sophisticated Finite Element Analysis (FEA) engine but the design is carried out at a single pavement temperature, representing the

3 Prof Thompson presented data suggesting correlation coefficient $r^2 > 98\%$

hottest month. It seems that on balance the benefit of potentially improved estimates of the critical stress conditions is offset by the simplified temperature assumption[4].

The PerRoad pavement design program developed at NCAT at Auburn University is a truly original software package for the design of perpetual pavements. PerRoad is a pavement design package that employs the WESLEA (US Corp of Engineers) layered elastic model, and allows the analysis of the pavement damage over 5 climatic conditions. PerRoads' unique characteristic is that the user can specify the probable variability in the key materials input parameters (user defined distribution type and coefficient of variation) and estimate the consequences using Monte Carlo simulations to yield a probabilistic design response.



M-E Perpetual Pavement Design and Analysis Tool

Discussions with NAPA and FHWA indicated that the only state DOT in the US which has currently implemented the perpetual pavement concept in their pavement design system is the Illinois DOT (using the Illi-Pave FEA software).

Mix design and functional characteristics

It is evident that the Superpave exclusion zone in the mix grading envelope has been widely abandoned, and practitioners are tending to maximum density gradation. Virginia DOT has implemented a permeability requirement for surface mixes in their specification. This requirement effectively excludes the use of coarsely graded mixes in surfacing layers (due to concerns with permeability and moisture damage). While the theoretical benefits of large stone mixes are well known there is an acknowledgement that handling difficulties and particularly the risk of segregation renders them potentially hazardous. The handling benefits and higher bitumen content in smaller sized and finer mixes – particularly in lower layers – make the achievement of excellent fatigue performance, low permeability and durability in the asphalt foundation considerably more reliable.

The "Rich Bottom" or high fatigue asphalt subbase layer is being widely researched and has been implemented in a number of projects and full scale trials at NCAT. It is evident that the primary objective for the Rich Bottom is improved compaction and low insitu voids by the addition of slightly higher bitumen content (e.g. 0.5%). The US practitioners are aware of the potential permeability reversal issues and thus are focused on compaction standards in all layers within the pavement structure.

[4] It is probable that the critical stress estimates by FEA will be "different" to that by LEA. In order to determine which estimate is "right" the long term pavement performance data must be reanalysed using the FEA – a task that is beyond the Australian resources.

The US continues to use both Superpave and Marshall mix design methods according to the preference of each agency[5]. However, most states have now moved over to the Superpave design system. Debate continues to rage over the number of Superpave Gyratory Compactor (SGC) cycles to design air voids to optimise bitumen content. A general sense is that Superpave mixes designed at currently specified compaction cycles are too dry and lacking in durability (i.e. raveling and cracking are the primary distress mechanisms being observed). Several DOTs have reduced the number of cycles as a means of increasing the binder content of their mixes.

In respect of deformation resistance, Prof Monismith continues to have success with the Simple Shear Test – Constant Height (SST-CH) apparatus albeit conceding the general move toward acceptance of the Flow Time (FT) or Flow Number (FN) from the AMPT as the preferred measure of asphalt deformation resistance.

Construction standards

The vital importance of asphalt compaction in the development of layer stiffness, fatigue resistance and durability, and reduced permeability continues to demand the attention of researchers and practitioners. The full scale trials and laboratory research at NCAT has graphically demonstrated the effect of layer thickness and mix gradation on asphalt compaction and resulted in recommendations to increase layer thickness relative to nominal mix size (typically a minimum of 3 times for fine graded mixes and 4 times for coarse graded mixes)[6].

The full scale trials have emphasised the importance of interface bonding following some cases of dramatic failures due to debonding at the asphalt layer interfaces. The dramatic failure of an NCAT test track section which included a geotextile membrane at the interface of a 'mill and fill' pavement rehabilitation treatment flags the need for caution in the use of such solutions. Full scale trials on the NCAT test track confirmed the need for excellent bonding between asphalt layers within a thick asphalt pavement structure. Poor bonding between asphalt layers on several test sections had resulted in significantly reduced pavement life.

Summary and recommendations

The Perpetual Pavements, or Long-Life Pavements, concepts appear to have been accepted in the USA and are being incorporated into pavement design guides in the USA with trial projects ongoing to allow specific design criteria to be established. Australian flexible pavement design practice should investigate the opportunities for inclusion of Fatigue Endurance Limits into local practice. To this end AAPA should support the planning required and include the contacts which have been established with our US colleagues who have graciously agreed to assist. Likewise local connections with agency and ARRB personnel have been established and these will be fostered and expanded such that industry is not working in isolation.

[5] CalTrans is continuing to use the Hveem system

[6] The French practice of placing substantially thicker layers (layer thickness by NMAS typically 5 to as much as 10) was discussed briefly at NCAT. It was agreed this could be the topic of further research or at least discussions with French practitioners

The fundamental laboratory tools existing in Australia may be used to facilitate the characterisation of our local products to allow comparison with US materials that have proven successful in limited full scale trials and on many major highway projects constructed over the last 60 years. This laboratory characterisation testing can be undertaken at an industry wide level and a library of local asphalt material performance characteristics can be developed. As is the recommended practice in the US the library can be used to validate, at a local level, the predictive models (e.g. Shell (which is currently used by several state road authorities in Australia) or Hirsch).

NCAT test track providing field proof for very long life flexible pavements

As part of AAPA's "Pavements for Life" project the PP / Long-life pavement design packages should be examined for local relevance and potential for conversion into SI units. The potential to modify the Austroads basic LEA tool (CIRCLY) modified is another option to be considered.

The development of specific asphalt mix designs and construction specifications is an essential part of the AAPA's "Pavements for Life" project, and this should be undertaken in partnership with the road agencies (through Austroads) and the consulting fraternity. It is universally agreed that the sound pavement support conditions and assured materials quality, along with the delivery of reliable high construction quality is vital to the achievement of the truly long-life pavements. It is also agreed that this cannot be achieved by tightening specification requirements alone, and that effort is required to improve the constructability of the pavements.

Perpetual Pavements Concepts -Questions & Responses

ASPHALT MATERIALS PRACTICE

Mix design methods – SHRP / other

Preferred gradation WRT maximum density?

- *The exclusion zone has been widely abandoned in favour of near maximum density gradations (NCHRP Rpt. 464)*[7]
- *It was agreed the use of smaller nominal size aggregate (e.g. UC suggested a maximum nominal aggregate size of 20 mm) should be considered for the PP foundation layers because of improved workability, fatigue resistance and fewer issues with segregation during construction.*

Binder content optimization?

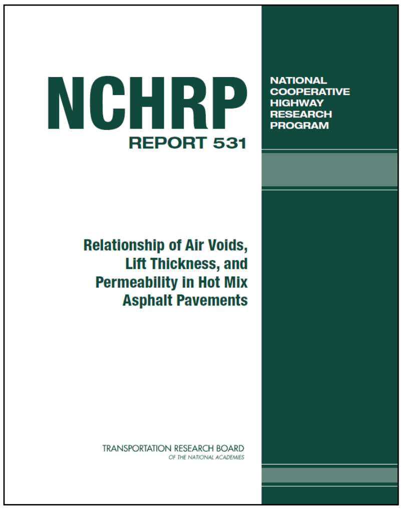
- *Debate continues to rage about SGC cycles for binder content optimisation purposes – general view is that the Superpave mixes are too dry and lack durability (NCHRP Rpt. 573)*

Any special requirements – aggregate / filler / ?

- *Not stated beyond aggregate NMAS*

Design for moisture resistance?

- *A paper was presented at the ISAP conference in which the AMPT cyclic compression test was used to measure moisture sensitivity*
- *NCAT have completed substantial research into the relationship between voids, layer thickness and permeability (NCHRP Rpt. 531)*
- *TSR is still widely used for assessment of stripping potential but few practitioners and researchers are confident that it accurately predicts the stripping potential of a mix.*
- *Some DOTs (such as Texas, Colorado, Oklahoma, and Nebraska) use the Hamburg wheel tracker to assess stripping potential. Most research facilities are continuing to assess the suitability of the Hamburg wheel tracker to evaluate stripping potential.*



Permeability requirements – methods of assessment?

- *Virginia DOT have adopted the permeameter developed by Florida DOT to assess the permeability characteristics of surfacing mixes at the mix design stage. They have a maximum limit of 15 μm/s at 7.5% air voids (VDOT Test Method 120). This assessment methodology excludes the use of excessively coarse dense graded asphalt mixes in surfacing layers.*

SMA design methods - special requirements?

- *Not discussed in detail during the tour.*
- *VAA indicated that it is common practice to bump up the PG binder grade one level for SMA. i.e. a stiffer grade of binder is typically used in SMA compared to dense graded asphalt.*

Design special requirements WMA / RAP ?

- covered in detail separately but current position in respect to PP relevant here)

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7 Relevant NCHRP reports are generally to be found free for download at the NCAT website www.eng.auburn.edu/research/centers/ncat/

Binders

PG specification?

- *The SHRP PG (Performance Graded) specification has been universally adopted across the USA. The low temperature test requirements (e.g. Bending Beam Rheometer) have limited relevance in Australia*

Modified binders – types, purpose and application?

- *The PG system has largely masked the type of polymer modification i.e. the achievement of high performance grades will almost certainly demand polymer modification but the type and quantity is not necessarily declared*
- *PMB's are essentially used in high performance, heavy traffic situations, unlike Australia, the cold temperature requirements in parts of the USA can also drive the need for PMB's to meet the low temperature binder classifications.*
- *PMB modification may be required to satisfy extreme deformation specifications e.g. SST-CH cycles to 5% strain; AMPT FN to tertiary flow*
- *PMB modification may become economically viable to increase the FEL[8] of asphalt albeit the U Cal work suggests increasing the stiffness of the mix (reducing the critical strain) is the more economic solution.*

Performance testing – durability, adhesion and visco-elastic behavior?

- *The Dynamic Shear Rheometer (DSR) is generally the standard tool in the US for bitumen characterisation; the DSR oscillation test determines the complex shear modulus[9] G* and the visco-elastic properties of the binder across the full spectrum of temperature and load frequency enabling the development of master curves. Nonetheless, this temperature-frequency sweep test is performed within a rather small strain range (about 10%). Thus, the properties in large strains need to be observed using different methods, such as the Multiple Stress Creep Recovery (MSCR) Test recently adopted in the PG binder specification*
- *The DSR measured G* parameter is the binder characteristic used in the Hirsch model for the prediction of the asphalt dynamic modulus. The Hirsch model has shown good correlation between the 'predicted' asphalt E* parameter and the 'measured E*' over the temperature/load frequency spectrum*
- *Australian research with the DSR has demonstrated that it can quantify the significant stiffening of the binder mastic that will occur with different fillers and this may significantly increase the asphalt dynamic modulus. Use of different fillers will also affect rut resistance, durability and fatigue performance.*
- *The Pressure Ageing Vessel (PAV) is used by NCAT to evaluate the aging of bitumen[10]*

Dynamic Shear Rheometer
Photo: Jason Jones

[8] The FEL issue with PMB mixes is complicated by the apparent reduction in healing i.e. micro-crack re-adherence is inhibited by the polymer component

[9] The complex shear modulus is related to the binder compression modulus E* in the approximate relationship E* = 3. G*

[10] I am unaware of any specification requirements / limits.

What are the grades of binders typically used in PP construction? Are modified binders commonly used and if so how are they considered in the context of pavement design?

- *This is unknown because of the PG requirements do not directly reflect polymer type or content; in Australia it is unlikely that there will be economic benefit in the use of PMB other than in upper layers*

NCAT is currently hosting trials of Thiopave. What are the early observations from these trials and how does it compare with other heavy duty pavement structures?

- *This was not directly discussed in detail as part of the tour although commercial trials are underway on the NCAT test track on Thiopave pavement structures*.

Asphalt materials performance characterization

Adoption of the AMPT (Asphalt Mix Performance Tester)?

- *Widespread acceptance among US research and the FHWA laboratories for dynamic modulus master curve development and flow tests under cyclical compression (flow time and flow number).*
- *New test procedures under development e.g. fatigue testing using cyclical direct tension, moisture sensitivity using cyclical compression testing*
- *Implementation in Australia will provide a platform for comparative studies and facilitate calibration of test data.*

Which modulus for design purposes – resilient / dynamic / with or without confinement – could also use flexural modulus from fatigue beams?

- *Dynamic modulus used in the US PP design methods – particularly MEPDG and PerRoads which conduct analyses over the pavement temperature spectrum*
- *Generally unconfined dynamic modulus data used – considered to be the conservative option albeit there is recognition that confinement better represents the field condition*
- *Flexural modulus from fatigue testing not used.*
- *The Hirsch model was considered by several researchers to provide a reasonable estimate of the dynamic modulus of asphalt.*

Calibration against field performance – status (particularly FHWA trailer)?

- *No calibration data between the laboratory measurements of dynamic modulus and other mix properties e.g. volumetrics and the field performance of asphalt materials was obtained as part of the tour – unfortunately the manager of the FHWA field facility was unavailable (on leave); further attempts at communication will occur.*

Sample preparation – compaction; lab / plant materials?

- *Slabs for fatigue beams and cores for Hamburg, APA and SST-CH testing generally manufactured using frames and pedestrian rollers to better replicate aggregate orientation*
- *Cores (100mm) for dynamic modulus and flow tests continue to be taken from 150mm SGC cylinders to remove the boundary conditions (recognising the voids in the extracted core vary from the parent specimen)*

Deformation resistance – wheel track / SST-CH / AMPT?

- *California is about the only state using the SST-CH test. The cost and complexity of the test is one of the factors hindering its acceptance*
- *The AMPT flow tests – flow time (time to tertiary flow under static load) and flow time (number of compression cycles to tertiary flow) are gaining more broader acceptance – some tentative recommendations from NCAT (e.g. Tran suggests FN > 1200 for traffic > 30x10^6 ESA's)*
- *It is observed NCAT also have the Hamburg and APA devices but presented only AMPT data.*

Asphalt fatigue limit / endurance limit

Research backing / concept validation?

- *FEL concept accepted by all researchers interviewed.*
- *Evidence of the FEL concept was confirmed as part of NCHRP 9-38 (reported in NCHRP Rpt. 646)*
- *FEL concept is subject of ongoing studies focused on quantification and field calibration. e.g. NCHRP project 9-44A.*

Considerable work already published e.g. NCHRP Rpt. 646. Effect of temperature / load spectrum effect of strain level used during testing on performance?

- *Based on full scale field trials (on pavements loaded to approximately 20 million ESALs), NCAT have proposed designing perpetual pavements based on a cumulative frequency distribution of allowable strains rather than a single FEL value.*

Laboratory verification protocols?

- *The Australian test method (constant strain) is consistent with US practice.*
- *NCHRP Rpt 646 provides a protocol for estimating the FEL based on the laboratory fatigue beam (constant strain) test.*
- *Illinois U (Carpenter) is developing a protocol to facilitate getting a laboratory FEL within a reasonable time frame (to be followed up)*

Is any form of laboratory fatigue testing undertaken? And, if so, is this used in design?

- *See previous*

OTHER MATERIALS PRACTICE

Subgrade preparation (NB no freeze thaw in Australia)

Drainage requirements / moisture content limits / compaction standards?

- *No new advice – best Australian practice is adequate if properly applied.*

Capping layers / subbase preparation / material requirements?

- *Constant emphasis was made of the need for meticulous foundation preparation – capping layer must be able to carry heavy construction equipment without deformation*
- *Some preference for insitu lime stabilisation to improve moisture resistance and enhance bearing capacity*

Compaction standards / dry-back?

- *No new advice – best Australian practice is adequate if properly applied e.g top of capping layer to 100% MDD; dry back to <70% DOS.*

Prime?

- *The achievement of good interface bond emphasised*

Performance requirements under construction traffic?

- *Not covered during tour*

Rehabilitation of PCC pavements

Advances in crack retarding treatments?

- *A geofabric membrane was placed on the I-710; it was located immediately above the thin regulating course under approximately 225mm of asphalt*

- *The evidence of the dramatic failure of the geofabric interlayer when placed within 50mm of the surface in the NCAT trial suggests they should only be used in specific circumstances* [11].

Crack and seat / rubblised?

- *Prof Thompson provided detail of the rubblisation of a Continuously Reinforced Concrete Pavement (CRCP) on the Illinois I-70*
- *The asphalt overlay design using ILLI-PAVE (FEA) assumed the rubblised CRCP had the properties of unbound granular base layer and a method for estimating the foundation stiffness was presented.*

Illinois rubblizing practice: The stages of rubblizing a PCC pavement before overlaying with asphalt, both of the pavement breakers have been proved to be effective

California I710 case study / others?

- *Prof Monismith provided detail on mix design and overlay thickness design details*
- *Overlay thickness design for the cracked and seated PCC utilised FEA*

DESIGN PRACTICE

Layered Elastic Analysis (LEA) / Finite Element Analysis (NB LEA used in Australia)?

- *LEA most commonly used – has the most consistent calibration and validation against field performance*
- *FEA used in MEPDG for PCC pavements (an appropriate use because the joints).*

Performance verification / model calibration?

- *FHWA ALF program – perhaps more focused on deformations, thin surfacing, new materials e.g. WMA*
- *NCAT full scale test track the most significant related research e.g. the FEL distribution*

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[11] Similar instances of failure due to the use of geofabric interlayers have been recorded in Australia e.g. RTA

Modeling temperature / load spectrum?

- *MEPDG models the full temperature distribution (requires climatic data unavailable in Australia)*
- *PerRoad models 5 discrete temperatures to represent the annual distribution*

What material characteristics?

- *Dynamic modulus and fatigue parameters (constant and exponent) used by MEPDG and PerRoads*
- *PerRoad enables consideration of material and construction variability in the design process. The default characterisation method is based on the Witczak model (with upper and lower moduli limits included). The design modulus is assumed using the Witczak Model which is based on PG binder grade and the temperature of the asphalt (determined for up to 5 seasons using the AI procedure (for pavement temperature)).*

Design and performance of high modulus layers in pavements – EME's?

- *There were no examples of the use of extremely hard binders presented, such as is used in the French practice (e.g. 10/15 pen).*
- *In Australia it has not been possible to obtain extremely hard grades thus some additional thickness will be required to limit strain; notwithstanding the lessons of the EME with respect to binder content, grading, and performance limits are appropriate (e.g. the fatigue requirement* $N > 10^6$ *@ 130* $\mu\varepsilon$*;* 15^oC*, 10 Hz)*

What fatigue relationships used – Is Shell equation used?

- *There are a number of fatigue relationships developed in the US based on the correlation of various field trials and LTPP studies; it is impossible to directly apply any of these relationships in Australian practice without calibration*

In Australia, pavement designs are typically done at the initial design based on generic material properties and not on "contract specific" materials. Is this approach adopted in USA?

- *Either generic material properties or 'generic' local material properties are used.*
- *It is suggested that the approach recommended by Dr Von Quintus has merit i.e. the establishment of a National asphalt material characteristics library*
- *Given Australia's relatively small number of bitumen sources and aggregate types it is feasible to design an experiment to develop master curves for the mixes and binders, selected on the basis of them providing the principal structural components in the PP designs i.e. asphalt base and subbase*
- *The asphalt material characteristics library can be used to calibrate the Hirsch model for local application; this can then be readily used by agency and consulting personnel for design purposes*
- *It is feasible that on major projects some validation testing should be undertaken prior to the start of the project (providing adequate time is available for the time consuming test regime)*
- *The suggested material characterisation tests are not QA/QC tests; generally the standard test protocols will be adequate to ensure the mix volumetrics comply with the design model, with perhaps routine DSR evaluation of the binder to ensure compliance with the G* parameters used in design*

PP would have biggest application in heavily trafficked urban locations where there are issues with service authorities. How are these handled?

- *The PP will not be significantly thicker than conventional or composite pavement sections thus the below ground services requirement will not alter.*

CONSTRUCTION PRACTICE - ASPHALT

Layer thickness fn NMAS (Nominal Maximum Aggregate Size)?

- *US work suggests layer thickness typically 4 times the NMAS for coarse graded mixes and 3 times the NMAS for fine graded mixes results in improved compaction and reduced permeability (NCHRP Rpt. 531)*
- *NCAT personnel support the suggestion that we should focus on using appropriate lift thickness (for the given mix size and gradation) to facilitate heat retention and compaction. Research suggests that for coarser mix gradations, adequate compaction can be achieved with appropriate rolling practices at layer thickness greater than 4 times the maximum nominal aggregate size. Research also suggests that smaller NMAS (such as 20 mm mixes) and finer gradations assist compaction and reduce permeability without increased risk of deformation*

Treatment to assure bond at interfaces?

- *Although no details were provided it was accepted that interface bond is often neglected and is a common source of premature failures (even at the NCAT test track)*
- *The implementation of bond coat materials i.e bitumen applications at layer interfaces that do not track off, should be a priority in all pavements and especially PP's. Research is currently underway at a number of research facilities, including NCAT, investigating layer bonding requirements and test methods.*

Virginia DoT: SMA over PCC, produced using Warm Mix Asphalt techniques

Treatments to improve early life skid resistance of SMA's?

- *Gritting was the only method nominated, although gritting is not generally used in the US.*

Treatment to minimize moisture ingress in base layers (in addition to competent subsurface drainage)

- *Focus on reducing permeability of base layers by refining gradation and layer thickness to maximise compactability*
- *Fog seal application is sometimes used if inclement weather is imminent; bond coat will practically assist waterproofing by minimising the loss of bitumen by "tracking off"*

Compaction standards / conformance limits; self-diagnostic rollers?

- *Generally specifying insitu void limits – assist compaction by attention to gradation, layer thickness and maximising bitumen content within the limits of the performance requirements e.g. deformation*
- *Self-diagnostic rollers not discussed?*

Tests to measure insitu density and permeability of thin asphalt layers?

- *Not discussed in detail w.r.t. perpetual pavements.*
- *Virginia DOT were developing a 4.75 mm preventative maintenance mix. They are looking to specify a compaction standard of ≤ 10% air voids. These are currently evaluating this requirement using their permeability test.*

Pay factors to encourage superior delivery?

- *Not discussed in detail.*

Case studies – innovative and superior project delivery?

- *Not discussed in detail*

LONG TERM PAVEMENT PERFORMANCE PROJECT

Current status?

- *Report by Dr Von Quintus; LTPP studies have been used to refute "myths" that asphalt pavements do not survive to provide "long life" relationship with FHWA studies (AMPT trailer)*
    - *Result pending further contact with Youtcheff and Corrigan*
    - *Most long life performance studies have been based on the performance of older mixes (designed using Marshall) which contain much more binder that the dry Superpave mixes currently used across the US.*
    - *Summary of findings*
- *Relevance to PP*
    - *LTPP data supports the FEL concept and suggests the value is around 65 – 70 $\mu\varepsilon$*

US ACCEPTANCE OF PP

What is the level of acceptance?

- *Low. The tour group was advised that only Illinois DOT has included PP concepts in their design system. California has undertaken project designed using the FEL approach.*

What are the factors that swayed supporting agencies?

- None – refer above

Life cycling costing – maintenance diaries for PP?

- *Review APA procedure*

TECHNOLOGY TRANSFER – US, EUROPE & AUSTRALIA

Corresponding membership of appropriate NCHRP / FEHRL committees?

- *Fundamental – most benefit is gained by face to face participation in selected forums to build trust and networking*
- *I Rickards met with Dr Mike Nunn and will report separately on the EU developments; briefly;*
    - *French and German reports (extracts provided) show the pavement deflection is stable or trending downward in the majority of the many pavements studied (100's); this is the classic definition of the achievement of PP status*
    - *The Highways Agency UK has commissioned this research and report on a radical approach to the design of PP's based on the fact that they simply have not observed the classic "bottom up" fatigue cracking*
    - *He states:* **"Pragmatic, evidence based approach suggests that fatigue is not a problem even on relatively thin pavements in the UK"**

Cooperative research – materials exchange and characterization studies?

- *This has been agreed with NCAT subject to agreed terms*

Sponsored visits for workshops with agency / industry / consultant personnel?

- *Consideration to be given for major Australian and International conferences*

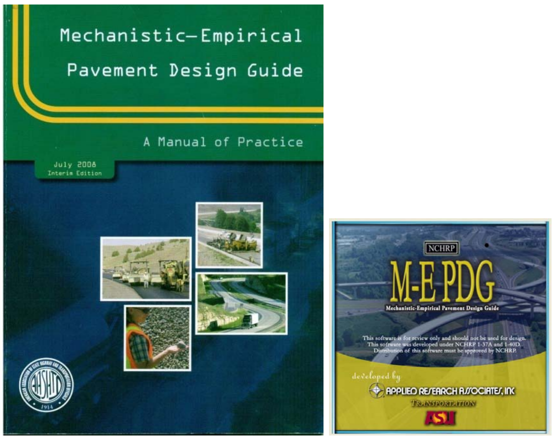
Personnel exchange – higher degree studies?

- *This has been agreed with NCAT subject to agreed terms*

What is the overall level of undergraduate training in pavements generally and asphalt specifically? How are any deficiencies being addressed as an industry?

- *Far more common in US academia e.g. U Cal Berkeley / Davis; U Illinois; U Auburn/NCAT; U Arizona, U Wisconsin, U Washington*
- *NCAT conduct Professor training courses to "train the trainer" in asphalt and pavement technology*

<u>Late questions received – answer if possible</u>



Revised MEPDG being prepared for release

Designs in USA vs Queensland?

- *TMR, like all Australian State Road Authorities, has adopted part 2 of the Austroads Guide to Pavement Technology as the basis for pavement thickness design.*
- *The approach to thickness design in the US varies from state to state. Many states will be moving to adopting the MEPDG in the future.*

Resurfacing strategies – thin & ultra thin as surfacing – is this being used?

- *There was limited discussion about the use of thin surfacings. The primary asphalt surfacing type in the US appears to be dense graded asphalt.*
    - *CalTrans also use Crumb rubber open graded and gap graded asphalt where additional surface drainage is required.*
    - *Virginia commonly use SMA on their interstate network. Virginia DOT is also currently developing a 4.75 mm nominal dense graded asphalt mix (to be laid 25 mm thick) for use as a preventative maintenance treatment to combat reduced funding levels.*
    - *SCDOT are finding increasing usage of OGA on their high speed network.*

How is top down cracking monitored?

- Not discussed in detail. However, observations at NCAT suggest that top-down cracking is usually limited to the top two layers of the pavement structure (i.e. top 100 mm).

Do perpetual pavements really work?

- *Research undertaken by NCAT and NAPA suggest that long life flexible pavements can be achieved. However, the thickness of asphalt pavements typically used on heavily trafficked routes in the US exceed the thickness of asphalt pavement designs typically used in Australia.*

Can it be transferred to Queensland?

- *Some of the concepts identified during the tour might be able to be transferred. However, significant additional research is required for these concepts to be calibrated and translated to a robust system ready for implementation. It is suggested that further investigation of the fatigue endurance limit should be undertaken by the Austroads Pavement Structure Reference Group in light of the findings of NCHRP Rpt 646*[12].

[12] Reference Material #2

Reference Material

List the presentations or other material gathered during the tour.

1. AP-T131/09 Asphalt Fatigue Endurance Limit, Austroads Technical Report, November 2009 www.austroads.com.au
2. NCHRP Report 646 Validating the Fatigue Endurance Limit for Hot Mix Asphalt, Transportation Research Board www.TRB.org
3. Phase III NCAT Test Track Findings, NCAT Report 09-08, NCAT at Auburn University, December 2009
4. Lab Testing & Modeling for Structural Performance of Fully Flexible Permeable Pavements – D Jones, J Harvey, H Li, T Wang, L Chair & B Campbell, University of California Pavement Research Centre, August 2010, presentation
5. The Phase One I-710 Freeway Rehabilitation Project: Initial Design to Performance After Six Years of Traffic, Carl Monismith, UCPRC, UC Berkeley, August 2010, presentation
6. Endurance Limit, HMA, Carl Monismith, UCPRC, UC Berkeley, August 2010, presentation
7. Materials Characterisation, Carl Monismith, UCPRC, UC Berkeley, August 2010, presentation
8. Perpetual Pavements – Overview, Asphalt Pavement Alliance, David Newcomb, presented by Rita Leahy, August 2010
9. LTPP & Modeling, AAPA Study Tour, FHWA Turner-Fairbank Centre, H.L. Von Quintus, August 2010, presentation
10. Perpetual Pavement Design: An Overview, Marshall R. Thompson, University of Illinois, presentation
11. Perpetual Pavements & Concrete Pavement Rubblizing, Marshall R. Thompson, University of Illinois, presentation
12. Rehabilitation of Concrete Pavements Utilizing Rubblization and Crack-and-Seat Methods: Phase II – Performance Evaluation of Rubbilized Pavements in Iowa, National Concrete Pavement Technology Centre, Iowa State University.
13. Transport Research Circular Number E-C087, Rubblization of Portland Cement Concrete Pavements, January 2006, www.TRB.org
14. Mixture Performance Testing, AAPA Study Tour 2010, Nam Tran, NCAT Auburn University, August 2010, presentation
15. NCAT Pavement Test Track, Buzz Powell, NCAT Auburn University, August 2010, presentation
16. Perpetual Pavement Design and Case Studies, David Timm, Department of Civil Engineering, Auburn University, August 2010, presentation

17. Perpetual Pavement Design Concepts and Case Studies, David Timm, Department of Civil Engineering, Auburn University, August 2010, presentation
18. NCAT Brochure, Methodology and Calibration of Fatigue Transfer Functions for Mechanistic – Empirical Flexible Pavement Design, Research Synopsis 06-03
19. NCAT Brochure: Recalibration of the Asphalt Layer Coefficient, Research Synopsis 09-03
20. NCAT Research Achieving Real-World Results, Third Pavement Test Track Conference Held, Hot Mix Asphalt Technology, May/June 2009
21. Summary of Binder Fatigue Findings from FHWA ALF and Full-Scale Accelerated Aging Activities, Nelson Gibson, FHWA, Binder Expert Task Group, Irvine, CA, February 2010, presentation
22. Perpetual Pavements – A Synthesis, David Newcomb, Richard Willis, David Tim, Asphalt Pavement Alliance IM-40
23. PerRoad software http://asphaltroads.org/PerpetualPavement

5. WARM MIX ASPHALT

Working Group

Leader: Cassandra Simpson Group: Cassandra Simpson, Warren Carter, Jason Jones*, Greg Stephenson

Tour scope

Warm Mix Asphalt is asphalt made at a lower temperature than conventional hot mix asphalt. The different manufacturing process for WMA causes a temporary reduction in the viscosity of the asphalt binder, which allows for better coating, and easier compaction. WMA has the following benefits:

- Reduced energy consumption during asphalt manufacturing. WMA process improves coating of materials allowing for lower temperatures to be used in asphalt manufacture.
- Reduced climate impact through lower fuel consumption and reduced greenhouse gas generation.
- The materials and asphalt are at lower temperature compared to HMA resulting in improved and safer workplaces with health and safety benefits .
- Improved productivity as deep / thick asphalt works can be opened to traffic more quickly. This benefits the transport industry and commuters by reducing the length of time the road is closed for repair.
- Improved productivity through an extended paving season and longer haul distances as WMA is easier to compact at lower temperatures.

HMA on left and WMA on right being loaded from storage bins.

There are various ways to produce WMA:

- Additives are introduced to the asphalt mix to lower the viscosity of the binder.
- Foaming of bitumen through the direct injection of water – Bitumen foaming systems.
- Combinations of the above

WMA was included as a major topic for the Study Tour due to interest within the Australian asphalt industry. Asphalt suppliers, purchasers and designers were interested to gather more information for the USA experience with WMA.

Additive for WMA

Feedback from

- California – Caltrans / Granite, APACA, CalAPA / UC Davis
- Washington, DC – FHWA/ NAPA
- Virginia – VDOT / VAA
- Tennessee – Astec
- Illinois – DOT & University
- Texas – DOT
- North Carolina – Boggs / NCDOT
- South Carolina – Boggs & Banks / SCDOT
- Alabama – NCAT

Observations

The following section provides the delegates observations from three groups in the USA.

1. Observations from Department of Transport

Varied response from DOT depending on location e.g. State, and depth of experience with WMA

Usage:

- Trialing of WMA technologies on DOT projects commenced in 2006. Most DOTs have undertaken demonstration trials. The rate of implementation has been mixed (but generally quite rapid).
- WMA has generally been used in dense graded asphalt mixes (and predominantly in surfacing layers).

- WMA has been used with other mix types including SMA (Virginia, Maryland), OGA (California) and crumb rubber asphalt (California).
- Some DOTs (such as SCDOT) have limited its use to lower traffic volume roads (until more experience is gained) while others allow its use on any road irrespective of traffic volume.

Approval Process

- Most DOTs are developing an 'Approved List' of acceptable WMA technologies.
- Approval procedures usually require the submittal (to the state DOT asphalt engineer) of documentation from a minimum of three construction projects using the WMA technology, preferably with at least one constructed in the state in question. Documentation usually includes a mix design with mechanical test properties and Quality Control / Quality Assurance (QC/QA) test results measured during production.

Specifications

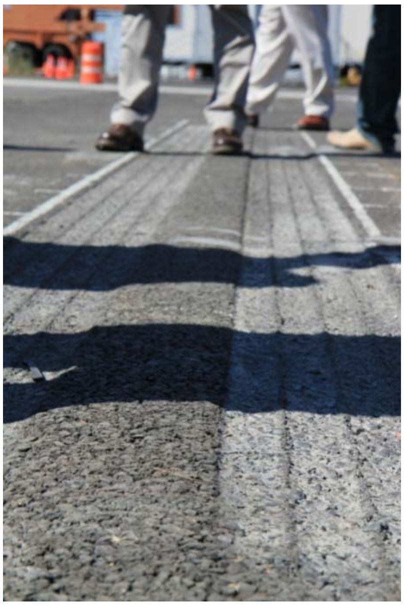
- Generally prefer permissive specifications → contractors choice
- Some DOTs are specifying its use in "non-attainment areas"- Counties included in the Clean Air Act's National Ambient Air Quality Standards (NAAQS) requiring special air quality control.

Preferred technologies

- Under permissive specification arrangements, the bitumen foaming systems are becoming the preferred WMA technology – no ongoing material / additive cost.

Caltrans

- Not all WMA technologies are considered equal i.e. bitumen foaming systems differ depending on the manufacturer of the unit, creating the need to assess each one individually (Caltrans)
- WMA is working well but still proceeding with caution (Caltrans)
- California has "mandated" the use of scrap rubber in asphalt, 30% by 2013 is the requirement across all asphalt used by CALTRANS. WMA will help promote the use of rubberised pavement in cooler climates and has overcome some of the fuming issues of mixing rubber at hot mix temperatures.



Accelerated load testing of WMA in California

- WMA allows overlays on pavements with existing rubber crack sealing where the maximum permitted temperature is 235°F (113°C) to avoid "reactivating" the crack sealer.

Virginian DOT

- VDOT has accepted WMA and allow it in normal specifications but accredits each supplier/plant to enable them to supply WMA.
- VDOT indicated that foam mix still sticks to plant and equipment – some producers tending to make at too low a temperature. (estimated 275°F - 285°F / 135°C - 140°C is the optimum temperature)
- VDOT believe WMA designs should be based on hotmix designs and just allow for the additive – but ensure that the increased compactability doesn't adversely affect the voids (allow @1% decrease in voids but don't adjust binder content)
- VDOT has accepted WMA and allow it in normal specifications with the Contractor permitted to use WMA unless otherwise shown on the plans.

Texas DOT

- TxDOT were initially cautious and saw no benefit to them (only savings to the Contractor) – have since changed as the benefit is a pavement with greater durability (due to improved and more consistent compaction). Other benefits include reduced emissions, extended paving season and improved night time paving.
- TxDOT believe bitumen foaming systems can't achieve desired requirements in "non-attainment areas" – high smog risk locations i.e. temperature decreases of the bitumen foaming systems aren't as good as some additive processes.
- TxDOT approve the WMA process/technology, not the Contractor's ability to make WMA (this risk is believed to be addressed through the overall contractor registration system)
- TxDOT allows WMA on all projects as the Contractor's option and requires WMA on some projects. Overall performance has been good. Less compactive effort required. Less bitumen absorption. More difficulty in meeting TxDOT's Hamburg requirement. WMA is relatively insensitive to variations in compaction temperature.

Testing of WMA and HMA by TxDOT

North Carolina DOT

- NCDOT believe adhesion agents are mandatory if a TSR < 85% is obtained.

South Carolina DOT

- SCDOT have similar approach to NCDOT but use a hydrated lime/pugmill process prior to drying of the aggregate.
- SCDOT only use WMA incorporating RAP i.e. no virgin WMA mixes.

Kansas DOT

- Kansas DOT. Warm Mix Asphalt (WMA) is defined as additives or processes that allow a reduction in the temperature at which asphalt mixtures are produced and placed. However, not all additives or processes result in potentially the same temperature reductions. For example, the following table shows the maximum mix temperature reduction permitted by Kansas Department of Transportation for different WMA technologies. The temperature reduction attained by foaming techniques is in the order of half that attained by additives.

KANSAS DEPARTMENT OF TRANSPORTATION - APPROVED WARM MIX ASPHALT ADDITIVES			
WMA Technology	**Process Type**	**Supplier**	**Max Mix Temp Reduction[1]**
Advera	Foaming	PQ Corporation	30°F (17°C)
Aquablack Solutions	Foaming	Maxam Equipment	30°F (17°C)
Aspha-Min	Foaming	Aspha-Min	30°F (17°C)
Double Barrel Green	Foaming	Astec Industries Inc.	30°F (17°C)
Evotherm	Chemical Additive	MeadWestvaco Asphalt Innovations	70°F (39°C)
Redi-Set WMX	Chemical Additive	Akzo Nobel Surfactants	70°F (39°C)
Sasobit	Organic Additive	Sasol Wax Americas, Inc.	70°F (39°C)

[1] Mixing temperature range is provided by the Asphalt Binder Supplier. When using WMA, the mixing temperature may be reduced no more than that shown for the specific WMA technology. The minimum mixing temperature for WMA is 220°F (104°C).

2. Observations from Contractor/Industry (including NAPA, etc)

Contractors

- Primary benefits identified by Contractors:
  - Equal or better compaction
  - Longer haul potential due to lower placement temperature
  - Cool weather paving potential
  - Longer compaction time
  - Reduced production temperatures means there are less odours and smoke at the plant and the paving site. WMA is preferred over HMA with the paving crews.
  - Reduced fuel consumption

NAPA

- Over 1000 WMA projects nationally to date
- Approximately 10% of asphalt work in the US is WMA
- Expect within 5 years, 50% of asphalt will be WMA

- Primary drivers:
  - Better air quality
  - Better energy efficiency
  - Better performance
  - Better compaction
  - Better working conditions
- WMA can assist with producing / paving in non-attainment areas

Boggs Construction indicated the following:

- They use the Double Barrel Green system
- Primary benefits include easier to achieve specified field density and improved workability
- It is important not to produce the warm mix too hot. Placement issues were experienced when production temperatures exceed 140°C.
- Boggs have not trialed WMA with PMB's or CRA
- Boggs use hot mix designs and then change to the WMA process.
- Boggs perceive the biggest risk as stripping but have not seen any evidence.

Granite Constructions

- Granite constructions use WMA on most municipal works, and some Caltrans works
- Granite sees the main benefit as workability (increased window of compaction)and improved productivity
- Granite have held WMA (foam) for 24 hours in hot storage bins without issues arising
- Granite believe that WMA with 25% RAP result in a binder with similar characteristics as to a virgin hotmix binder (RTFO aged binder)
- Granite believe the largest risk is going overboard with RAP in WMA – the need to increase it slowly and manage the moisture content of the RAP.
- Granite sees the main benefit as workability and improved productivity

Placement of WMA at Anchorage International Airport

Banks Construction

- Banks indicated that the energy savings expected with WMA is not evident
- Banks indicated the biggest benefit is the improved/more consistent compaction and the reduction in penalties for non-compliance re. compaction
- Banks had issues with the Gen 1 Astec Green unit – been addressed with Gen 2 and changing to a black water tanks from a white water tank which prevented algal growth.

Astec

- ASTEC have installed over 350 of the estimated 500 units of all types of bitumen foaming systems are operating in USA. See Photo

Astec Foam WMA Unit

3. Observations from Researchers

General

- Have not experienced performance issues in warm/hot climates and no freeze States (FHWA)
- TSR's of WMA are generally lower than those obtained from testing hotmix (FHWA)
- NCAT cautioned against the use of foam technology in the northern States i.e. cold/freeze affected.
- NCAT indicated best success at implementation of WMA has been where the DOT and Contractors have worked together rather than having the process mandated (or restricted)
- Lab prepared WMA samples give poorer results than plant produced samples (NCAT)
- Designs are based on adding the warm mix technology to a standard hotmix design (NCAT)
- Contractors should nominate the production and lay down temperature regimes/limits (NCAT)
- Some moisture susceptibility issues have been observed when WMA production temperatures were below 260°F (127°C) (NCAT)
- Believe that there may be some trial sites with moisture issues but yet to confirm (NCAT)
- No indication that three warm-mix additives tested (Advera WMA®, Evotherm™, Sasobit®) influence rutting or moisture sensitivity performance etc (UCPRC).
- Construction quality remains the key concept.

NCAT

NCAT evaluation of WMA technologies indicates the following:

- Moisture Susceptibility:
  - Tensile Strength Ratio (TSR):
    - Typically lower ITS for WMA than HMA
      - Except Sasobit and sometimes Aspha-min
    - ITS improves with reheating
      - Sometimes helps TSRs sometimes not
    - TSR affected by binder grading, RAP content, and mixing temperature
    - WMA technology does not seem to have a significant effect on moisture sensitivity results
  - Hamburg:
    - WMA stripping inflection point typically lower
      - Except Sasobit
- Rutting and Permanent Deformation:
  - Increased rutting has been measured in the laboratory, appears to be less ageing of the binder in the laboratory
  - Field data indicates rutting resistance is not decreased with WMA
- Cracking
  - Field data indicates that WMA is not more prone to cracking
  - Field project in Colorado has WMA sections with less cracking than HMA
  - Continue to monitor cracking – long-term

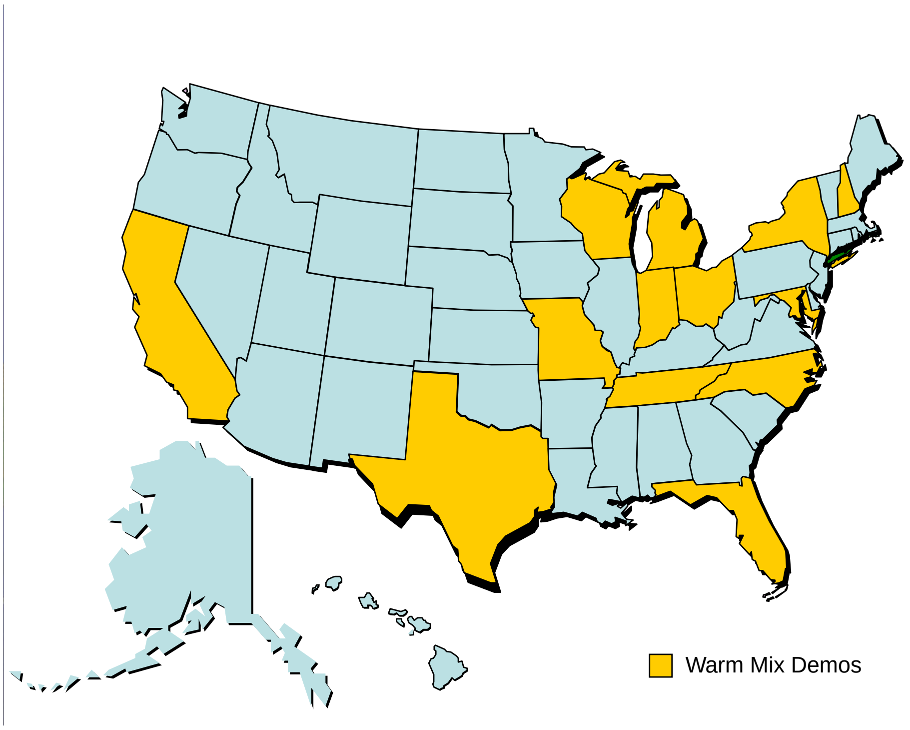
FHWA

FHWA advised there are NCHRP projects underway that are investigating WMA technologies including:

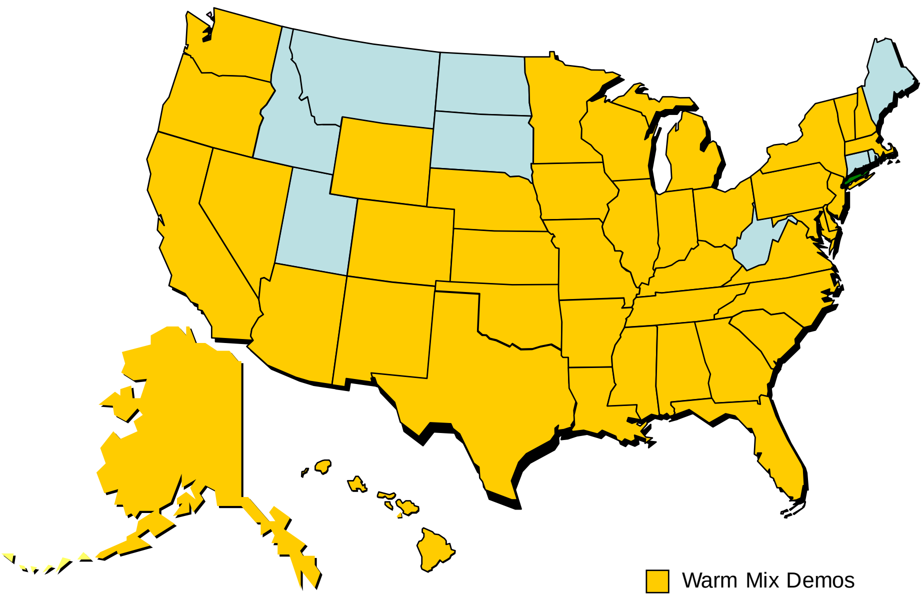
- 9-43: Mix Design Practices for WMA
- 9-49: Engineering Properties, Emissions and Field Performance
- 9-49A: Long Term Field Performance of Warm Mix Asphalt Technologies
  - Phase 1, Moisture Susceptibility
  - Phase 2, Long Term Performance

Preliminary findings of project 9-43 include:

- Process specific specimen fabrication procedures are required
- Recommended binder grade changes based on production temperature
- Recommended maximum RAP stiffness based on compaction temperature
- Coating evaluated at production temperature
- Rutting resistance evaluated for 3 million ESALs or greater mixtures
- Preliminary findings of NCHRP 9-43 is that WMA mixture design should be the same as that for hot mix asphalt with a mandatory test for Rutting Resistance utilizing the AMPT Flow Number (Fn) test. Mixture analysis should include Optional Performance Tests such as Fatigue Cracking, Modulus, Thermal Cracking.



Warm Mix Demonstration Projects in the U.S. as of Jan. 2007



Warm Mix Demonstration Projects in the U.S. as of Jan. 2010

Summary of Conclusion on USA knowledge/developments for WMA

The USA appears to have a trend towards acceptance of WMA based on the outcomes of positive performance from field trials undertaken in each state. Contractors see significant benefits with using WMA over conventional HMA. These benefits include:

- More consistent (and higher) compaction results. This has resulted in being able to achieve the specified compaction standard more easily
- Extended paving season (able to pave in cooler weather conditions)

- Increased haul distance
- Reduced emissions (which assists when producing / paving in non-attainment areas)
- Energy / fuel savings (due to lower production temperatures)
- Health and safety benefits

State DOTs initially had concerns with the performance and additional cost of warm mix asphalt. Most state DOTs have observed good performance from their WMA trial sections and WMA is increasingly being seen as an acceptable technology. Most state road authorities are moving toward using permissive specifications for the supply of warm mix asphalt. Therefore it will be the Contractor's choice whether WMA is used on a particular project. Increasingly the designation of 'non-attainment areas' is affecting asphalt operations across the country. WMA is being seen as a technology that Contractors can use to overcome these issues. Some DOTs are specifying the use of WMA in non-attainment areas to overcome project specific issues.

The number of warm mix asphalt technologies available is continuing to increase on a monthly basis. There are currently 23 warm mix asphalt technologies that have been identified by FHWA.

Most state road authorities are developing an approved list of WMA technologies to ensure only systems that have at least some performance history are used on their projects. FHWA and NCAT are working towards a national certification program for WMA technologies to provide a more uniform and national approach to the approval process for WMA technologies.

Technologies

Technologies that appear to have gained acceptance by one or more state DOTs are:

- Foaming Systems
  - Astec - Double Barrel Green
  - Maxam - Aquablack
  - Gencor - Ultrafoam GX
  - Terex
  - Meeker -Aquafoam
- Water carrying (chemical additives)
  - Advera
  - Aspha-min
- Chemical additives
  - Evotherm (DAT, 3G)
- Rheological modifiers
  - Sasobit
  - Rediset-WMX

The foaming systems appear to have a distinct advantage over other WMA technologies due to no additive being required (and hence no ongoing cost).

Once the foaming unit is purchased, the only ongoing cost is maintenance of the foaming unit and water tank. The Virginia Asphalt Association indicated that of the 44 plants within Virginia that can supply WMA, only two use additives (with the 42 remaining plants being foaming units). The cost of WMA additives is generally in the range of $3–5/ton of asphalt. However, the cost of WMA additives is reducing quickly so that they can compete with the foaming systems.

Technical Issues

There are a number of technical issues with WMA that are continuing to be investigated. These include:

- Mix design procedures:
    - Current process is to use an existing HMA design with the WMA additive
    - FHWA is currently investigating design procedures for WMA
- Moisture Susceptibility
    - Several investigations have reported low tensile strength and tensile strength ratio (TSR) test results for WMA. Observations to date indicate that low tensile strength results with WMA do not appear to correlate with moisture damage in the field.
- Rutting and Permanent Deformation:
    - Several investigations have reported poor test results for WMA when tested with the Hamburg or APA rutting tests. Observations to date indicate that poor laboratory test results do not appear to correlate with rutting in the field.
- Curing procedures:
    - Curing procedures of test specimens appear to have a more significant impact on the test results for WMA than HMA. Further investigation of the curing procedures for WMA test specimens is required.

Savings

Despite the above short comings with laboratory testing / material characterisation of WMA, short term field performance of WMA appears to be very good. However, longer term monitoring will be required to confirm the performance outcomes of WMA. The lower fuel costs appear to amount to only $1/tonne of asphalt. Therefore the long term performance of WMA needs to be equivalent to HMA for it to be a cost effective treatment.

Initial Softness

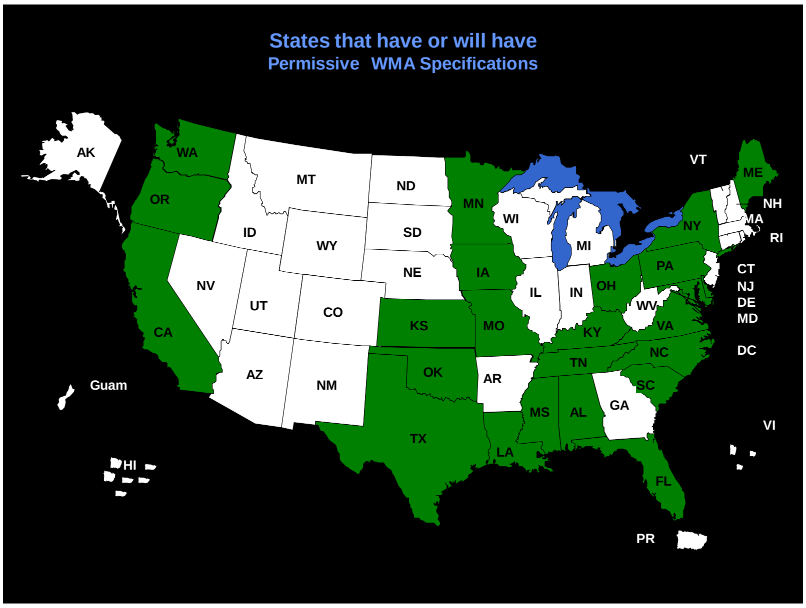
WMA (except Sasobit) appears to be initially 'softer' (and less rut resistant) than HMA (possible due to less oxidation of the binder during the manufacturing process – it has also been suggested that some of the light fractions in bitumen are removed at the higher temperatures of hot mix production remain active in the WMA binder) but gains strength rapidly and has similar rut resistance to HMA within two years of placement. Due to the large quantities of RAP available in the US, most asphalt mix contains at least some RAP. The lower stiffness of the WMA binder is possibly being offset by the high stiffness RAP binder. In most circumstances, WMA is being used in combination with at least 10% RAP.

Rapid implementation

Implementation of WMA is occurring rapidly in the US. NAPA indicated that approximately 10% of asphalt supplied in the US is WMA. This amount is expected to increase to 50% within 5 years. Implementation is primarily being driven by Contractors due to construction benefits associated with the technology. Environmental benefits are an important, but secondary factor. State DOTs are becoming increasingly accepting of WMA, provided it gives equal or better performance than HMA. State DOTs that allow WMA are generally moving towards permissive specifications once initial demonstration projects are constructed within their state and performance is proven. A range of technical issues associated with material characterisation and performance assessment are currently being investigated. These issues will need to be resolved before WMA is fully accepted by most state DOTs.

Overall, the push for WMA appears to have come from additive manufacturers and contractors with construction benefits such as compaction and rideability often being the driving factor. The actual method used depends on the additives marketed in the area and the willingness of the contractor to work with the suppliers. Often these become the "approved" process because the Road Authority has some experience/exposure to products that were demonstrated locally. Due to the on-going cost for supply of the additives, mechanical foaming systems appear to be the most common form of WMA technology being used.

Approved WMA technologies vary by state with some states only allowing bitumen foaming systems (water injection) whilst other states only allow additives. Most states allow some bitumen foaming systems and additive methods. Most states that allow WMA do not specify that WMA must be used leaving it as a Contractor's choice It appears that contractors use WMA, especially where water injection is used, on their private and municipal works where possible.



Source: NAPA 2010 (States with WMA specification shown in Green)

The majority of projects incorporating WMA have used dense-graded mixes. However, SMA and open-graded mixes have been produced with warm mix technology.

Technical Working Group

FHWA has a national WMA Technical Working Group (TWG) consisting of NAPA, FHWA and Academia. The TWG Deliverables include WMA Guide Specifications, Testing Framework for Initial Pilot Projects, and support for National Cooperative Highway Research Program (NCHRP) projects including: NCHRP 09-43 "Mix Design Practices for WMA" NCHRP 9-47A "Engineering Properties, Emissions, and Field Performance" and NCHRP 9-49 "Long Term Field Performance of Warm Mix Asphalt Technologies". Issues surrounding sample conditioning prior to performance tests are still to be resolved.

Warm Mix Asphalt - Questions & Responses

Processes

What process/es of WMA have achieved adoption?

Approved WMA technologies vary by state with some states allowing bitumen foaming systems (water injection) only whilst other states only allow additives. However, most states allow some water injection and additive methods. Most states that allow WMA do not specify that WMA must be used leaving it as a Contractor's choice It appears that contractors use WMA, especially where water injection is used, on their private and municipal works where possible.

The actual method used depends on the additives marketed in the area and the willingness of the contractor to work with the suppliers. Often these become the "approved" process because the Road Authority has some experience/exposure to products that were demonstrated locally.

Over 23 WMA technologies are commercially available and are summarised into the following broad categories:

- *Free water systems*
  - *Bitumen foaming systems - mechanical foaming by injecting water which converts to steam creating foamed bitumen*
  - *Manufacturers include Astec "Double Barrel® Green", Gencor "Ultrafoam GX™', Maxam "Aquablack", Meeker "Aquafoam", Stansteel "Accu Shear", Terex/CMI, Shell WAM Foam and others*
- *Water carrying chemical additives*
  - *Additives introduce water to mix which converts to steam creating foam*
  - *Synthetic Zeolites such as Aspha-min and Advera WMA*
- *Water carrying non-chemical additives*
  - *Wet fines added to heated coarse aggregate and binder*
- *Chemical additives*
  - *Additives to reduce internal friction with no effect on binder properties*
  - *Additives: Evotherm ET, Evotherm DAT, Evotherm 3G, Cecabase RT, HyperTherm*
- *Rheological modifiers*
  - Temporary modify rheological properties of binder at mixing temperatures and act as a compaction aid
  - *Additives: Sasobit, Rediset WMX, TLA-X, Thiopave, Sonne Warmix*

Is there any framework to assess new additives?

- *NCAT has undertaken a project to collect historical information to document construction, placement, and mix properties on existing public road projects and has proposed a "National Certification Program". The states would use information when approving a WMA technology but it would not be the exclusive way for approval in that state.*

- *Caltrans has a "Draft Warm Mix Approval Criteria for New Products (8/11/2009)" which includes a 12 month field study or HVS study (HMA control required). Work can be done in any state, although state approved tests must be followed. NYSDOT has a "WMA Technology Approval Process Concept" – Mix performance is based on AMPT (tentative pending additional information) measurements of Dynamic Modulus and Flow Number.*
- *Texas Department of Transportation Approval requires the submittal of documentation from a minimum of 3 construction projects using the WMA technology, preferably a minimum of one in the State of Texas. Documentation must include a mixture design with mechanical property test results and Quality Control/Quality Assurance (QC/QA) test results measured during production.*
- *Virginia Department of Transportation "Approved Warm-Mix Asphalt Products and Processes" states "New products/processes will be evaluated by the District Materials Engineer and a central committee. Once approved, the product/process will be added to this approved list. The evaluation procedure involves documentation and independent test data to support the new WMA product or process, mix design submittals and a trial section."*
- *Oklahoma Department Of Transportation "Special Provision For Warm Mix Asphalt Material Requirements" states "use only WMA additives or processes listed on the Department's approved list maintained by the Materials Division. The Materials Division Engineer may accept new additives or processes with sufficient evidence of performance."*

Are environmental issues influencing the adoption of WMA?

- *Environmental benefits are generally a secondary driving factor. WMA may be specified in a few districts in Texas which require WMA by plan note (contract variation) for Environmental reasons in "non attainment areas" for Counties included in the Clean Air Act's National Ambient Air Quality Standards (NAAQS).*
- *Caltrans is working on WMA Implementation to give improved performance (lower in place air voids) and sustainability benefits as part of the Governor's Climate Action Plan.*
- *TxDOT claims a Direct Energy Savings of approximately US$1/ton.*

Development of carbon calculator for WMA and RAP?

- *There did not appear to be active work to develop a carbon calculator for WMA and RAP. This is partly due to the push for the products coming from Contractors for "constructability" issues.*
- *Caltrans - Since 2007 Life Cycle Cost Analysis has became a requirement for all projects on the State Highway System, regardless of their funding source. This may provide a mechanism to ultimately incorporate a carbon calculator.*
- *US EPA Green Highways Program (GHP) supports use of WMA.*
- *UCPRC has ongoing research measuring hydrocarbon emissions on the loose mix and compacted mat of WMA.*

Use

Any changes to handling, placing and compacting WMA?

- *No changes with the exception of some locations using one less roller. Comments were that it is just like hotmix but placed at a lower temperature. Would advise that caution be taken if considering reducing the number of rollers as emphasis should be to get it right in the initial stage.*
- *Some specifications have altered pavement temperature requirements for WMA e.g. WMA allow >0°C and HMA >4°C (ALDOT 410.03.b.3). FLDOT allow a 5°F decrease in ambient temperature if WMA is used.*

Compaction temperature - specification limits if applied?

- *Caltrans treat WMA the same as hotmix i.e. same temperature requirements prior to opening to traffic and a minimum temperature (applicable to both) behind the paver is 250°F (121°C).*
- *TxDOT has some temperature limitations in non-attainment areas (EPA restrictions exist) or over crack sealing where the maximum temperature is 235°F (113°C). Generally it is left to the contractor to propose production and compaction temperature regimes.*
- *The foam processes are being used somewhere in the range 275-290°F (135-143°C). The zeolites @ 250°F (121°C). The chemical additives 230-250°F (110-121°C)*

Storage time changes?

- *The was not real indication as to different limitations for WMA. There were indications (VDOT) that foamed WMA had been stored for up to three days without issues.*

How is moisture content addressed with the foamed WMA?

- *Moisture content of the WMA isn't perceived to be an issue.*
- *With wet aggregate the production rate was slowed to ensure adequate drying.*

Why does the USA appear to have MC limits for WMA?

- *The USA does not appear to have MC limits for WMA. The producers are generally assessed to be suitable/non-suitable for producing WMA.*

Are the asphalt samples handled and compacted differently for WMA vs HMA

- *This depends on the State. Some had differing conditioning temperatures. VDOT reheated samples and test them as per hotmix requirements.*
- *OKDOT heat/condition the WMA sample for 4 hours.*
- *It was indicated that it is satisfactory to reheat foam mix that had cooled, to its production temperature and still test as a WMA.*

Are any additional asphalt mix design tests in use? Are some redundant?

- *Again, this is State dependent. Some have different limits on the moisture sensitivity (TSR) results (NCDOT >85%; Caltrans >70%). Various States have different views on this test i.e. from it should be mandatory, to, it is not applicable.*
- *The Hamburg wheel tracking test is mandatory in TxDOT and is used to determine if an adhesion agent is required.*

- *Generally, the mix design is undertaken without the additive/process i.e. a hotmix design is undertaken, and then the warm mix additive/process is used.*

What is the experience of using WMA in: Bitumen crumb rubber asphalt (CRA), SMA, OGA

- *Some States have used warm mix technologies with CRA, PMB, SMA and OG's. The indications that the processes are applicable. The temperature differential is of a similar magnitude i.e. a nominal drop of "X" °C (nominally 50°F / 28°C) is applicable – depending on the technology.*
- *Placemen of CRA at lower temperature reduced fuming.*

How does WMA cope with modified binders? Is there any pressure to move away from modified binders?

- *Again, a nominal 50°F is able to be achieved when modified binders are used.*
- *There is no pressure to move away from PMB's – they are seen as premium binders and used where appropriate.*
- *The quantity of polymer used in PMB's in USA is generally lower than the percentage used in Australia, so the USA experience may not be directly comparable.*

Will there be any effects when recycling wax based WMA?

- *None has been recycled to date, but the indication was that the low levels being used i.e. generally 1.5% will not adversely impact on the binder properties – but all agreed that they will slightly stiffen the binder.*

What is the effect of WMA on the performance of the bag house?

- *Care has to be exercised so that the plant is operated above the dew point, but there were no indications that problems exist. This may have been due to the push to include RAP in the WMA, so the aggregates had to still be superheated to enable a satisfactory heat transfer to the RAP.*

What steps are taken to overcome reduction in the stiffness of the binder due to lower mixing temperatures?

- *Although there was some concern as to the potential for early rutting, this wasn't identified as a problem in the field or through APT testing. There were several examples of the WMA binder ageing to an equivalent level as hot mix within 2 years of service. The addition of RAP was again seen as a precaution against this potential issue.*

Is there any experience with modified binders (i.e. PG70+) in warm mixtures? Are there considered to be any restrictions on the types of binder that can be used in WMA?

- *PG76 was indicated to have been used without issue – again a nominal 50°F / 28°C drop in the binder temperature was indicated to be applicable.*
- *No feedback was received that would preclude warm mix technologies from being used with any binders.*

Has the US produced SMA and OGA through a WMA process?

- *Warm mix (wax) SMA was placed on the Beltway (VDOT) to minimise potential issues of rutting due to opening to traffic.*
- *SMA using foam technology has been placed in Virginia.*

WMA and RAP

Is the asphalt mix design re-deigned for RAP? How – binder content, class of bitumen?

To understand the impact on the inclusion of RAP into asphalt generally it must be appreciated that virgin source aggregates typically used in USA are a "combined" grading passing one sieve and retained on a lower sieve e.g. passing ½" (13mm) and retained on ¼" (6.7mm) giving more fractions than the single size aggregates typically used in Australia. There is potentially more variability in the US virgin mixes. Therefore, greater use is made of fractionated (single size) RAP to reduce the variability of the final mix. As RAP contents increase, it becomes more important to accurately determine properties of RAP and control its consistency (NCAT). Fractionation helps for design of high RAP mixes.

ASTEC comments that with Warm Mix (hot foam), field density can be achieved without changing bitumen grades at 50% RAP

Current FHWA Binder Guidelines for RAP in HMA.

0-15% RAP	*No Change in Virgin Binder*
16-25%RAP	*Bump Virgin Binder Down 1 PG Grade*
> 25% RAP	*Use Blending Chart to Determine Virgin Binder Grade*

Possible Binder Guidelines suggested for RAP in WMA?

0-25 % RAP	*No Change in Virgin Binder*
26-35% RAP	*Bump Virgin Binder Down 1 PG Grade*
> 35% RAP	*Use Blending Chart to Determine Virgin Binder Grade*

Whilst these are quoted as percentage RAP, they should actually be interpreted as percentage of total binder from RAP.

NCAT concluded that there is no strong evidence to support bumping down the virgin binder grade for high RAP mixes. Banks Construction SC (Surface Mix with PG 64-22 bitumen) commented that 20% RAP to 40% RAP results in <9% increase in Recovered Viscosity.

There has been no change in the total bitumen content due to the use of WMA.

To assess the impact of RAP on "combined" binder stiffness, expanded RAP mixing studies utilizing dynamic modulus, E, evaluation criteria developed by Advanced Asphalt Technologies (Bonaquist & Christensen) have been undertaken. E* from samples prepared at the specified mixing and compaction temperatures are compared to fully blended condition E* determined through the Hirsch model. This model assumes 100% blending of RAP and virgin binders. It is still unclear whether RAP and new binders mix completely at WMA process temperatures. NCAT have suggested that Interfacial Mixing Studies, Atomic Force Microscope and Lab Mixing Studies are required.*

Limitations on RAP inclusion? Plant restrictions or field performance ?

The use of fractionated RAP and non-fractionated raw materials were discussed above. Prior to crushing, screening, and separation of RAP, SCDOT Specifications were limited and restricted to milled material only with limited percent of RAP. Cost to process RAP (Labour, Equipment, Utilities, Maintenance, Depreciation (10 yr)) is US$3.15 per ton. (Banks Constructions) Banks Constructions and Boggs Constructions both have separate 3 bins feeders for recycled materials – Coarse RAP, *Fine RAP and RAS recycled asphalt roofing shingles. These are separate to the virgin material feed bins.*

It was reported that by using standard PG64-22 bitumen, you produce a much softer product than with virgin mix due to lower temperature resulting in less oxidation, light oil remains in bitumen and steam produced from drying the RAP creates an inert atmosphere.

What is the maximum RAP used in WMA? Is there any limit on RAP quantity and quality depending on the WMA technology or process (e.g. Wax and foaming)?

Granite Constructions have used 15% to 20% RAP in their WMA for State Authority work and 10% to 30% RAP for local authority work. ASTEC state that between 8 and 10 million tons of warm mix asphalt have been produced with 20% to 50% RAP.

Whilst most State Road Authorities have maximum limits on the amount of RAP allowed in mixes, the actual amount used was often less than the permitted amount depending on locality and availability of RAP.

A potential limitation on the use of RAP with WMA is the ability to dry virgin and RAP materials at lower temperatures. To overcome this, it has been suggested that moisture in RAP should be minimised by covering stockpiles and placing the stockpiles on sloped pavement to ensure drainage.

TxDOT saw advantages in combining WMA with increased use of RAP to use under-oxidized virgin binder to "reactivate" over-oxidized binder in the RAP. On this basis, it would be expected that lower temperature WMA (additives) may be able to accommodate more RAP than foamed WMA systems.

Acceptance by DOT

Which DOT allow WMA?

- *The Federal Highway Administration indicated that approximately 23 of the 50 DOTs allow the use of WMA in their hot mix asphalt specification (or have supplementary provisions that allow its use).*

Caltrans approach to implementation of WMA has been as follows:

1. *Lab and APT study*
2. *Pilot field projects*
3. *Formation of a state TWG*
4. *Development of an Approval Process*
5. *Specification Changes*
6. *District Engineer "Workshops"*
7. *Implementation of a Contractor Option*

Cathrina Barros (from Caltrans) advised that Caltrans has laid approximately 50,000 tonnes of WMA on 15 projects (between 2006 – 2009). Approximately 800,000 tons is proposed for projects in 2010 – 2011. WMA has been primarily used in the surfacing layer of Caltrans projects.

<u>Texas DOT</u>
WMA is now allowed for use as a Contractor's option on most projects. A few Districts require WMA by plan note (contract variation) due to project specific reasons such as:

- *Environmental constraints – non – attainment areas; and*
- *Overlays on projects with rubber crack seal.*

WMA can be used on interstate, US highways, state highways and FM roadways and has also been used on various local government and commercial projects. WMA has primarily been used with dense graded asphalt containing PG 64-22 (straight bitumen) or 76-22 (polymer modified) binders. However, there has also been some project specific usage with SMA and UTA surfacings.

TxDOT current have 9 approved WMA technologies.

<u>SCDOT</u> allows the use of WMA via a supplemental technical specification. Use of both foaming systems and chemical additive technologies have been included in the specifications. The specific WMA technology must be approved by SCDOT's asphalt materials engineer prior to use. WMA can only be used on low volume primary and secondary roads (AADT ≤ 3000) that contain PG 64-22 binder (which is similar to class 320 bitumen). Either foaming systems (such as Double Barrel Green) or chemical additives (Evotherm 3G or equivalent) may be used. SCDOT requires the WMA design to include 1% hydrated lime and tensile strength testing to be completed on a weekly basis due to concerns with moisture sensitivity. Some SCDOT personnel have ongoing concerns with WMA.

<u>NCDOT</u> allows the use of WMA via a supplemental specification. NCDOT has an approved WMA technology list. Current approved technologies include the Double Barrel Green, Evotherm, Advera and Sasobit. NCDOT requires a liquid antistrip to be added to WMA design due to concerns with moisture sensitivity. TSR results around 85% are typical. NCDOT does not include a freeze thaw cycle as part of their testing protocol. They have generally found that TSR results are usually around 3% lower for WMA when compared to the equivalent HMA design. NCDOT also limits its use to lower volume roads (AADT ≤ 500).

Under what conditions? Warranties? Is the option of HMA/WMA up to the supplier?

- *NCAT advised that most states which allow WMA and allow contractors to make the choice on the use of WMA or HMA.*
- *Caltrans is currently developing an Approval Process for New Technologies (such as WMA). The proposed system will require a summary report to be prepared by the technology provider and submitted to CalTrans for review. The summary report shall include:*
    - *Lab and field test results;*
    - *Laboratory testing includes:*
    - *Rutting performance*
    - *Cracking performance*
    - *Moisture Sensitivity*
    - *OGFC durability*
    - *Field testing includes:*

- *At least 3 monitored tests*
  - *25,000 AADT or APT*
  - *12 months monitoring*
- *Work can be completed in any state, although state approved tests must be followed, and a HMA control section must be included.*
- *Once the technology is considered acceptable it will be added to the approved list.*
- *Currently only one technology, Sasobit, has been approved. Advera and Evotherm are anticipated to be approved in the near future.*
- *Future projects will be specified as follows:*
- *District specifies the use of WMA – unique climates, long haulage, etc; or*
- *Contractor's option to use Caltrans approved WMA technology (i.e. permissive specification*).

Used with PMB?

- *WMA can be used for all mix types and binder types used in Virginia. This includes PG binder grades 64 – 22, 70 – 22 and 76 – 22 with dense graded asphalt and stone mastic asphalt mix types. Mix design testing (for WMA technologies other than foaming systems) requires a 'standard' hot mix design and WMA design (with the WMA additive) to be completed. VDOT personnel indicated that the* binder content of the two designs is always the same.

Any specific layers of asphalt pavements?

- *Not limited*

How was WMA introduced to the DOT? Did they run projects?

- *The National Centre for Asphalt Technology (NCAT) advised that WMA demonstration projects have been constructed in 44 of the 50 states that make up the mainland United States of America.*

  WMA has been introduced to most states through demonstration projects and presentations. The primary concern of DOT engineers is the potential moisture sensitivity of the material. NCAT is working towards the development of a national certification program for WMA technologies. Such a Virginia DOT

- *Trenton Clark (Asphalt Program Manager for VDOT) advised that WMA was first trialed by Virginia DOT in 2006. Sasobit and Evotherm were initially investigated. Initial trials were completed on three low volume roads within the state. Each trial site had a control hot mix asphalt section laid adjacent to the WMA trial site. The WMA trial sites performed equally as well has the HMA control sections. VTRC reports 07-R25, 09-R11 and 10-R17 document the construction, laboratory testing and performance of these trial sections.*

- *Texas DOT*

  Following initial trialing in 2006, the use of WMA has gained rapid acceptance. TxDOT have completed or in the process of constructing over 80 projects involving more than 1.7 million tons of WMA.

How is WMA specified in contracts

- *NCAT advised that most states which allow WMA do not specify that WMA must be used (i.e. Contractors choice).*
- *Where WMA has been included in the contract documentation, acceptable WMA technologies have been nominated. WMA technologies used to date include advera, evotherm and sasobit. WMA has been used with polymer modified dense graded and open graded asphalts, crumb rubber gap graded and open graded asphalts, and conventional dense graded asphalts.*

Virginia DOT

In 2008, a number of asphalt plants were produced or retrofitted with foaming units. VDOT introduced special provisions for use of WMA in 2009. The special provision is essentially a permissive specification that allows WMA to be used on any contract. It is the Contractors choice as to whether WMA or HMA is supplied to a particular project.

VDOT has a list of approved WMA technologies. Sasobit, Evotherm (Emulsion and 3G), Double Barrel Green, Aqua Black, Ultrafoam GX and Accushear has been approved for use in Virginia.

Additional requirements associated with the use of WMA are as follows:

- *The design and production mix must achieve a minimum tensile strength ratio of 0.80;*
- *Only approved WMA technologies can be used;*
- *Mix volumetric properties are determined by allowing the mix sample to cool below 37°C and reheated to the same preparation temperature specified for hot mix asphalt. The Asphalt Program Manager (Trenton Clark) for VDOT advised that recent testing indicated that this protocol was not necessary and the impact on the measured properties was relatively low (≈0.2%).*
- *A production and placement trial is required at the commencement of each project where WMA is used.*

Texas DOT

WMA is currently specified using Special Provision 341-020. TxDOT has an approved WMA technology list. Approval is granted via the submission of the following information to TxDOT:

- *Documentation from at least 3 construction projects using the WMA technology*
- *Mix design and mechanical test results and Quality Control / Quality Assurance results measured during construction.*

Project reports

Are project reports of WMA available?

- *Yes various reports from across USA. Refer References Section.*

Is data available for bitumen testing, asphalt performance tests, field performance data?

- *NCAT has data which shows the lab results showed a change for WMA in recovered viscosity and wheel tracking, and noted the difference was not apparent from field samples after one year, and the field performance seemed to be the same*

- *TxDOT has laboratory data of comparison works, but has no plans to publish. The data appeared to be a sensitivity analysis of asphalt tests which could help short-cut the Australian assessment of conditioning of lab samples.*

Are there comparison projects? HMA and WMA

- *NCAT is collating data from across the USA*
- *CalTRANS has data, as TxDOT. All DOT that met with the Study Tour appear to have field sites comparing WAM to HMA.*

What is the impact of WMA technologies on bitumen chemistry (e.g. Modifiers such as SBS)?

- *NCAT showed some impact on the recovered bitumen results, and some change on the wheel tracking. The tests were re-checked from field sites at various times and showed the field samples showed little difference in results. It appears the reduced hardening of the binder in the WMA is not maintained in field situations.*

Are there any changes to testing/confirmation requirements (e.g. Lowering preparation and testing temperatures)?

- *There has been some checking of different conditioning temperatures and times for WMA for lab samples. There appears to be no set rules, although most accept the lab mix should be prepared and conditioned at the same temperature as planned for the field works*

Impact on asphalt performance

Any stiffness/fatigue issues – good or bad ? since less oxidisation may give longer service life, Cold temperature with cracking ? Hot temperature with 'softer' binder – softer binder may be an advantage in low traffic applications where oxidation is the terminal condition?

- *NCAT reported the following:*
  - *WMA technologies do not decrease cracking resistance (even for waxes) and no stiffness or fatigue issues have been identified (when mix is designed / produced properly). However there may be issues with stiffness if WMA additive is not blended in properly. Although there are no signs of fatigue at this time, all pavements are relatively young (< 5 years old).*
  - *WMA binder is softer than HMA binder at the time of construction. However, the binder stiffens faster than HMA binder in the first two years (and resembles HMA after two years);*
  - *Research indicates WMA is unlikely to be more prone to fatigue than HMA (i.e. most likely the same).*

Is there any difference in performance between WMA produced by different methods – is all WMA treated the same?

- *NCAT reported the following: Some improvement in asphalt overlay rideability has been reported;*
- *Where possible moisture damage has been reported in WMA sections, similar moisture damage has been reported in HMA sections;*

- *Significant performance testing has been undertaken with WMA demonstration projects. Findings of these investigations include:*
  - *Tensile Strength Ratio (TSR)*
    - *Tensile strength results are typically lower for WMA than HMA (except for Sasobit and Aspha-min.*
    - *TSR results affected by binder grade, RAP content and mixing temperature.*
    - *WMA technology does not seem to have a significant effect on moisture susceptibility results.*
  - *Rutting and permanent deformation evaluation*
    - *Increased rutting (measured with Hamburg or APA devices) is normally observed in the laboratory with WMA.*
    - *TxDOT reported that rutting performance of laboratory mixes appears to improve when samples are cured in the laboratory at 135^{o}C for 4 hours.*
    - *University of California indicated that 2 of the 3 WMA technologies tested under HVS testing showed more rutting than the control HMA sections. However, the longer term rutting performance was similar to the control HMA section. The Sasobit section had significant lower rut depths than the other sections.*
    - *Field data indicates that rutting resistance is not decreased with WMA.*

NAPA indicated that although technology suppliers claim there are differences between the foaming systems, there is no documented evidence that suggests the performance of the final product is significantly different. Most state DOT's view each technology separately. This is reflected in their current approval processes. However, once they are approved they are treated the same.

Late questions received – answer if possible

- Pro's and Con's
- What to look out for in using it
- Loadings
- Mix design – simulating the construction
- What incentives are there for the Road Authority to change to WMA
- All of the above issues are covered in previous sections

Reference Material

List the presentations or other material gathered during the tour.

1. "Proposed Approval Process For New Or Significantly Modified Warm Mix Asphalt Technologies" (Draft), California Department of Transportation (Caltrans), 8/11/2009.
2. "Special Provision For Warm Mix Asphalt Material Requirements", Oklahoma Department of Transportation, 7-8-09.
3. "Special Provision To The Standard Specifications, Edition 2007 - Section 602 -Hot Mix Asphalt (HMA) Construction - (Quality Control/Quality Assurance (QC/QA))", Kansas Department Of Transportation.
4. "Warm Mix Asphalt - Materials Bulletin No. 03-09 – DCE Memorandum No. 03-09", Florida Department of Transportation, 26 March 2009.
5. "Warm Mix Asphalt Information", Florida Department of Transportation.
6. "Warm Mix Asphalt Products & Processes - List II-27", Alabama Department Of Transportation, Approval Date 5/4/2009.
7. "WMA Technology Approval Process Concept", New York State Department of Transportation
8. Andrea Kvasnak, "Warm Mix Asphalt Overview", National Center for Asphalt Technology, Presentation
9. Barros C (2010), WMA and CA, Presentation to AAPA Study Tour, UCPRC, Davis, California.
10. Clark T (2010), VDOT – Overview of 2010 Warm Mix in Virginia, Presentation to AAPA Study Tour, Virginia DOT, Richmond, Virginia.
11. Dale A. Rand, "TxDOT Experience with Warm Mix Asphalt", Presentation August 14, 2010
12. David Jones, "Caltrans Warm-Mix Asphalt Study", Australian Visit to UCPRC, 9 August, 2010
13. Diefenderfer S, Hearson A (2008), Laboratory Evaluation of a Warm Mix Technology for Use in Virginia, Report No FHWA/VTRC 09-R11, Virginia Transportation Research Council, Charlottesville, Virginia.
14. Diefenderfer S, Hearson A (2010), Performance of Virginia's Warm Mix Asphalt Trial Sections, Report No FHWA/VTRC 10-R17, Virginia Transportation Research Council, Charlottesville, Virginia.
15. Diefenderfer S, McGhee K, Donaldson B (2007), Installation of Warm Mix Asphalt Projects in Virginia, Report No FHWA/VRTC 07-R25, Virginia Transportation Research Council, Charlottesville, Virginia.
16. Estakhri C, Button J, Alvarez A (2010), Field and Laboratory Investigation of Warm Mix Asphalt in Texas, Report No FHWA/TX-10/0-5597-2, Texas Transportation Institute, College Station, Texas.
17. Jones D (2010), State Approval Processes for Warm-Mix Asphalt, Presentation to AAPA Study Tour, UCPRC, Davis, California.

18. Newcomb D (2010), Warm Mix Asphalt – The Future of Flexible Pavements, Presentation to AAPA Study Tour, Turner-Fairbanks Highway Research Centre, Virginia.

19. Randy C. West, "Increasing RAP Contents in Asphalt Mixtures", National Center for Asphalt Technology, Australia Asphalt Pavement Association 2010 Study Tour, August 18, 2010

20. Stephanos P (2010), What's New in WMA?, Presentation to AAPA Study Tour, Turner-Fairbanks Highway Research Centre, Virginia.

21. Texas Department of Transportation, Material / Producer List – Warm Mix Asphalt, 20/5/2009.

22. Tony Limas, Granite Construction Company, "Warm Mix Asphalt - A Contractors Experience", AAPA 2010 Study Tour, August 10, 2010.

23. Virginia Department of Transportation, Approved Products List No 66 – Approved Warm Mix Asphalt Products & Processes, June 2009.

24. Warm-Mix Asphalt: Best Practices, Quality Improvement Series 125, NAPA, December 2007

6. RECYCLED ASPHALT PAVEMENTS

Working Group

Leader: Trevor Distin Group: Rick Hennig, Robert Patience

Tour scope

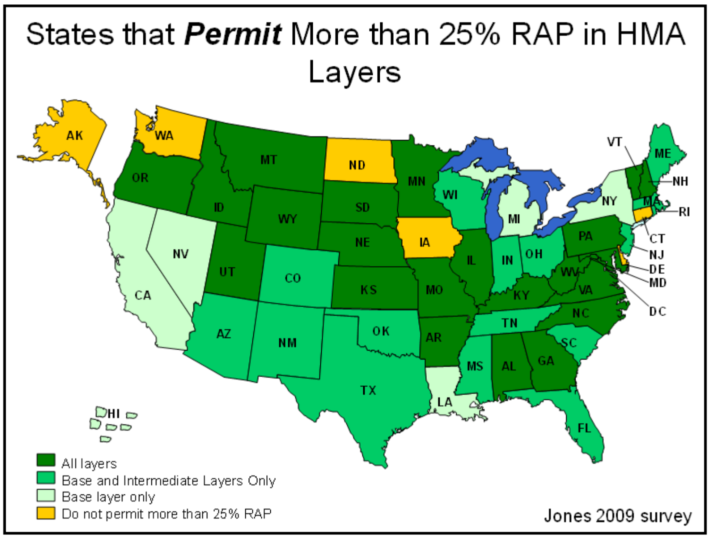
Recycled Asphalt Pavements - gaining a better understanding of higher percentages of RAP, inclusion in WMA and update on USA experience across the States in use in surface layers.

Feedback from

- California – Caltrans / Granite, APACA, CalAPA / UC Davis
- Washington, DC – FHWA / NAPA
- Virginia – VDOT / VAA
- Tennessee – Astec
- Illinois – DOT & University
- Texas - DOT
- North Carolina – Boggs / NCDOT
- South Carolina – Boggs & Banks / SCDOT
- Alabama - NCAT

Observations

The USA produces about 600 million tons of asphalt and generates about 100 million tons of RAP each year. This equates to an average of 17% RAP which can be recycled. 23 States have experience with using more than 25% RAP in their asphalt mixes. 11 States have experience with WMA and high RAP.

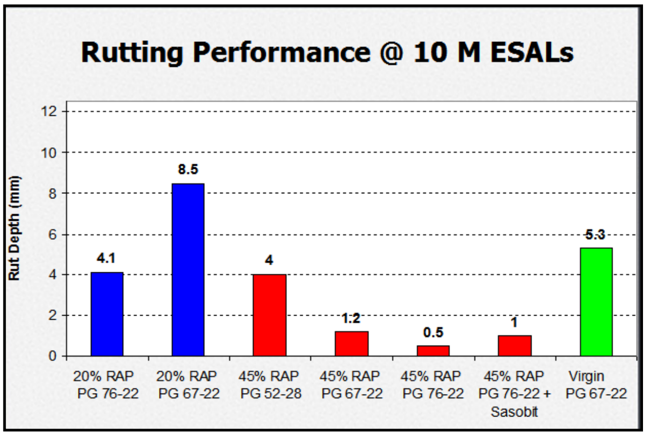


NAPA – Survey of RAP usage 2009

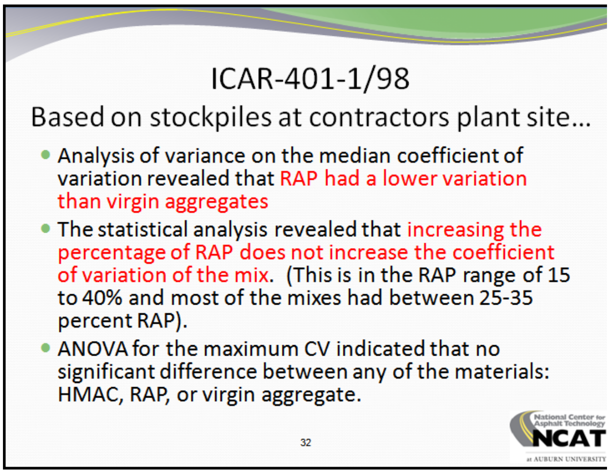
The main concerns of the Road Authorities and their engineers over using RAP in HMA are:

- stiffening of HMA could lead to early cracking ;
- durability of surface layers could lead to raveling ;
- use of high RAP may negate the benefit of using PMBs; and
- meeting skid resistance requirements.

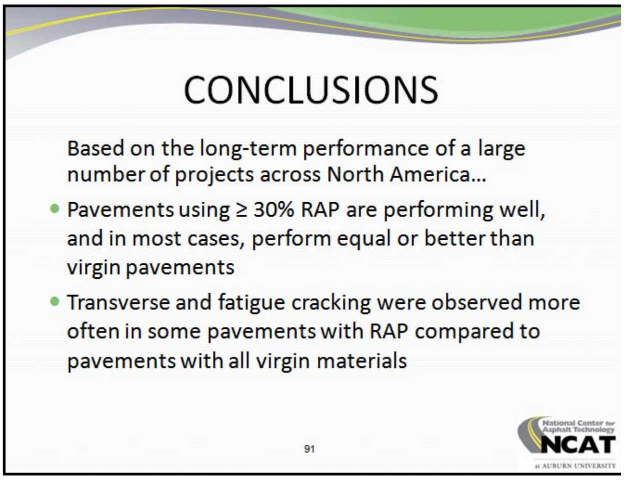
Notwithstanding the above, increasing the % of RAP reduces the potential of a mix to rut. Adding high % of RAP to a mix is reported to stiffen the binder to a higher performance grade. It was reported that substituting 50% RAP for 4% PMB was found to render the same rutting performance in wearing courses. Increasing the % RAP up to 40% does not increase the coefficient of variability of the asphalt mix provided the RAP is correctly managed and tested. LTPP monitoring was carried out on 18 test sections across the USA on virgin and recycled asphalt mixes which had been in-service for up to 17 years.



Don Brock – Astec Inc



Randy West, NCAT

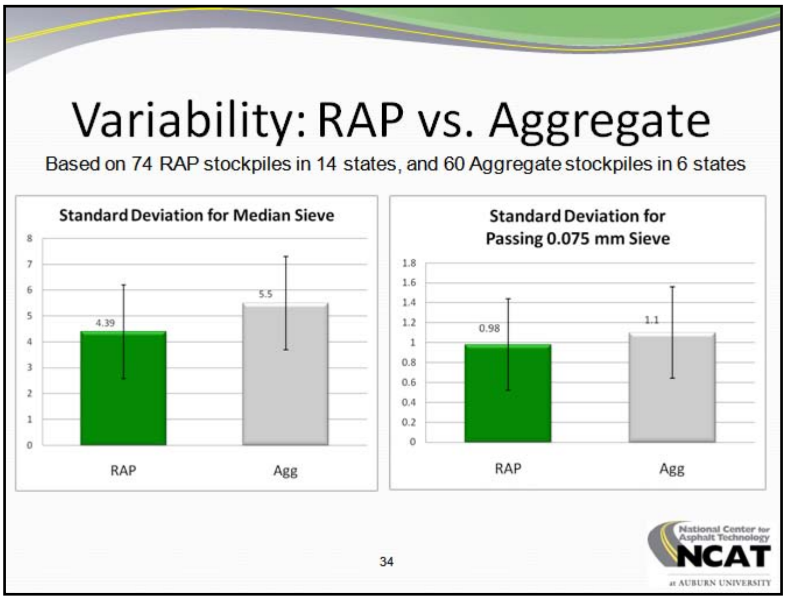


Randy West, NCAT

The findings were as follows:

- Pavements using ≥ 30% RAP are performing well, and in most cases, rutting performance was equal to virgin pavements
- Transverse and fatigue cracking were observed more often in some pavements with RAP compared to pavements with all virgin materials
- Differences in cracking performance for several locations may have been due to higher dust contents and/or lower asphalt contents

Some high performing contractors view RAP as a valuable material and have invested considerable resources in processing and monitoring of the quality. In some cases they found less non conformances in the grading of RAP than virgin aggregates supplied by the quarry.



Randy West, NCAT

The key benefits of RAP to contractors are:

- Reduction in energy requirements to heat virgin aggregates and binders. The savings from RAP are higher than using WMA technology;
- Can be used as a hedge against rising bitumen prices in times of global uncertainty: and
- Reduces the amount of virgin aggregates and bitumen usage and helps reduce raw material costs.

The % of RAP that can be utilised by HMA contractors in their mixes is limited by RAP availability, type of plant, DOT specifications and quality of the RAP.

Economics was the main driver for using RAP, now sustainability has become an added driver. However some perceptions still exist that recycled HMA is inferior all virgin material HMA. This stifles the effort to increase recycling. The goal in the USA is to increase the average amount of RAP used in all mixes to 25% by 2013.

'Trade your old pavement in for a new one'

Recycled Asphalt Pavement - Questions & Responses

Amount of RAP used?

6 States do not permit > 25% RAP in HMA

7 states permit > 25% RAP in base mixes only

14 states permit > 25% RAP in base and intermediate layers only

23 states permit > 25% RAP in all layers

What % of RAP are in use?

- *All DOT's visited on the tour permitted the use of RAP in their mixes. The % permitted varied by layer e.g. base vs. wearing course, mix type e.g. SMA vs. dense graded asphalt and binder type used in new mix e.g. rubber vs. unmodified. Below is a summary by State DOT visited:*
- *Caltrans: Allows 15% in wearing courses without additional testing. If the Contractor wishes to use more he can increase up to 30% provided he undertakes additional tests. Do not allow any RAP in bitumen rubber modified asphalt or open graded asphalt. Have not use any RAP in WMA but believe that there is value to add RAP to increase the stiffness of the mix.*
- *VDOT: Allows < 30% RAP in wearing course and intermediate layers. % in wearing course depends on binder type with max of 20% allowed for SMA*
- *Base course < 35% RAP*
- *South Carolina: Allows a maximum of 30% non fractionated RAP in base, 25% in intermediate and 20% in wearing courses. If the RAP is fractionated then the amount can be increased to 30% for intermediate and 25% for wearing courses. The specification restricts the amount of RAP to 15% if added via the hot elevator and does not allow the use of recycling agents.*
- *North Carolina*
  Allows up to 50% RAP in recycled asphalt except for wearing courses and mixes containing recycled singles. For wearing courses up to 20% RAP with a maximum size of 50mm or up to 30% with a maximum size of 25 mm can be used in wearing course. When the % binder from the RAP constitutes >20 <30% of the total binder then the next softer grade of binder must be used. When the RAP % is >30% the engineer will approve the virgin binder grade to be used.
- *The new approach is to base the maximum % of RAP that can be used in a mix on the net effect that the RAP binder has on the properties of the new mix. In other words the limiting factor for determining the maximum % RAP will be based primarily on the properties of the recovered aged binder and the % of binder in the RAP. For example a coarse graded RAP will typically have a lower binder content vis-à-vis fine RAP e.g. 4 vs 7%. This means that you could use almost double the amount of coarse RAP in a mix vs fine RAP for the same amount of aged binder.*

For RAP at higher %

Are there requirements for stockpile management?

- *Sample RAP stock piles daily and check moisture contents, grading and binder contents*
- *Do not crush RAP to avoid producing fines*
- *Avoiding segregation within stock piles helps meet binder content and air voids in new mix*

Different tests for the RAP?

- *Binder content. Ignition oven is preferred except when dolomitic aggregates are used*
- *Aggregate grading. Variability in binder content is managed by sorting RAP into fractions (0 - 6mm and 6-12mm)*
- *Aggregate bulk specific gravity*
- *Fine aggregate angularity*
- *Additional tests may be required if aggregate is used in wearing courses e.g. LA abrasion (polishing of stone is not an issue in the states we visited)*
- *Calculate standard deviations and compare binder content, % passing median and 0.075mm sieves with acceptable tolerances (slide 61 Randy West)*

Re-design for the mix?

- *Mix design process not too different from virgin mixes*
- *Estimate bulk specific gravity of RAP because ignition oven affects RAP. Be careful of the effect that a slight error in the RAP SG can have on the VMA of the mix when increasing % RAP in mix. (slide 58 Randy West)*
- *Heat RAP more gradually to a lower temperature before adding RAP to virgin aggregates*
- *Reduce binder content of new mix to account for aged binder in RAP*

Binder class of the mix?

- *FHWA recommendations were that no change in the binder grade was necessary if the % RAP was < 15%. If the % RAP was > 15% but < 25% then 'bump' to the next softer grade of bitumen. For RAP > 25% then use blending charts (slide 18 NAPA presentation).*
- *However preliminary studies have shown that up to 20% RAP can be used without changing binder grade (slide 17 of FHWA presentation)*
- *Based on the current NCAT test sections where 20 & 45% RAP mixes have been placed as wearing courses with different virgin binders, there is no strong evidence to bump down the grade of virgin binder when increasing the amount of RAP. (slide 101 Randy West)*

Tests to measure effect of comingling of virgin with aged binder?

- *There is still debate on whether 100% mixing takes place between the aged binder in the RAP and the virgin bitumen and whether a softer virgin binder should be used.*
- *AASHTO M323 for Superpave mix designs recommends that a soft virgin binder is added when over 15% RAP is added and assumes complete blending of the soft binder with the aged binder. Below 15% RAP it ignores the influence of the aged binder properties in the RAP and treats the RAP as 'black' rock. It recommends that blending charts be used for characterising the binder when > 25% RAP is used.*

- *Contractors have had blending charts developed on recovered binder for samples of fine and coarse graded RAP taken from their stockpiles to determine the appropriate grade of base binder to use when adding various % of RAP using the Superpave binder grading system.*

Lab protocol for preparation of high RAP mixes?

- *See report NCHRP 9-46: Mix design and evaluation procedure for high RAP (50%)*

Any restrictions on the layers for use of RAP?

- *Where skid resistance is a concern use smaller sized fractionated RAP i.e. < 7mm which does not have a bearing on skid resistance of the wearing course.*

DOT specifications?

- *DOT specifications and practices varied by state.*
- *Some DOT's only allow RAP obtained from their projects to be used in their mixes. This restricts the full use of RAP.*

Does the asphalt supplier or DOT do the mix design?

What other sources of recycled materials such as crushed glass is used in asphalt? And how common is this?

- *Recycled roof singles (RAS) are used in the manufacture of HMA. RAS have a binder content of 20% and up to 25% is allowed to replace virgin binder in HMA. The binder in RAS is very stiff.*
- *Stripping problems were reported when using recycled glass in HMA.*

Recycling mixes with RAP – how many times can it be recycled?

- *Continuously, slight change in function in the mix, aggregate wears, binder ages*

How is the RAP stockpile managed? What tests? Why?

- *Samples should be taken for every 1000 tons of RAP with a minimum of 10 samples per stock pile.*
- *Do not combine samples from same RAP stock pile.*
- *The contractor needs to develop a work sheet to manage the RAP inventory to control the quantity needed for each mix based on the target binder contents. NCAT have developed a simple RAP Inventory worksheet (Slide 14 West presentation)*
- *It is important that the profiling is done in such a way that the RAP is not contaminated.*
- *It is advantageous to keep profilings from large projects in separate stock piles to save on processing costs.*
- *Unprocessed RAP from multiple sources is not suitable for use in new mixes.*
- *Avoid crushing RAP as it increases the dust content which in turn can limit the % RAP used in a mix. If you need to crush first screen the RAP and only crush the oversized RAP.*
- *Screening the RAP into more than 2 sizes allows the contractor more flexibility to use the RAP in any mix type.*
- *A survey carried out by NCAT found that the variability for non-fractionated RAP was lower than fractionated RAP (slide 37 Randy West)if sourced from a single source with the profiling carefully managed?*

- *The RAP screen sizes varied but the most common were minus 19mm to minus 6 mm and minus 6 mm or minus 12.5 mm.*
- *Avoid building stock piles of RAP with steep sides as this will cause segregation in the stock piles.*
- *Minimise the amount of moisture in RAP by covering the stock piles or sloping the pavement underneath.*

Control of RAP materials

- *Some DOT's take ownership of the RAP and use it in maintenance applications. In a low bid competitive environment HMA contractors will use RAP in its most economic application.*
- *Most clients prefer the contractor to take ownership of the RAP.*

How is moisture content addressed with high RAP?

- *The stream generated from the RAP during mixing at lower temperatures reduces the rate of oxidisation of the new binder. (slide 55 of Don Brock presentation)*
- *Moisture content is more significant at high RAP contents. The amount of heating required? increases exponentially as the moisture and RAP contents increase (slide 41 Randy West)*

How are RAP mixes treated in design – if considered at all! Such as stiffness and fatigue relationships – are these different to virgin mixes?

- *No evidence was presented in regard to designing RAP mixes differently from virgin mixes*
- *The focus is on controlling the properties of the RAP mixes to make their properties as similar as possible to virgin mixes or controlling where the RAP is used in the pavement*
- *There may be opportunity to increase the use of RAP if the benefits of aged binders can be maximised through suitable design e.g. rutting resistance for WMA mixes*

Are there any restrictions on different binder types in recycled asphalt?

- *This appears to be controlled by controlling the % RAP allowed in each layer and or aged binder testing/blending rather than preventing the reuse of PMB or crumbed rubber mixes*

What proportion of the binder content in RAP is taken into account in the overall percentage of bitumen in the mix?

- *Generally it seems that all the binder content identified in the testing is considered in the design of the RAP mixes. There was some discussion about the concept of "black rock" i.e. rock covered by dead binder. Most seem to accept that the benefits of a bitumen coated rock cancelled out the negative effects of the dead binder. No strong evidence was presented? The focus was on modifying the combined binder properties by using lower stiffness binders although the degree of blending of the aged and virgin binders is still not proven.*

What motivates to use RAP

- *The main driver for the use of RAP in HMA is economics. Contractors see RAP as a hedge against rising bitumen prices. (Slide 6 NAPA presentation) Sustainability has become a new driver. NAPA reported that 25% RAP usage neutralised the carbon foot print of a HMA plant.*

WMA and RAP

Is the asphalt mix design re-designed for RAP? How – binder content, class of bitumen?

- *Same as for HMA RAP above*

Limitations on RAP inclusion? Is this plant restrictions or field performance?

- *The consensus was that reduced mix temperature allows more RAP to be used.*
- *By using higher % RAP in the manufacture of WMA the temperature of the bag house would be increased thus overcoming the problem of moisture accumulation in the extraction bags.*
- *The aged binder on the RAP also works as an anti stripping measure and helps improve the TSR values.*
- *Some problems were reported in South Carolina with using unfractionated RAP in WMA vs. normal HMA with lumping at higher RAP %.*
- *The WMA test sections at University of California Davis for the APT did not incorporate any RAP but believe that there is value to add RAP to stiffen the mixes. TxDOT reported up to 40% RAP was being used successfully in their WMA projects across the state.*

What is the maximum RAP used in WMA? Is there any limit on RAP quantity and quality depending on the WMA technology or process (e.g. Wax and foaming)?

- *The consensus was that you could increase the upper limits on the % RAP for WMA vis-à-vis HMA when considering a change in binder grade. The following limits were proposed for WMA by a contractor (Granite Construction) in California(slide 12 Granite Construction presentation)*
    - *< 25% no change in binder grade**
    - *>25 < 35% then 'bump' to a the next softer grade of bitumen*
    - *> 35% use blending charts*

  **Granite found that the recovered binder from WMA with 25% RAP had the same rheological properties as HMA with virgin bitumen. (Slide 13 Granite presentation)*
- *During the placing of the trial sections at NCAT they found that they could manufacture WMA with foam technology with up to 50% RAP without changing to a softer grade of bitumen to achieve density.*

Reference Material

List the presentations or other material gathered during the tour.

1. Innovations in Using High Percent RAP Mixes, David Newcomb, NAPA, August 2010, presentation
2. National Effort to Increase RAP use, Pete Stephanos, FHWA, August 2010, presentation
3. Recycled Materials and New Pavement Technologies, DelDOT Design Teams, Jim Pappas, Sept 2009, presentation
4. The Green Pavement, Don Brock, Astec Inc, Tennessee, August 2010, presentation
5. Plant procession strategies to maximize RAP use, G. Reid Banks, Banks Construction Company, South Carolina, August 2010, presentation.
6. Recycled Asphalt Pavement (RAP) and Asphalt Shingles, SCDOT Supplemental Technical Specification, Designation SC-M-407 (07/09)
7. Banks Construction – recovered RAP gradation history 2009/2010
8. Banks Construction – Recovered Binder RAP Blending Charts
9. Increasing RAP Contents in Asphalt Mixtures, Randy C. West, NCAT Auburn University, AAPA Study Tour, August 2010, presentation
10. AASHTO M323 (Jan 2007): Specification for Superpave volumetric mix design uses aggregate and mixture properties to produce a hot-mix asphalt (HMA) job-mix formula.
11. Appendix AASHTO M323: RAP blending charts
12. NCHRP 9-46: Mix design and evaluation procedure for high RAP (50%)
13. NCHRP 452: Recommended use of RAP in Superpave mix design
14. www.moreRAP.us
15. Technical Paper T-127: Milling and Recycling by Don Brock
16. NAPA Quality Improvement Series 124: Designing HMA mixtures with high RAP content
17. NAPA Information series 123: Recycling hot mix asphalt pavements
18. Use of RAP and RAS in Virginia, Trenton Clark, VDOT, August 2010, presentation

Possible application of RAP recommendations

From a sustainability position every effort should be made to ensure that RAP is reused in the most optimal way in asphalt without comprising the performance of the recycled asphalt. RAP is an engineered product and if managed properly is a valuable resource which cannot be ignored. It can help reduce the cost of asphalt by preserving and reducing our demand for non renewable aggregates and bitumen.

Like the USA we find that the specifications for reusing RAP in asphalt vary by State. Currently the specifications in Australia typically limit the % of RAP that can be used by layer type (wearing course vs. base course), mix type (SMA vs. DG) and contractor competency. Based on the findings from the study tour there is scope to reconsider the criteria used to set the limits for the maximum amount of RAP that can be used in a particular mix and application. During the service life of asphalt the aggregate properties remain relative unchanged whilst the binder ages, thus it stand to reason that the aged binder in the RAP will have the greatest influence on the performance of the recycled asphalt. Therefore the proposed criteria for determining the limit for the % RAP allowed should be changed depending on the contribution of the RAP binder to the total binder of the mix. In other words the properties of the aged binder and the binder content of the RAP should be the determining factor for what % RAP is added to the mix for the given specification limits.

If we take a specification which restricts the maximum % RAP in the recycled asphalt to say 15% of total mix, this limit could be changed depending on the binder content of the RAP used. For example if we used a RAP with a binder content of 4.0% then the actual aged binder content in a 6.0% recycled mix is only 10%. In this case the % RAP should be increased to 22.5% to render an equivalent aged binder content of 15%.

In the same context if we look at the rheological properties of the aged binder in the RAP we can also determine what effect they are likely to have on the recycled asphalt mix binder properties. For example if the recovered binder viscosity @ 60 °C of the RAP is 5000 Pa.s and it is blended with a C450 bitumen to manufacture recycled asphalt then the recycled binder viscosity can be calculated as follows:

15%log5000 + 85%log750* = 997Pa.s

(*For the purpose of this exercise we assume that the C450 bitumen has an aged binder viscosity represented by the RTFOT with a typical value of 750Pa.s and that the RAP binder viscosity does not change during mixing.)

This value is well below the RTFOT limit of 1150Pa.s for C450. This means that the % of aged binder can be increased to 23% before the limit of 1150 Pa.s is reached.

Proposed specification limits for RAP

Mix & layer	**< 15% RAP**	**>15% <30% RAP**	**> 30% RAP**
Wearing courses:			
Dense graded	Must fractionate RAP < 14 mm	Only if aged binder content of recycled asphalt does not exceed 30%.	Only if recovered binder viscosity of recycled asphalt is below 1150 Pa.s
SMA & OGA	No RAP allowed		
Intermediate course	RAP must be screened but not necessary to fractionated into different sizes	Must fractionate RAP	
Base course	RAP must be screened but not necessary to fractionated into different sizes		Must fractionate RAP

The above recommendations assume that the RAP is subject to strict handling and processing requirements as covered by the current specifications. This must include stock pile management and frequency testing of the RAP for binder and moisture content, and grading.

Issues such as concerns over limiting RAP usage in wearing courses because of concerns over skid resistance are addressed by fractionating the RAP into a smaller fractions

7. ACCELERATED PAVEMENT TESTING

Working Group

Leader: Mervyn Henderson Group: Kym Neaylon, Russell Clayton

Tour scope

The AAPA Study Tour visited three research facilities that employ Accelerated Pavement Testing, namely, University of California Pavement Research Centre (UCPRC) at Davis and Berkeley, Federal Highway Administration (FHWA) Turner-Fairbank Highway Research Center (TFHRC) at Mclean, Virginia, and the National Centre for Asphalt Technology (NCAT) at Auburn, Alabama. Virginia Department of Transport at Richmond, Virginia, was also visited, but they do not have APT facilities.

Most of the time was spent on exploring the results of the research into Warm Mix Asphalt, Recycled Asphalt Pavements and Perpetual Pavements by way of formal presentations that occupied most of the days. We were able to briefly visit the laboratories at each research centre. Brief visits were held to the see the test sections where the HVSs and ALFs were stationed. We were also entertained to a ride around the NCAT circuit. There were no formal presentations held on the operation of the HVS and ALF. A short presentation was given at NCAT on the construction and operation of the test track.

University of California Pavement Research Centre

Two Mk4 Heavy Vehicle Simulators (HVS) are used. The HVSs are at the UCPRC at Davis. Testing is done on a test area, inside an indoor facility and some testing has also been done on roads in California.

UCPRC HVS with climate control*

UCPRC Wheel loading test section*

UCPRC Test section with HVS in the background*

UCPRC Indoor testing facility at Davis*

*Photos: MG Henderson

Turner-Fairbank Highway Research Centre

According to Jack Youtcheff, APT started in 2002 using two Accelerated loading facilities (ALFs) that are set up at the test site at the Turner-Fairbank Highway Research Center, Mclean, Virginia.


TFHRC ALFs and adjacent test sites*


TFHRC Font: Fatigue tests,
Back: Rutting tests*


TFHRC close-up of ALF*


TFHRC Loading wheel with super single*

*Photos: ARRB Ltd

National Centre for Asphalt Technology

The 2.7 km Test Track is located 30 minutes from the campus of Auburn University, Alabama. A lifetime of truck traffic (10 million standard axle loads) is applied over a two-year period. A fleet of 5 Class 8 tractors, each with three heavily weighted trailers, run 18 hours a day, with two shifts of drivers, 5 a.m. to 2 p.m. and 2 p.m. to 11 p.m. Each rig in the 5 truck fleet targets running 1,095 km per day (547 km per driver) for a total of more than 1.2 million km each year. This schedule allows 10 to 15 years of damage to be compressed into two years. Since all sections are subjected to identical and precisely monitored levels of traffic, it is also possible to complete meaningful intra-sponsor and inter-sponsor field performance comparisons. Unlike conventional efforts on public roadways, research at the NCAT Pavement Test Track is conducted in a private facility where axle loadings are precisely monitored and environmental effects are identical for every mix. Realistic traffic wander of the vehicles is achieved.


NCAT Tractor with 3 trailers#


NCAT close-up of tractor with 3 trailers*


NCAT aerial view of test track ##


NCAT straight on south side: note substitute truck#

#Photo ARRB Ltd
*Photo MG Henderson
##Photo NCAT

R&D Program

UCPRC

Road Research Map: research areas are (Reference 9):

- Development of a Caltrans Pavement Management System
- Pavement Smoothness
- Pavement Preservation
- Quiet Pavements
- Pavement Construction Practices
- Mechanistic-Empirical Design
- Long-life Pavements
- Pavement Recycling and Sustainability

ALF at Turner-Fairbank Highway Research Centre

Photo: RM Vos

TFHRC

R&D strategies are (Reference 10):

- Long-Term Infrastructure Performance
- Durable Infrastructure Systems
- Accelerated Highway Construction
- Environmentally Sensitive Highway Infrastructure
- Performance-Based Specifications
- Comprehensive and Integrated Infrastructure Asset Management

The test site comprised different types of asphalt with various binders/additives that had been tested in support of the introduction of WMA and RAP. We were not supplied with details of actual projects currently being undertaken.

NCAT

NCAT's mission is to be a world leader and authority in asphalt research, development, technology, and education in the areas of (Reference 11):

- Pavement structural design
- Construction methods
- Materials and testing
- Performance measurement and prediction
- Pavement preservation, rehabilitation, recycling and maintenance
- Environment and highway safety

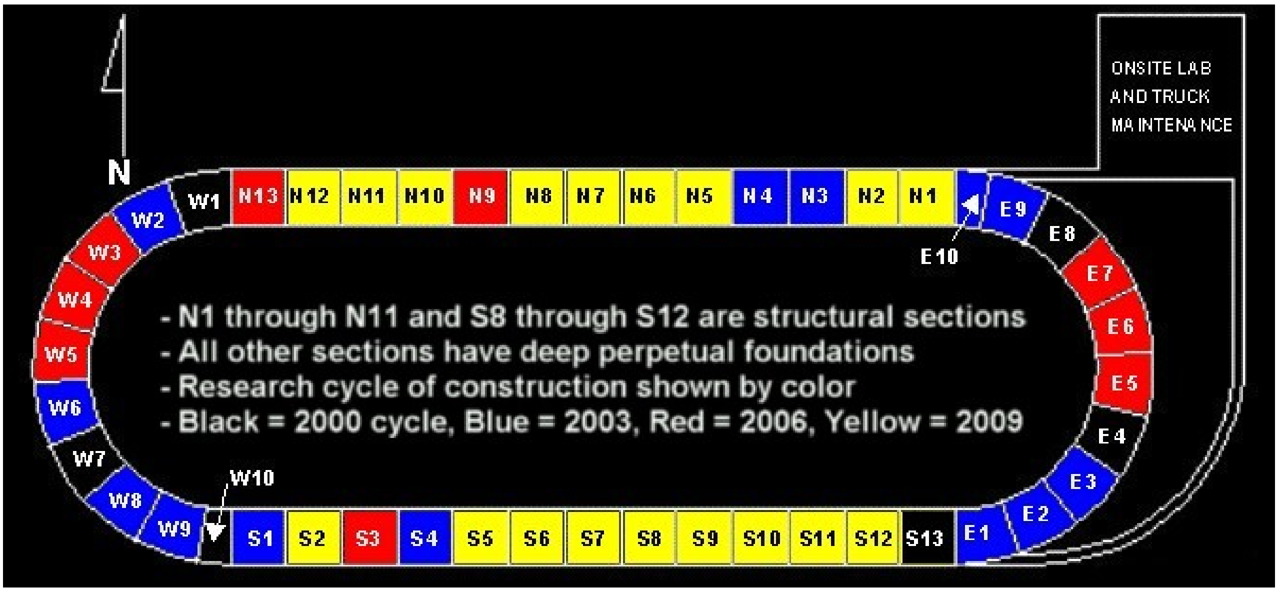
Focus Areas are:

- Sustainable pavements
- M-E pavement design calibration

- Lab tests for predicting performance
- Perpetual pavement design
- Porous friction courses mixes
- Pavement reflectivity
- Pavement friction

Experimental sections on the Pavement Test Track are cooperatively funded by external sponsors, most commonly state DOT's, with subsequent operation and research managed by NCAT. Forty-five different flexible pavements have been installed at the facility, each 6.1 m in length. Materials and methods unique to section sponsors were imported during construction to maximize the applicability of results. Laboratory testing is conducted on plant-produced material to facilitate practical laboratory to field performance correlations. The track is currently on its fourth test cycle.

Reconstruction of the 2009 experiment was completed in August of 2009 by East Alabama Paving, who was selected as the contractor via a competitive bidding process. The fourth research cycle again consists of extended traffic sections, new mix performance sections, and instrumented structural sections. The instrumented structural sections are part of a larger, multi-state validation effort for mechanistic-empirical and perpetual pavement design. Another 10 million ESALs is planned to be completed by the fall of 2011. On 17 July 2010, 2010 some 4,351,278 ESALs as of 2,300 hours had been applied. Rut depths measured on 26/7/2010 averaged 4.8 mm, while roughness averaged 1.41 m per km (Reference 11).



A 3 year project cycle costs US$10M, of which US$2.5M is construction costs.

Current research objectives of test sections at NCAT are as follows:

- HVS PG67 and PG76 validation with high friction surface performance
- Performance of coarse gradation
- Performance of a variety of polymer modified binders
- RAP mix design / construction/ performance with or without Sasobit performance

- Hot control /Shell Thiopave for WMA Certification Program
- Evotherm WMA with Latex performance
- Surface cracks in PFC via Spray Paver/ Track Paving performance
- Perpetual Pavement concept
- M-E design validation/ calibration
- Mill/ inlay Rehab 2006, Fabric interlayer performance
- Performance of SMA with High F&E aggregates/ Columbus Granite/ 100% Limestone/ High LA Abrasion loss
- Twin layer drainable mix with F&E aggregates performance
- Low volume road preservation
- Durability of coarse gravel mix
- High RAP Content Gravel Superpave
- 100% Gravel / Limestone OGFP performance
- Proprietary epoxy surface treatment performance
- SBS-modified/ GTR-modified Superpave mix performance
- GE Buildup with PFC surface performance
- GE Foamed/ additized WMA performance
- GE+ Trinidad Lake Asphalt pellets performance
- Performance of early Superpave mix

Overview of feedback on key issues

A key issue for DOTs is the usefulness of supporting and investing in APT. In California UCPRC is involved in supporting CALTRANS through a wide-ranging research effort. CALTRANS trials new technology through UCPRC. In the case of WMA, this involves using the HVS to prove the product used in the production of WMA. Without conclusive APT tests, CALTRANS does not use new technology and products on the road network. FHWA TFHRC has provided direct support to DOTs through its research program with the assistance of accelerated pavement testing at the TFHRC test facility. Similarly, NCAT has a large research program that supports DOTs, and private suppliers of bitumen and asphalt products.

The use of APT in the USA has become widespread. It provides the means to test new products and technologies rapidly while simulating real traffic loading on test pavements and thus avoiding the risks associated with proving new products and technologies on the road network over extended periods under unknown loading and environmental conditions. It therefore provides confidence and reduces risk for DOTs when applying new products, technologies and methods.

In support of DOTs, APT provides insight into pavement preservation, quiet pavements, pavement construction practices, mechanistic-empirical design, long-life pavements, performance based specifications, durable pavements, pavement recycling and sustainability.

Accelerated Pavement Test Methods - Questions & Responses

Current status of HVS at U Cal; summary of findings and implementation

Two HVSs are in use. The wheel is not driven and for surfacing mixes the pavement is tested in one direction. For structural analysis the wheel operates loaded in both directions. The two machines have applied 4 billion ESAL's since 1975 (HVSs originally owned by the Council for Scientific and Industrial Research, South Africa). Monthly operating cost is U$50k. Considered to be very reliable and work 23 out of 24 hours. Test tracks are at Davis, which has an indoor facility and testing has also been done on the California road network. High loads have been tested using an aircraft B737 wheel.

UCPRC Davis HVS Photo: RM Vos

A new, modular Mk6 HVS has been ordered. Cost US$1.6 million for HVS Mk6. The Mk6 runs faster, and now that the beam is fixed the carriage can wander. Two hydraulic pistons push up on a beam. Because of its modular design, the Mk6 can be lengthened to achieve a longer test section.

Current status of ALF at FHWA Turner Fairbank

FHWAs two ALFs were constructed in 1986 and 1991 in the USA from a design supplied by ARRB. Both ALFs are in use. Upgrading of the control systems (electronics and electrics) is envisaged as original systems are outdated and no longer serviceable due to age. Otherwise ALF is very reliable. Each machine is capable of applying an average of 35,000 axle passes per week at a half-axle load ranging from 44 to 100 kN. A super single tyre is also being used for testing. Loading is unidirectional with evidence of bounce of the load on approach. The wheel is driven and uses an air suspension system. It is very difficult to provide temperature control because of the design of the loading facility.

There are 24 full-scale test sections, each 14 metres by 4 metres.

Accelerated aging is being researched to complement accelerated loading.

Also APT at WesTrack in Nevada where FHWA is the project sponsor—http://www.westrack.com/wt_02.htm

Current status of full scale test track NCAT

The test track is located 30 minutes from the campus of Auburn University, Alabama. The test track was constructed in 2000 as a 2.7 km closed loop facility and includes an office research laboratory and workshop space. The test track was developed as a partnership between Auburn University *(who purchased the land) and the Alabama Department of Transportation (ALDOT) who built the original research infrastructure. The cost of site development, construction of the test track pavement foundation and buildings, and data infrastructure was funded by ALDOT. This made it possible for other states to conduct cost-effective pavement research without start-up cost. The pooled fund research cooperative with 3-year sponsorship commitments that was chosen as the original funding model for track construction and operations is still in use today (Reference 8).*

A 3 year project cycle costs US$10M, of which US$2.5M is construction costs

Status other APT equipment (Texas, FAA Atlantic City etc)

Not discussed.

Instrumentation developments

A variety of instrumentation was used at the APT facilities

- *Multi-Depth Deflectometers (MDD)*
- *Temperature Probes*
- *Road Surface Deflectometer*
- *Laser Profilometer*
- *Crack Activity Meter*
- *Joint Activity Meter*
- *Strain gauges*
- *Pressure gauges*
- *QPR to determine crack density*
- *PSPA: portable seismic pavement analyser used to measure the rate of deterioration*
- *Reliability issues have been experienced with equipment operating in the elevated temperature environment. Military specification cabling and instrumentation appears to have circumvented this issue.*

The only new development we were told about was an "aggregate" temperature sensor which is still under development at UCPRC.

NCAT ARAN Profilometer#

NCAT Falling Weight Deflectometer*

NCAT Strain gauge installation#

NCAT Trench after completion of loading#

#Photos NCAT
*Photo MG Henderson

Construction issues – how representative are test tracks of actual constructed pavements? (Tolerances and Quality Control may be higher than routine pavements.)

At Davis the contractors had difficulty building a conforming mix. Low densities and high air void a problem, which was primarily due to cold construction plant. Therefore it is best to build sections in the height of summer. This was not such an issue with WMA.

A detailed specification is used at NCAT. The test sections are constructed under contract. NCAT use the plant on site and quality is generally very good. NCAT have a relationship with one contractor who understands their needs. Research is focused on many sources of aggregate that are shipped in from sometimes great distances. A lot of effort is put into getting mix design and production mixes optimal. Test sections are short so mixing and construction plant are not optimised. There is no history with the mix so the margin for error is considerable. Considerable effort is made during the construction of tests sections to control the product and reduce variability. This is not always possible due to the small quantities required. The materials are sampled and tested in the research centre laboratories to determine compliance. At NCAT, only the centre portion of the test section is instrumented to avoid variability associated with the beginning and end of the section.

Environmental controls – properties of AC are temperature and load duration dependent. How are these controlled/monitored and interpreted?

A variety of temperature controls were used at UCPRC and FHWA HR. These included an indoor pavement testing facility at UCPRC with accompanying climate control equipment (heaters, chillers, temperature control housing). The test facility should be orientated so that shadow effects from trees or buildings are eliminated. At FHWA TFHRC radiant heaters are used to condition and age the binder before the testing commences. A climate control housing is used outside as no indoor facility exists. At NCAT there is a weather station to monitor temperature and rainfall. The test track is positioned east west so both legs of the track receive the same exposure. Analysis of mid-depth temperature and strain indicates much higher tensile strain in summer and thinner pavements more vulnerable. Rolling thin film oven is used for conditioning of laboratory bitumen samples. A high pressure ageing tester is also used.

Test tracks can accelerate the actual traffic loading. How are long term material changes—such as bitumen hardening —considered?

At FHWA TFHRC radiant heaters are used to condition and age the binder before the testing commences. At NCAT only normal atmospheric ageing takes place at the test track. The field trails continue for 2 years so that some ageing occurs in situ. Some test sections have been in place for 10 years and some focus is on the age affects on the pavements. FHWA use infra red heating to expose the pavement to elevated temperatures for a period before the testing commences, the aim being to heat the pavement to 50^{0}C and age/stiffen the binder.

FHWA has a continuing investigation into binder fatigue using the ALF to validate several candidate binder parameters involving stiffness reduction, strength and fracture. The test sections were aged using radiant heaters. Findings included:

- *Similarly PG graded materials exhibit different fatigue cracking performance*

- *Crumb rubber asphalt has the ability to arrest or slow crack propagation*
- *Fibres are very effective in reducing fatigue cracking*
- *Binder tests cannot easily provide insight for structural effects (100 mm vs. 150 mm thick), fibre modified mixtures. Mix testing is important and simplified fatigue testing with the AMPT is of high value*
- *Critical Tip Opening Displacement (CTOD) and Binder Yield Energy Test (BYET) appear to be the most effective properties for determining fatigue performance*

Methods—data collection and analysis

Data collection was automated through direct or wireless connections to the instrumentation. At Davis there had been instrument and cable failures at high temp testing. They now use military specification equipment—more tolerant. The exception to electronic data acquisition is mapping of cracks on the surface that requires an experienced person. At NCAT, trucking is suspended every Monday so pavement performance can be quantified. An inertial profiler equipped with a full lane width dual scanning laser "rut bar" is run weekly around the entire track in order to determine individual wheel path roughness, right wheel path macrotexture and individual wheel path rutting for every experimental section.

Additionally, 3 random locations were selected within each section in a stratified manner to serve as the fixed test location for non-destructive wheel path densities using a nuclear gauge. Transverse profiles are measured along these same locations so that rutting may be verified using a contact method. Falling weight deflectomer testing is typically run weekly, which is also the case with high speed structural response data collection and surface crack mapping. Every month, wet ribbed surface friction testing is run with a full scale friction trailer.

Sound and permeability testing are run quarterly in order to characterise how the pavement surfaces are changing over time. Cores are cut each quarter from the wheel path of every section so that densification of each layer can be considered

NCAT/Auburn use and distribute PerRoad 3.5, which is downloadable as shareware. It appears to be flexible enough for use outside of USA. User controlled fatigue and environmental controls can be input. The analysis uses Monte Carlo simulation to accommodate all variables.

Equivalencies to convert tri and quad axles to ESA's – any impacts due to rapid repeat loading of multiple axles compared to single axle loads.

No information was obtained on equivalencies to convert tri and quad axles to ESAs.

NCAT currently uses a tractor with twin drive axles fitted with dual wheels that tows three trailers with single axles that are fitted with dual wheel—see photo below. The graph plotting strain against time indicates the effect of strain reversal that takes place with the passage of dual axles compared with single axles.

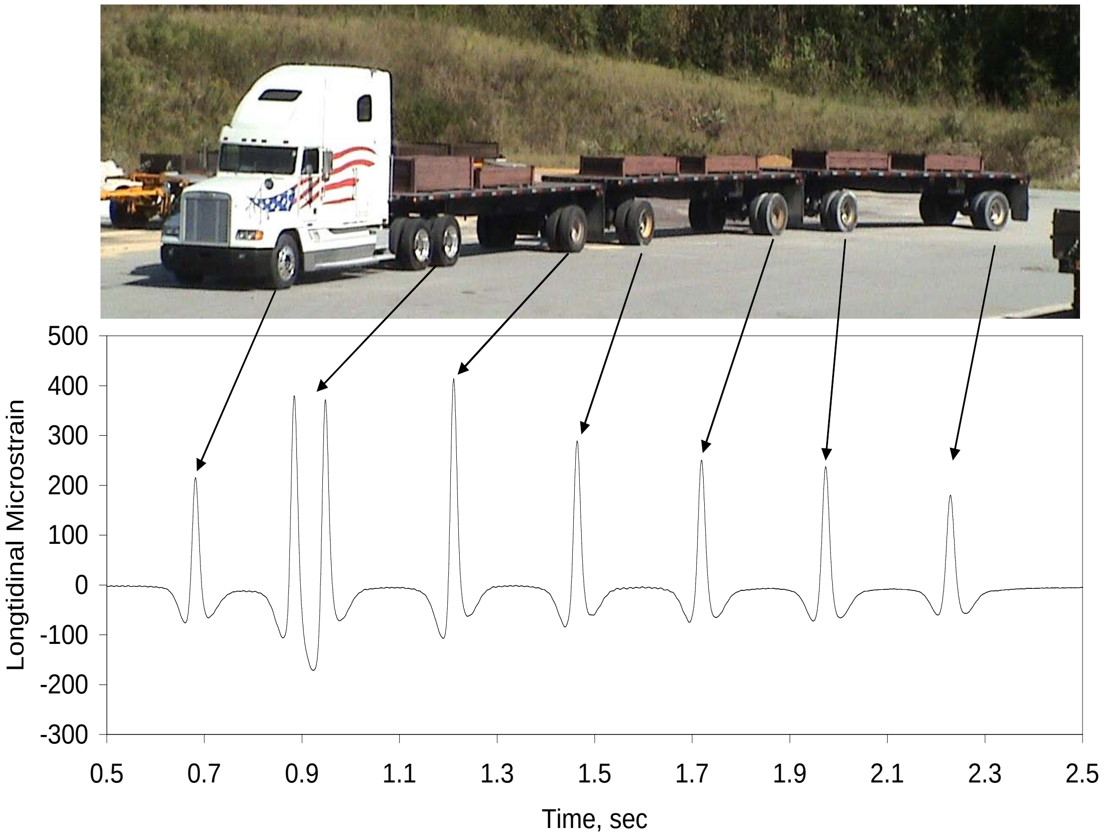


Photo and graph from NCAT presentation—see reference 1.

Has there been any attempt to validate/confirm the weighted mean annual pavement temperature (WMAPT) concepts.

The temperature of the pavement at the mid-depth is currently considered the most appropriate pavement temperature for modeling. NCAT analysis of temperature vs strain performance showed very strong correlation to stiffness of the pavement. (less stiff and higher deflections and strains in warm weather and vice versa.) Currently the test track has 184 probes located throughout the depth of the pavements with 11,500 temperature readings taken each day. Whilst this aspect was not discussed in any detail the information should be readily available.

All of the research centres visited had been involved in accelerated testing of WMA. Results of these tests are contained elsewhere in the report.

What are the US experiences with accelerated ageing tests for bitumen? Is there a recognised test method to mimic the long terms ageing characteristics of bitumen? How is low temperature performance of bitumen measured?

The rolling thin film oven (RTFO) and the pressure ageing vessel (PAV) is used to condition bitumen before laboratory manufactured specimens are manufactured. At FHWA RTFO is used for short term ageing and PAV for long term ageing of bitumen. Details are shown in the picture below.

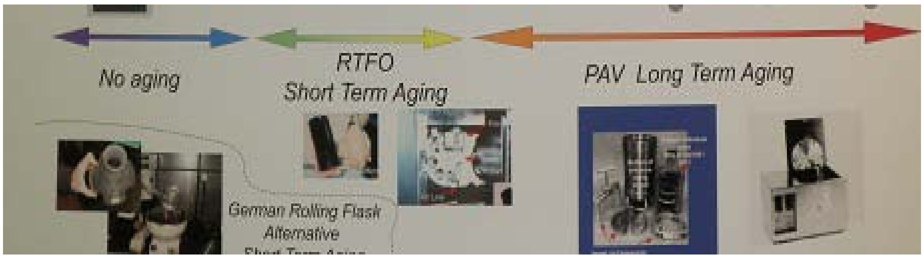


Photo: R Clayton

Is APT useful to a road owner?

This question has been addressed under " feedback on key issues".

How does the loading compare to that on the network – axle configurations – bridge impacts

Both UCPRC and FHWA TFHRC APT devices used only single axle/ single wheel or dual wheel configurations for testing.

Marginal material evaluation – is it done (i.e. Queensland requirements)?

No testing of marginal granular materials was done at any of the research centres. At NCAT some of the test sections contained asphalt that had been manufactured using softer aggregates.

Other equipment associated with APT?

UCPRC use Simple Shear Test because it simulates that way asphalt fails in a road. Use rolling wheel compaction to fabricate samples that are cored to produce specimens for testing. They also do fatigue testing using the 4 point bending beam test.

At FHWA TFHRC the Asphalt Mix Performance Tester (AMPT) is used for determining E. Dynamic Shear Rheometer for binder tests for rutting and fatigue. The Direct Tensile test is used for fatigue grading of binders and the Bending Beam Rheometer for low temperature cracking tests.*

At NCAT Dynamic modulus (triaxial cell) is used. Studies carried out to compare modulus determination against predictive methods. AASHTO 79 Hirsch model appears to be the most robust procedure for the prediction of maximum E. Confined and unconfined tests are possible, but they prefer unconfined. Asphalt Pavement Analyser (APA) and Hamburg Wheel Tracking Device (HWTD) used and correlated with flow number and actual rutting behaviour. Fatigue resistance predicted with 4 point beam test and push-pull fatigue testing for bottom up cracking. NCAT is pursuing the endurance limit. Energy ratio is used for prediction of top down cracking.*

A selection of photographs of test apparatus from the laboratories of the research centres is shown below

UCPRC Simple Shear Test#

UCPRC Simple Shear Test close-up*

Hamburg Rut Test*

UCPRC 4 Pt Bending Fatigue Test#

FHWA HRC Rheometer*

FHWA HRC Rheometer*

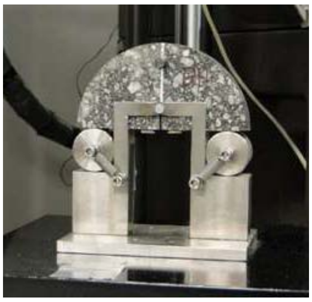
FHWA HRC AMPT apparatus*

FHWA HRC AMPT test*

NCAT 4 point bending beam test *

NCAT Asphalt Mix Performance Tester (AMPT)*

NCAT Resilient Modulus test*



NCAT Semi-circular beam test*

*Photos: MG Henderson
#Photo: RM Vos

Concluding remarks

The APT research facilities visited provided healthy examples of APT in practice. The research centres were actively involved in research into the topics that the AAPA Study tour was most interested in, namely, WMA, RAP and Perpetual Pavements. APT clearly demonstrated that it is a valuable tool to obtain research results not possible to achieve within such short timeframes using other methods. The cost of such a facility appears quite high, but when compared to the cost of premature failure on the network and the political embarrassment, it worthy of consideration. The success of these research facilities is achieved through a co-operative approach between academia, construction, consulting and road authorities.

Reference Material

List the presentations or other material gathered during the tour.

1. Presentation: "NCAT Welcomes the Australian Asphalt Study Tour"
2. NCAT Report 06-05 Phase Two NCAT Test Track Results, December 2006
3. Presentation: Perpetual Pavement Designs and Concepts Dr David Timm 2010
4. Presentation:"University Pavement Research Centre Overview" John Harvey 2010
5. Presentation: " Caltrans Warm Mix Asphalt Study" Dave Jones 2010
6. Presentation: "Summary of Binder Fatigue findings from FHWA ALF + Full-scale accelerated aging activities" Nelson Gibson, FHWA Office of Infrastructure Development, February 2010
7. Willis, R., D. Timm, et al. (2009). Phase III NCAT Test track findings. National Centre for Asphalt Technology. NCAT Report 09-08)
8. Partnered Pavement Research Center (PPRC) Research Road Map, 2008, at http://www.ucprc.ucdavis.edu/
9. The Highways of the Future—A Strategic Plan for Highway Infrastructure Research and Development Publication No. FHWA-HRT-08-068 July 2008 at http://www.tfhrc.gov/
10. NCAT Website a http://www.ncat.us

8. GENERAL

Working Group

Leader: Rob Vos Group: Andrew Bethune, Nigel Preston

The intention is that the views, experiences, and responses to the general issues be extracted from the DOT / FHWA and Research organisations should be reported on the questions posed and responses. When diverse views are held they should be reported

Tour scope

General Issues – ranging from sprayed sealing to performance contracting these issues were not central to the study tour goals and responses are reported where they are relevant.

Feedback from

- California – Caltrans / Granite, APACA, CalAPA / UC Davis
- Washington, DC – FHWA / NAPA
- Virginia – VDOT / VAA
- Tennessee – Astec
- Illinois – DOT & University
- Texas - DOT
- North Carolina – Boggs / NCDOT
- South Carolina – Boggs & Banks / SCDOT
- Alabama - NCAT

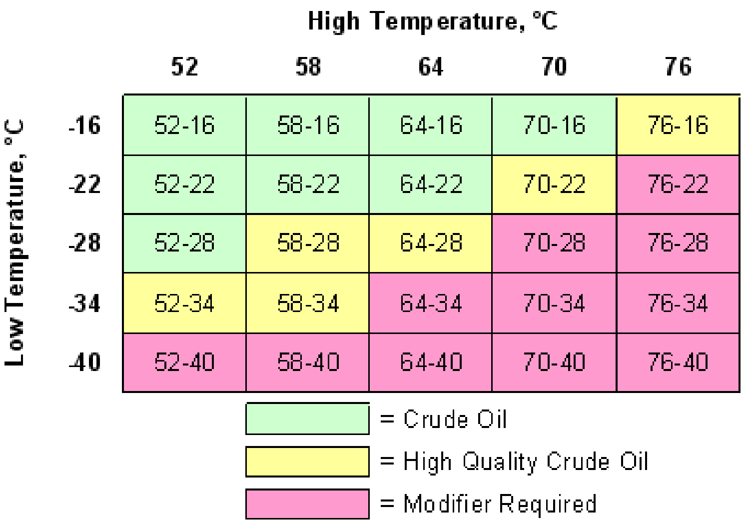
Observations

Binders

The Australian bitumen supply industry is going through a period of change with increasing quantities of imported product arriving on our shores manufactured from a wider variety of crude sources than the historical datum. These changes in bitumen supply in Australia are causing some concern amongst users and purchasers of the product particularly with the asset owners. The Tour group wanted to explore the status of bitumen supply and specification in the USA to assess whether similar concerns are being experienced in America.

Following the Strategic Highway Research Program (SHRP) in the early 1990s, the 50 states in the US progressively moved away from traditional penetration or pen/vis specifications and adopted the Performance Grade (PG) binder specification system.

The PG system indicates the temperature range over which a binder will exhibit satisfactory rheological behaviour. For example a bitumen with a PG classification of PG 64 -22 will be considered suitable for use as an asphalt binder in a location where the average 7 day maximum pavement temperature at a pavement depth of 20mm is 64 degrees C and the average minimum 7 day surface temperature is -22 degrees C. Hence, the PG system is theoretically based on performance characteristics rather than the traditional empirical nexus relating physical properties with observed performance.



Prediction of PG grades from different crude oil blends from www.pavementinteractive.org

The geographical size of Australia is very similar to the contiguous states of the US , but of course the USA is much more densely populated and has a far more intensive road network. The USA consumes around 30 million tonnes of bitumen per annum compared with approximately 900 kt consumed in Australia and hence takes bitumen from a much wider variety of sources and crude types than experienced in Australia.

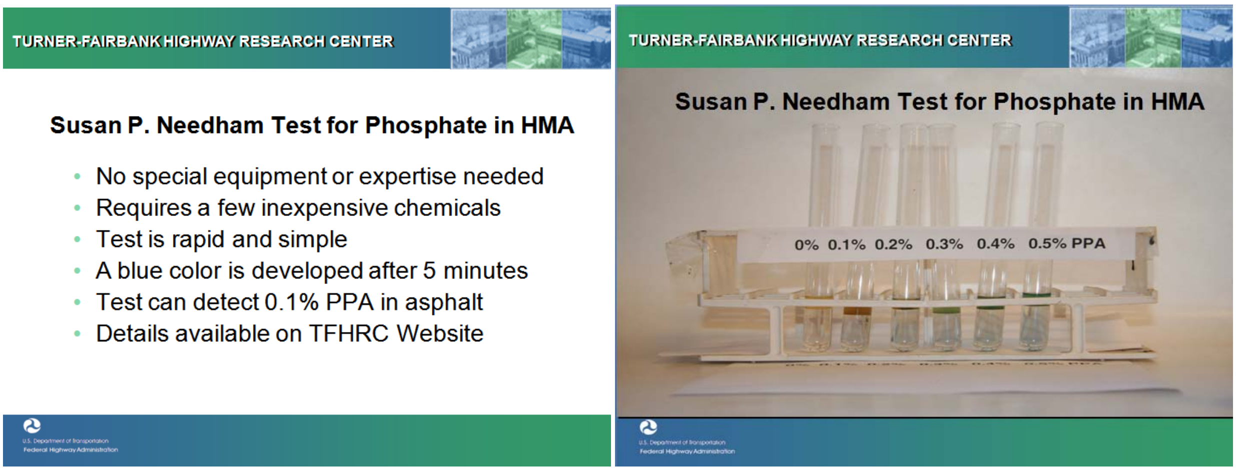
Feedback from the Americans was explicit in that the PG binder specification system was considered to be satisfactory and delivered fit for purpose binders. There was an absence of concern about bitumen issues per se and there were no reports of concerns relating to feedstock types or chemical composition.

It was evident that both clients and specifiers recognised that construction practices are far more influential on the performance of asphalt than minor variations in bitumen characteristics. Whilst the FHWA are carrying out some research into the chemical constitution of bitumen (asphaltene and maltenes) the work is associated with matching virgin bitumen characteristics with RAP bitumen. We were not made aware of any other research programs being undertaken on bitumen types.

PPA Addition

The USA has reported the use of Poly Phosphoric Acid (PPA) as an additive to boost the PG classification of given binders. This subject was raised by the Study Group in order to better understand the US experiences with this technique.

Acid modification of bitumen has the effect of stiffening the binder thus changing the physical characteristics. Recognition of this effect has lead to the concept of 'grade bumping where a binder with PG characteristics of say 64 -22, can have the upper temperature class lifted to 70 through acid addition. In principle the grade bumping should improve the engineering properties of the bitumen although work carried out at Turner Fairbank has shown that this isn't always the case. Whilst PPA addition does appear to have a beneficial effect in terms of deformation resistance, it is generally inferior to polymer modified binders.



FHWA: PPA presentation – test for Phosphate in HMA

Generally, binders are not 'checked' to assess whether they have received some form of modification or not, so most agencies do not monitor the overall use of PPA addition. However, it was reported that some road authorities ensure SBS modification of bitumen when required by implementing an "elastic recovery' requirement to the PG specification. This approach precludes acid modification as the elasticity of the binder is not augmented by the acid.

Tack coats

The importance of good tack coating practice was emphasized by researchers, DOT’s and industry alike. Work continues on pavement layer bond strength determination with results on the limits to application rate of tack coats and the resultant impact on the pavement structural life. High application rates are being placed with beneficial effects leading to the use of trackless tack coats to prevent pickup under construction traffic. [11 & 21]

Foam Stabilisation

Similar to Australia, foam and chemical stabilisation of pavements is a technology applied to lower trafficked roads. FHWA and Dept of Transport personnel were not very familiar with the extent to which stabilisation is used or any developments in the technology.

Astec are beginning to build stabilisation machines as they believe that globally the market is expanding for stabilisation and Astec will compete with Wirtgen in the equipment supply space.

Chemical stabilisation is probably preferred to foam stabilisation but both technologies are used.

Sprayed Sealing

Australia, New Zealand and South Africa are considered to be the leaders in sprayed sealing design and practice. As such advice from our hosts was limited. Sprayed seals are used but the design / construction approach is variable.

Surface Friction

Skid resistance is managed as a road performance property linked to maintenance interventions and related to accident & accident risk. Standard ASTM test devices – locked wheel trainer on wetted surface with recommended intervention levels based on road usage. Aggregates are assessed for aggregate friction after polishing but texture depth appears to not be considered in surfacing selection or maintenance. However, open graded and stone mastic asphalt is commonly used on their high speed interstate road network which by nature addresses texture depth.

Stone Mastic Asphalt in Virginia to overlay cracked concrete pavements

General - Questions & Responses

How is texture depth on Dense Graded Asphalt (DGA) wearing course specified or managed for high speed traffic roads (e.g. 100 kph)?

- *Response included under "Late questions received – surface friction"*

What is/are the best product(s) for reinforced asphalt? What is the reason for using reinforced asphalt? Is there any best practice guidelines for constructing reinforced asphalt pavements? Specialised equipment etc?

- *Reinforced asphalt was not discussed in depth. The USA does not appear to try to employ this type of technology even though they have significant issues with reflection cracking from concrete bases and thermal cracking in the colder parts of the country.*
- *We received comment about the use of geofabrics to combat reflection cracking (NCAT). NCAT have used fabric on one of their test sections but it appears to have not reduced reflective cracking. Possible issues may have included type of geofabrics used, tack coat application and application of the fabric onto the pavement. Whilst geofabric appears to not have worked in this instance, it may be possibly be the application of the technology more than the product itself.*
- *Virginia DOT and Virginia Asphalt Association have attempted the use of geofabric and have not found it successful in reducing reflective cracking.*
- *Overall it appears the many US states have had negative experiences with this technology.*

Are they considering performance based asphalt specifications or staying with the 'recipe based' philosophies?

Many of the US states are staying with recipe based philosophies which are heavily reliant on vigilant surveillance and parallel lab testing between asphalt producers and the states DOT's. A summary of approaches from Virginia DOT, Caltrans, Texas DOT and NCAT are included below

- *Virginia DOT has an asphalt acceptance program in place where the contractor is required to supply Q&A records and independent test results, with regular monthly surveillance by the DOT. The Virginia DOT will be moving to a web based system to monitor contractors in March 2011.*
- *Catrina Barros from Caltrans noted they have a Materials Plant Quality Program (MPQP) in place as their inspection program. Similar to Virginia they also heavily rely on parallel testing as their method of surveilling and monitoring product.*
- *Caltrans also noted that their contracts are construct only styles contracts. They have recently had good experience in managing contracts through establishing partnering meetings. They have not moved to design and construct style contracts or alliances as this change would require a legislation change from the state legislator.*
- *Texas DOT, whilst sticking with recipe based philosophy, appears to be the state most flexible and open to trying new ideas and innovations.*
- *Andrea Kvasnak – NCAT advised that NCAP are setting up a national online certification for WAM, which can be found on www.warmmixasphaltcertification.com. As part of setting up*

the certification system they surveyed 50 states and received 30 responses on what various states wanted contained within the national online certification. The two top key responses states wanted was stripping and rutting results related to WAM.

A key weakness of these approaches is potential differences in test results. Caltrans and Virginia both noted that failure of a product is unlikely to be on a single test result but when successive or trends appear in test results.

In the states visited, either the DOT has internal lab facilities for testing of asphalt and bitumen or close relationships with Universities who carry out the testing functions on behalf of the state DOT.

Is there any development in terms of automated real time monitoring of asphalt on site (i.e. temperature and compaction records)? If yes, has this resulted in better site management?

- *Yes. Astec Industries provide the facility of real time monitoring of plant operations and in principle process control. This innovative company is at the forefront of plant technology and is continually researching to improve all aspects of asphalt production.*
- *There was no specific data however to indicate whether improved plant control systems were resulting in better asphalt on site.*

Are there any developments/facilities which produce on-line conformance information at asphalt production plants?

Yes – see above

How common is foam stabilisation used in the US? What grade of binder is normally used in foam stabilisation and what type of wearing surfaces are placed on top of stabilised pavements?

- *Stabilisation in general is not a very common maintenance activity although there does appear to be recognition of its potential value. Existing stabilisation works tend to be chemical rather than foam. Astec Industries are starting to manufacture Stabilising machines suggesting their inference that this maintenance activity is worthy of attention.*
- *This subject was not part of any presentations; the above answer has been collated from general discussions with US personnel.*

What is the US experience of the PG system of specifying binders particularly with PMBs (PG70+ binders).

All states use the PG (Performance Grade) binder system. This is a climatic related system classifying binders according to their rheological properties and suitability of use in a given temperature regime. We did not receive any reports of concerns about this specification system.

The US sources bitumen produced from a variety of crude types. Is there regional evidence of any difference in performance of binders and emulsions or are such effects dwarfed by climatic and traffic influences?

- *The US manufactures bitumen from a number of domestic crude sources as well as imported crude sources (notably South American). The general feeling appeared to be that the PG binder specification system is robust enough to ensure that fit for purpose binders are used in any given location. We did not receive any comments to suggest either regional or localised problems were being encountered with the binders being produced in the USA.*

- *Feedback suggested that construction practices were far more critical than small variations in binder characteristics in terms of asphalt performance.*
- *There is no strategic r&d program on bitumen in the US. The SHRP program in the early 1990s was the last co-ordinated effort looking at all aspects of bitumen which lead to the Performance Grade concept.*
- *FHWA are carrying out some "constitutional" research on bitumen looking at the compatibility of virgin bitumen with RAP bitumen.*

Sprayed sealing

General statistics of sprayed sealed roads in the US. What proportion of the US network is sealed and what sector of the road network generally receives sealing treatments as opposed to asphalt?

Sprayed sealing was not really addressed as part of the Study Tour. Unlike Australia, the USA only uses sprayed seals and microsurfacings on lower trafficked roads outside of the principal highway network. California tends to use microsurfacings in preference to sprayed seals to avoid litigation issues resulting from 'broken windshields' due to loose and flying stone chips.

Consequently, in depth discussions on emulsion types, polymer emulsions and scrap rubber seals did not take place.

It was noted that Texas and Arizona would be the states that would most used spray seals mainly with emulsions.

Randy West at NCAT and Don Brock at Astec both suggested that Australia and South Africa would be far ahead on the USA in terms of 'chip sealing' technologies and site practices. It was suggested that Australia is able to apply sprayed seals on heavily trafficked roads due to the continued use of cutback bitumen rather than bitumen emulsion.

Emulsion usage?

- *The question of emulsion and their use was not raised by our hosts, emulsion usage for tack coats is common. Work on the development of Trackless Tack coats was discussed by Virginia DOT who will be requiring it for future overlay work. This appears to be driven by overlay construction under traffic requiring the asphalt delivery vehicles to travel on the tacked d surface with the resultant pickup and reduced asphalt adhesion.*

Inverted or non-ionic emulsions in sprayed sealing?

- *not covered*

What type of emulsion is generally used for sprayed sealing?

- *not covered*

What type of polymer is most commonly used in the manufacturing of Polymer Modified Bitumen (PMB) Emulsion?

- *not covered*

On low traffic volume streets, deterioration is caused by oxidisation over time. Is there an optimum level of oxidisation of asphalt that can be considered for a low cost treatment (rejuvenate or thin PMB emulsion spray surfacing)? If so, how is it measured?

- *not covered*

Are cutback binders still used for sprayed seals or are all seals emulsion? What type of emulsions are typically used in sealing operations?

- *Discussion was limited in relation to spray seals, however it was generally noted that emulsions has largely replaced cutbacks in the limited states that use spray sealing based on safety and environmental concerns.*

Scrap rubber usage?

- *In some States there was a "politically driven mandate" was enacted requiring up to 30% of scrap rubber in all asphalt binders. In the case of California this has driven its use. Where the mandate has been lifted, a number of the States have withdrawn from using crumb rubber binders.*
    - *What is the size and particle size distribution of scrap rubber for use in sprayed sealing and asphalt. What is the production method for obtaining the scrap rubber? See below*
    - *Is there a preference for how to incorporate scrap rubber into bitumen?*
      There are a number of blending methods used, with the States varying in their use of the methods.
        - *Terminal Blend – lower percentages of rubber – fully digested - liquid*
        - *Arizona method – partially digested – non-homogeneous – discrete rubber particles*
        - *Crumb rubber and SBS mixture*

(Details from Trevor Distin)

What measures are in place to reduce fuming when blending and spraying CRB?

- *Dave Jones (University of California Pavement Research Centre) noted that the State of California have legislated that paving materials must contain from 20% in 2007 to 35% crumb rubber by 2013, must include recycled tyres in the mix. California has reached 30% of all hot mix asphalt products by 2010.*
- *It appears California uses a far coarser grading of rubber than used in Australia, however it should be noted Australia primary use of rubber is in spray seal where the US use is for asphalt. It was also noted that the U.S. use car tyres as a source of rubber and are less stringent on the rubber introduced into the mix. There may be a possibility that in Australia, the conditions and controls on rubber may be too narrow and constrictive and would be worthy of further investigation.*
- *Catrina Barros (Caltrans) noted that she was aware of 4 states that use rubber in their asphalt, including Arizona, Texas, Florida and California with other states choosing not to adopt due to poor initial experience in using the product.*
- *Pete Stephanos FHWA – Program Management indicated they are investigating the use of a product called Plusright TM, comprising chunks of rubber that substitutes for aggregate*

Aggregate usage?

Steel furnace slag or similar materials in sprayed sealing?

Is graded aggregate used in sprayed sealing? How is this designed? Specifications?

How do they measure shape? (i.e. proportion calliper, ALD, AGD, etc?)

- *The aggregate provided to US asphalt plants is generally a graded product from quarries that similar to Australia produce aggregate for both asphalt and concrete products. This produces issues with keeping aggregate within grading envelopes and potential segregation. The U.S. practitioners considered Australia's approach of separating aggregate into fractions prior to introduction into the asphalt production process to be a better arrangement to control mix gradings and minimising segregation.*

Resurfacing

Acceptability of spray seal in urban areas?

not addressed – asphalt is the predominant surfacing

Options for resurfacing spray seals in urban areas where a spray surface is not accepted?

- *not addressed*

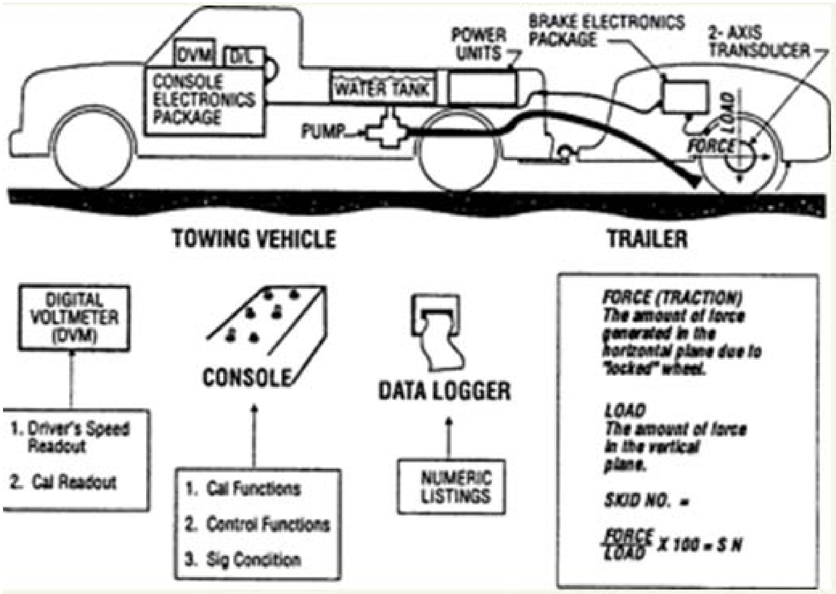
Late questions received – answer if possible

Surface friction, what is being done locally to evaluate

- *See below*

What are asset owner's responsibilities for surface friction.

- *Feedback was received in detail from Caltrans and in general discussion with Virginia and other State DOT's. It appears that skid resistance is not that much of an issue for their pavements.*
- *ASTM E274-06 test method for the determination of skid resistance is the basis of assessment using the either a ribbed or smooth full size automotive tyre mounted on a trailer dragged across a wetted surface at a standard test speed is 40 mph (65km/h).*
- *Test results Skid Number SN values are used to develop maintenance plans to address any need to improve skid resistance. Plans include the likely skid demand and are in most cases linked to reports of accidents. It appears that, in a number of States, that the test data is deleted after the maintenance plans are determined.*
- *Texture depth requirements – it appears that overall skid resistance values are what is measured and that texture depth is not measured independently. Management intervention is based on SN values with an awareness that texture plays a role in the SN.*



ASTM E274 Skid Measurement System

- *NCAT is undertaking evaluation work on surface friction using a Three Wheel polishing device in an attempt to model the surface friction changes that take place on the NCAT Test Track.*

Three Wheel Polishing Test Device

Are performance based contracts being used & what do they compromise

- *Issue not addressed directly – Virginia has PPP projects which are performance linked. Currently Macquarie / Transurban / Fluor are involved in PPP on High Occupancy lanes where asphalt is being used in preference to concrete with that decision made by the contractor on cost effectiveness grounds. Monismith et al of UC Berkeley/David and Caltrans have published on pay factor (bonus) linked to models developed on their Accelerated Pavement Testing for rutting and fatigue resistance.*

SMA – is it being used & what performance is being achieved.

- *Usage varies state by state. Virginia DOT and Maryland DOT are using SMA to surface distressed and cracked concrete roads. They report very good performance with surfacings* *lasting in excess of 10 years. Caltrans noted after bad experiences, they do not promote or use SMA in California.*

- *SMA was first used by VDOT on a major project in 1995 with mixed results. Critical issues for its success included aggregate structure, particle shape, adequate fines to produce mastic and proper bitumen content to meet mix volumetrics.*
- *In 2002 they reintroduced SMA in a major way. Much of their learning's have been through trial and error and two trips in Germany in 1995 and 2005 to assist in refining their specifications. It appears that they have experienced many problems in both production and placement, but have worked through these issues to achieve very good performance.*
- *What VDOT have learned through experience with the asphalt <u>production</u> process includes*
    - *Dry materials during production*
    - *Consistent monitoring of fibre flow*
    - *Calibration of plant due to higher bitumen contents*
    - *Consistent gradation of aggregates*
    - *Wasting of initial tonnage until plant production stabilises.*
- *What VDOT have learned through experience with the asphalt <u>placement</u> process includes*
    - *Proper paving equipment*
        - *Material transfer vehicle*
        - *Adequate paver screed size for initial compaction*
    - *Large rollers close to back of paver*
    - *Limited vibratory passes*
    - *Limit handwork*
- *Richard Schreck – Virginia Asphalt Association confirmed that Maryland and Virginia have both actively adopted SMA with good results.*

What research is being undertaken,

- *Each centre visited have different current research focus areas and projects. Typically for NCAT their research focus areas are:*
    - *Sustainable pavements*
    - *M-E pavement design calibration*
    - *Lab test for predicting performance*
    - *Perpetual pavement design*
    - *Porous friction courses mixes*
    - *Pavement reflectivity – UHI*
    - *Pavement friction*
- *NCAT Research In Progress – 33 projects, funds U$17 million, most completion 2010*
    - *Details in attached appendix*
- *NAPA's technical focus was:*
    - *Perpetual Pavements*
    - *Warm Mix*
    - *Recycled asphalt pavement & shingles*
    - *Thin asphalt overlays*

  - *Porous pavements*

What research development & management programs are available

- *A comment made on a number of occasions is, the US is 50 states bonded by a common currency, that's where the consistency stops. It appears the US has many research and development programs at many different levels including FHWA through Turner Fairbank Research*
  - *FHWA – Long Term Pavement Performance managed by Ray Bonaquist*
  - *State DOT using with internal resources or local universities.*
  - *Individual company trials, who appear to often use Ray Bonaquist for technical support*
  - *Astec Industries, who as a plant/machinery supplier has an impressive understanding of the issues and needs facing the industry.*
  - *NCAT, largely funded by states and private companies.*
- *In the states visited, either the DOT has internal lab facilities for testing of asphalt and bitumen or close relationships with Universities who carry out the testing functions on behalf of the state DOT. Much of the research appears to be similar or related in other states and is dominated by the experience and capability within the respective DOT or university.*
- *It was noticeable in a number of visits, that a significant amount of expense and energy is being placed into many research and development issues that are very relevant to Australia. It is considered that on a national level Australia should be monitoring the work undertaken through a combination of AAPA, AustRoads and ARRB resources to ensure we maximise the work being undertaken.*

Bitumen supply in the future – what constraints are there

- *This subject wasn't cited as a great concern. However, the emphasis on RAP usage and recycled shingles is reducing the demand for virgin products and is seen as a means of conserving bitumen supplies.*

Quality of imported oils/bitumen; controls instituted

- *The USA appears to be satisfied with the PG specification system. We did not receive any feedback about significant concerns with bitumen from either a national or regional perspective. It was stated that since the introduction of the PG system, more consistent fit for purpose bitumens had been supplied.*

QA/QC incentives & performance payment schemes (have they worked / what is targeted)

- *A driver for the introduction of WMA from industry is the ability to achieve density. Most states appear to have a penalty bonus system for achieving or not achieving density. Three contractors visited noted that WMA provided reduced potential for failures and higher chance of receiving a bonus from achieving density requirements.*

Modified Binder usage and issues

- *We didn't get a real feel for the proportion of modified binders that are used. Because of the PG system, modified binders are not specified per se, although the PG76 grade generally requires modification to achieve the specification requirements. Some Americans referred to a PG+ binder system whereby additional properties such as elastic recovery can be added to the PG requirement in effect demanding SBS modification.*

Life Cycle Assessment

- *The university of California Pavement Research Centre (UCPRC)(John Harvey) are working on an Environmental Life Cycle Assessment for Recycling and Sustainability on behalf of Caltrans. The work is attempting to place more consistency and rigour when undertaking life cycle assessment which Caltrans undertakes as part o f their procurement processes. During discussions it was obvious that environmental pressures and expectations are far greater than what is currently experienced in Australia at the moment. The details of the work to date are detailed at www.ucprc.ucdavis.edu/p-lca, and contains what they refer to as transparency documents which details the assumptions to determine the life cycle costing calculations.*

Network Performance Monitoring

- *The university of California Pavement Research Centre (UCPRC)(Dave Jones) presented the work they are undertaking in relation to the upgrading of the Caltrans Pavement Condition Survey. The initial surveys undertaken by Caltrans commenced in 1978 and have been based on high speed visual assessment around roughness and cracking with no structural monitoring.*
- *In March 2008, Caltrans sought and secured $20million over 3 years from the State of California (Finance Letter No.10) to undertake ground penetrating radar of the whole network and automated pavement condition surveys (APCS). This initial investment was based on the lack of records on pavement composition or depths. The business case presented noted that with this increased information, they would be able to use performance models to proactively predict the most cost efficient timing of preservation and rehabilitation, instead of current reactive decision trees. Their modeling is also looking to integrate condition, traffic, climate, structure. And have referenced medical studies for probability of survival of roads as a modeling approach.*
- *Caltrans has found difficulty with identifying distress. They have found their approach to automatic crack detection, not all that automatic and have had to use manual intervention to produce reliable results. As part of this work they have facilitated a method for semi automation of distress identification and quantification. In addition, they have implemented improved laser technology to measure rutting, ride quality and spalling.*
- *With the announcement on 6 September of $U50 billion for road & airports in the USA this is what they would have to use to replace their multilane Interstate network.*

Reference Material

List the presentations or other material gathered during the tour.

1. Construction Analysis for Pavement Rehabilitation Strategies CA4PRS, Eul-Bum Lee, UCPRC, Institute of Transport Studies, UC Berkeley, August 2010, presentation
2. HMA Sampling Strategies using Uniform Experimental Design for Quality Assurance, Bor-Wen Tsai and JianMiao You, UCPRC, UC Berkeley
3. Technical Topics No.6, Performance Graded (PG) Asphalts in California, Larry Santucci, Technology Transfer Program, UC Berkeley
4. Technical Topics No.7, Performance Graded (PG) Polymer Modified Asphalts in California, Larry Santucci, Technology Transfer Program, UC Berkeley
5. Technical Topics No.8, Recycled Asphalt Pavements – A strategy revisited, Larry Santucci, Technology Transfer Program, UC Berkeley
6. Pavement Technology Update, Recent findings on the use of tack coat between pavement layers, Larry Santucci, UCPRC, UC Berkeley - Davis
7. Pavement Technology Update, Rubber Roads: Waste tires find a home, Larry Santucci, UCPRC, UC Berkeley - Davis
8. Pavement Technology Update, Recent Warm Mix Asphalt hits the road, Larry Santucci, UCPRC, UC Berkeley - Davis
9. State of the Industry, Mike Acott, NAPA President, August 2010, presentation
10. Overview of TFHRC Research on Phosphoric Acid Modification of Asphalt, Office of Research Development and Technology, FHWA McLean, VA, AAPA August 2010, presentation
11. VDOT presentation covering the use of SMA in Virginia, High Modulus High Binder Base Mix in Virginia, Move to trackless tack coat materials in Virginia, Trenton Clark, August 2010
12. Roadtec, Cold in Situ Recycling, presentation
13. PP & Rubblization, Marshall R. Thompson, Dept of Civil Engineering, University of Illinois, August 2010, presentation
14. Trackless Tack Coat Materials – A laboratory evaluation for performance acceptance, Trenton Clark, Todd Rorrer, Kevin McGhee

9. APPENDICES

9.1 Detailed Itinerary

9.2 Tour Participants

9.3 Questions from Australia for the Study Tour

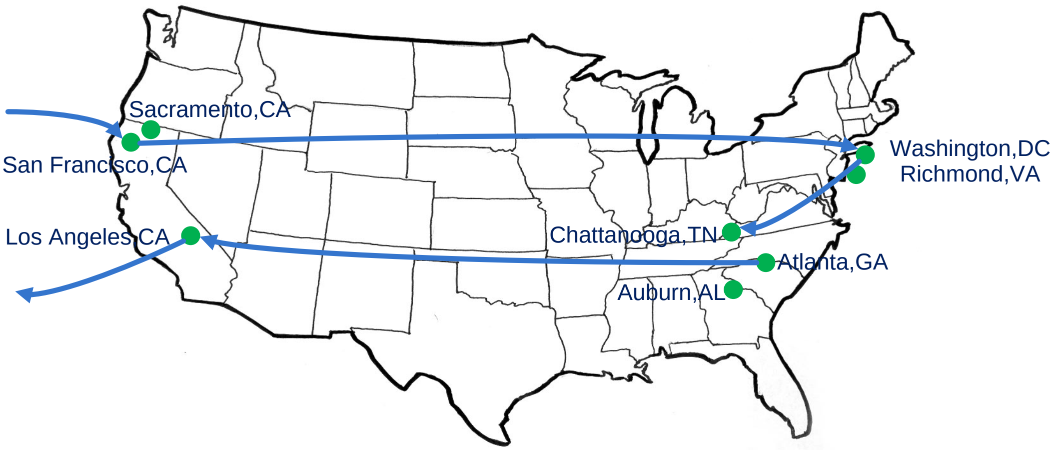
9.4 USA Acronyms, State Abbreviations, Conversions & Quotes

9.5 References

Appendix 9.1 - Detailed Itinerary

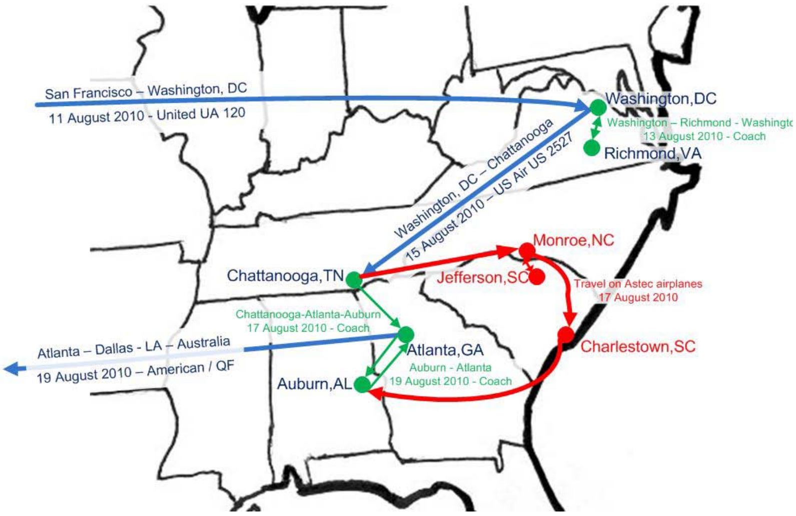
The tour travelled across the USA starting in California, then to Washington DC / Richmond VA, Chattanooga TN, and to Auburn AL. Travel was by air and bus with extra travel into South & North Carolina for the WMA & RAP group.

AAPA 2010 STUDY TOUR
Air Travel



California travel

Washington, Tennessee & Alabama travel



The tour party travelled to San Francisco, California on Saturday 7th August and departed from Los Angeles on the 19th of August.

The above outlines the travel across the USA where contact was made with leading researchers at Universities of California Davis and Berkeley, Illinois and the University of Auburn, National Centre for Asphalt Technology, staff of State Departments of Transport of California, Virginia, North & South Carolina, Texas, the Federal Highways Administration, Asphalt Pavement Association of California and Californian Asphalt Pavement Association, Virginian Asphalt Association, the National Asphalt Pavement Association, Astec Inc, Banks Construction, Reid Construction and Granite Construction.

CALIFORNIA

Monday 9 August 2010

8:00 am – 9:30 am	Tour coach from Handlery Union Square hotel, San Francisco for UC Davis University of California Pavement Research Center (UCPRC) UC Davis Advanced Transportation Infrastructure Research Center (ATIRC)
9:30 am	Greeted by hosts John Harvey & Dave Jones Participants: UCPRC: John Harvey, Dave Jones, Jon Lea, others? Caltrans: Nick Burmis, Joe Holland, Cathrina Barros, Kee Foo, Haiping Zhou Industry: Rita Leahy, Tony Limas, Brandon Millar
10:00 am	UCPRC Overview (John Harvey) WMA (Dave Jones, Cathrina Barros, Tony Limas, Brandon Millar)
12:30 pm – 1:30 pm	Lunch at UC Davis ATIRC
1:30pm	Porous Pavements (Dave Jones) Noise (Quiet Pavements) (John Harvey) Pavement Management System (John Harvey, Jon Lea, Joe Holland) High RAP Mixes (Tony Limas)
5:00pm – 6:00 pm	Depart for Sheraton Grand Hotel, Sacramento
7:00pm	Dinner in Downtown Sacramento – McCormick & Schmicks, 1111 J Street with Caltrans, UCPRC and Industry

Tuesday 10 August 2010

7:30 am	WMA/RAP group leaves Sheraton Grand Hotel, Sacramento
8:00 am	WMA/RAP group proceeds to Tony Limas, Granite Construction Plant for Plant and WMA project tour
10:45am – 12:30pm	WMA/RAP group - travel to UC Berkeley Richmond Field Station
8:00 am	PP& APT group leaves Sheraton Grand Hotel, Sacramento
9:30 am	APT/PP group proceeds to UC Berkeley Richmond Field Station University of California Pavement Research Center (UCPRC) UC Berkeley Institute of Transportation Studies Richmond Field Station (RFS), CA Hosts: Carl Monismith, Jim Signore, Lorina Popescu Participants: Carl Monismith, Jim Signore, Lorina Popescu, E B Lee, Bor-Wen Tsai, Irwin Guada, Terrie Bressette, Chris Gerber, Rita Leahy
9:30 am	Welcome by hosts Perpetual Pavements – I-710 – Technically (Carl Monismith) LCCA & CAP4RS (E B Lee) Materials Characterization (Carl Monismith) Fatigue Endurance Limit (Carl Monismith) Brief Tour of Lab (Jim Signore)

Tuesday 10 August 2010 (continued)

12:30 pm – 1:30 pm Perpetual Pavements - National Perspective (Rita Leahy)
Perpetual Pavement s- California I-710 – General Overview
CAP4RS & QC/QA Sampling – General Overview
5:45 pm – 6:15pm End of session – Tour coach to dinner – Spenger's Fresh Fish Grotto.
Caltrans, UCPRC & Industry invited to join
AAPA tour for dinner
8:30 pm – 9:00 pm Tour coach to Radisson Bay Front Hotel, Brisbane, CA

WASHINGTON

Thursday 12 August 2010

8:30am – 9:30am Tour coach from Hotel to Turner-Fairbanks Highway Research Centre
9:30-9:45 a.m. Welcome from FHWA/NAPA/VAA (*Pete Stephanos, Mike Acott, Richard Schreck)*

- Review of Agenda - Newcomb

9:45-11:15 a.m. Turner-Fairbank Highway Research Center Tour (*Jack Youtcheff)*

- Overview of FHWA Facilities
- Tour of the ALF
- Tour of the Labs
- Discussion

11:15-12:00 a.m. Binders (*Jack Youtcheff and Nelson Gibson)*

- PPA Modification
- PG Grading
- Polymer Modification

1:00-1:45 p.m. Performance Testing & Pavement Modeling

- Performance Testing – Ray Bonaquist
- LTTP Modeling – Harold Von Quintus

1:45-2:30 p.m. RAP

- State of Practice – Pete Stephanos
- Mix Design Issues – Ray Bonaquist

3:15-4:00 p.m. Warm Mix

- State of Practice – Pete Stephanos
- Permissive Specifications – Dave Newcomb
- Research – Ray Bonaquist

4:00-5:00 p.m. Mechanistic Design and Perpetual Pavements

- Mechanistic Design – Harold Von Quintus
- Perpetual – Dave Newcomb
- High Modulus Base – Trenton Clark

6:00-8:30 p.m. Dinner at Neyla, 3206 N St NW (near Wisconsin Ave.), Washington DC 20007

VIRGINIA

Friday 13 August 2010

8:00 am	Travel to Richmond, Virginia
10:00 am	Meeting at VDOT (Chief Engineer & Trenton Clark), organised by Richard Schreck VAA
	Travel to VDOT Materials Dept Conference venue
	Visit WMA & RAP sites in Virginia – travel by tour coach
5:00 pm	End of meetings & site visits including SMA rehab projects
6:00 pm	Dinner with invitations to participants VDOT, VAA
	- travel to after dinner in Richmond to Washington hotel by tour coach

TENNESSEE

Sunday 15 August 2010

3:47pm - 5:00 pm	Arrive Chattanooga – US Air flight 2547	
6:00 pm	Coach from hotel to Fairyland Club Restaurant atop Lookout Mountain	
6:30 pm	Welcome to Astec…………………………………	Ben Brock
7:00 pm	Dinner, return afterwards to Hotel by tour coach	

Monday 16 August 2010

7:30 am	Tour coach from Hotel to Roadtec	
7:45 am - 8:45 am	Tour Roadtec Manufacturing	
8:45 am	Depart Roadtec for Astec	
9:00 am - 10:00 am	Tour Astec Training Center & Manufacturing	
10:15 am 10:45 am	Astec Industries Overview……………………..	Don Brock
10:45 am 12:15pm	TxDOT Experience with Warm Mix Asphalt...	Dale Rand
12:15 pm 1:00 pm	Lunch at Astec	
1:00 pm 2:15 pm	Sustainability – Maximizing RAP & WMA……	Don Brock
2:15 pm 3:00 pm	In-Place Recycling……………………………	Jeff Richmond
3:15 pm 4:30 pm	Perpetual Pavements…………………………..	Dr. Marshall Thompson
4:30 pm 5:30 pm	Visit WMA & RAP job site City of Chattanooga June 2007 – tour coach	
5:30 pm	Tour coach, return to Hotel	
6:30 pm	Dinner Downtown, Chattanooga, TN travel by tour coach	

Tuesday 17 August 2010

Some tour participants will travel directly to NCAT (PP & APT / NCAT group)

The WMA & RAP group proceeds as below:

8:00 am	Travel in Astec aircraft to Monroe, SC
	To Boggs Construction in supplied transport
9:30 am	Arrive Asphalt Plant Site – Monroe, NC

- Overview of plant – Drew Boggs, President, Boggs Construction
- Tour plant
- Tour lab
- Presentation – Drew Boggs & NCDOT

TENNESSEE continued

11:30 am	Travel to by bus to Asphalt Plant & Crushing Plant site – Jefferson, SC	
12:00 pm	Lunch at plant site	
12:45–2:00 pm	Overview of Asphalt Plant……………………..	Drew Boggs
	• Tour Asphalt Plant	
	• Overview of Crushing Plant	
	• Tour Crushing Plant	
2:00p	Return to Airport – transport supplied by Boggs Construction	
2:30 pm	Depart for Charleston, SC in Astec aircraft	
3:30 pm	Travel from Charlestown, SC to Banks Construction- transport provided	
	• Overview……………………………….	Reid Banks, President, Banks Construction
	• Tour Asphalt Plant & RAP Fractionating Plant	
	• Tour Lab……………………………….	Randy Funderburk, Lab Manager
5:00 pm	Return on provided transport to airport & depart in Astec aircraft for Auburn	
5:00 pm*	Arrive Auburn travel by Tour Coach to Auburn University hotel	
5:30 pm*	Arrive Auburn University Hotel (refer to Alabama stop itinerary)	

ALABAMA

Tuesday 17 August 2010

7:30 am	WMA & RAP group to airport (travel details see Tennessee)		
	PP & APT / NCAT group depart by coach for Atlanta and NCAT		
12:30 pm	Arrive Auburn midday – book into Auburn University Hotel		
2:15 pm	Arrive at NCAT office		
2:25 pm	Greetings and introductions		
2:35 pm	NCAT Overview presentation	green room	Randy West
2:55 pm	Tour through lab		Jason Moore
	Binder Lab		Pamela Turner
	Extraction & Recovery Lab		Jason Moore
	Aggregate Lab		Nam Tran
	Mixing & Compaction Lab		Jason Moore
	Basic Testing Lab		Jason Moore
	Advanced Testing Lab		Andrea Kvasnak
	Friction & Polishing		Mike Heitzman
	Mobile Equipment		Jason Moore
	Training spaces		Jason Moore
3:45 pm	Perpetual Pavement Design and Case Studies		David Timm
5:00 pm	AAPA group depart for hotel by coach		

ALABAMA continued

Wednesday, 18 August 2010

9:00 am	Mixture Performance Testing	Nam Tran
10:00 am	break	
10:15 am	WMA Research and Field Evaluation Projects	Andrea Kvasnak
11:15 am	NCAT Test Track Overview	Buzz Powell
12:30 pm	Depart for the NCAT Test Track by coach	
1:00 pm	NCAT Track Tour	Buzz Powell
3:00 pm	Depart for NCAT office by coach	
3:30 pm	Perpetual Pavement Design Concepts and Case Studies	David Timm
4:30 pm	Adjourn for the day, return to the hotel by coach	

Thursday, 19 August 2010

8:30 am	Check out, Depart hotel in coach	
8:45 am	Arrive at NCAT	
9:00 am	Increasing RAP Contents in Asphalt Mixtures	Randy West
10:00 am	Other Issues including tour through lab for WMA & RAP group	
11:00 am	Collaboration and opportunities	
12:00 pm	Lunch break	
1:00 pm	Travel by coach NCAT Auburn to Atlanta airport	
4:50 pm	Departure from Atlanta on American Airlines flight to Dallas then to Los Angeles	
11:20 pm	Depart Qantas QF Los Angeles for Sydney / Brisbane	

Appendix 9.2 - Tour Participants

Andrew Bethune

Director, Asset Management, Network Planning, VicRoads
T: +61 3 9854 2015 M: +61 418 543 703
E: andrew.bethune@roads.vic.gov.au

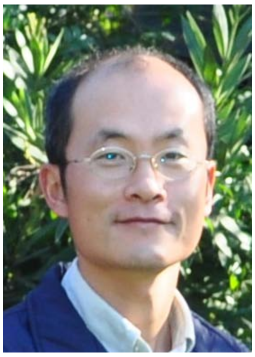
Gain understanding of current trends and emerging pressures in the US. Establish future networks to better understand and manage pavements.

16 years with VicRoads, previous role – Director SprayLine/VicRoads Road Services. Worked in various roles including traffic and transport, major projects, GeoPave and metro and rural regions.
B Eng(Civil&Comp) Master Tech Pavements

Warren Carter

National Technical Manager, Downer EDi Works
T: +61 2 8467 7216 M: +61 419 106 866
E: warren.carter@downerediworks.com.au

23rd year in the industry and had exposure to bitumen emulsions, polymer modified binders, sprayed sealing, asphalt and slurry/microsurfacing. Originally commenced in a laboratory role. The majority of my career has been in a technical role but have also held project management roles.



Young Choi

ARRB, Senior Research Scientist
T: +61 3 9881 1618 M: +61 468 613 603
E: young.choi@arrb.com.au

Learn from progress in the USA in WMA, SHRP program and Asphalt (simple) performance test.

7 years at NCPE (Nottingham Centre for Pavement Engineering) in the UK. 5 years at ARRB, Senior Research Scientist in bituminous and asphalt materials.
BSc (Agricultural Eng.), MSc and PhD in Pavement Engineering.

Russell Clayton

Global Service Line Leader, GHD Consulting Engineers
T: +61 8 6222 8769 M: +61 437 037 007
E: rclayton@ghd.com.au

Develop a better understanding of asphalt performance, from design through to construction. Obtain technical info on WMA,RAP and, application of PP and APT in OZ. Develop professional industry partnerships.

15 Years Ninham Shand Consulting director of geotechnical and pavement engineering. Last 7 years with GHD as principal geotechnical pavement engineer on major roads projects.

Trevor Distin

National Technology Manager, Boral Asphalt
T: +61 2 8801 2000 M: +61 401 892 719
E: Trevor.distin@boral.com.au

Find out more about operational issues & performance of WMA & RAP, design, construction & performance of PP.

10 years with Mobil Oil as Bitumen Technical Services Manager, 10 years with Colas Southern Africa as Marketing Manager, 3 years with Sabita as Executive Director.
B. Comm, Masters Dip Tech Civil

Mervyn Henderson

Project Manager , Metropolitan Region, Brisbane Office, Assets & Operations Division, Transport & Main Roads Department, Queensland Government
T: +61 7 3137 3087 M: +61 404 570 945
E : mervyn.g.henderson@tmr.qld.gov.au

Learn from progress in the USA, establish contacts for future sharing. Interest in APT for introduction to Queensland, WMA for all asphalts, performance of RAP at various %, PP concepts

32 years at Western Cape Roads Infrastructure Branch; 8 months at City of Cape Town; 1yr 10 months at Queensland Transport and Main Roads Department.
MScEng (Civil), GDipMgt (TechMgt), PrEng, (South Africa)

Rick Hennig

Director Statewide Operations & Programs, Transport Services Division, Department of Transport, Energy and Infrastructure
T: +61 8 8343 2722 M: +61 417 878 885
E: rick.hennig@sa.gov.au

Increase the use of recycled asphalt and warm mix asphalt within DTEI and South Australia. In particular understand what has prevented the asphalt companies from achieving significant reuse. Is there a technical barrier as well as financial?

Civil Engineer with 28 years experience in Dept for Transport with experience in road construction and maintenance.

Jason Jones

Senior Engineer (Pavement Design), Engineering & Technology Division, Department of Transport and Main Roads, Queensland Government
T: +61 7 3115 3027 M: +61 419 658 949
E: jason.d.jones@tmr.qld.gov.au

Learn from progress in the USA . Establish partnerships for future sharing. Topics of interest: - Field performance of WMA, use of PMBs in WMA, implementation of WMA in AC specifications, environmental benefits of WMA - Test procedures and results for fatigue endurance limit testing, progress on field trials / validation.

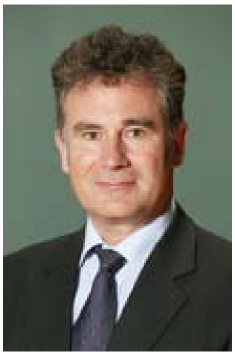
10 years at Department of Transport and Main Roads
B.Eng(Hons), M.Tech(Pavements), MIEAust, CPEng, RPEQ

Kym Neaylon

Principal Research Engineer and Team Leader Bituminous Surfacing, Australian Road Research Board (ARRB Group)
T: +61 3 9881 1629 M: +61 430 437 172
E: kym.neaylon@arrb.com.au

Wants to pick up new ideas and learn current status of US practice and research.

10 yrs of practical focus in mining, local government, road construction, and contract superintending. Then 17 years as surface dressing specialist culminating as materials group manager for the South Australian Government; last 3 years with ARRB . B. Eng (Civil); Chartered Engineer, current candidature for PhD (Civil)



Robert Patience

Group Technical Manager, Higgins Group
T: +64 6 357 1025 M: +64 27 446 7419
E: r.patience@higgins.co.nz

Interested in rebrand FDA as PP & LCCA, relating AMPT properties in pavement design & performance, RAP consistency.

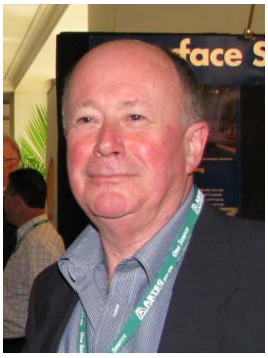
25 yrs roading & construction industry, last 10 years Technical Manager of contracting company, responsible for asphalt mix design, lab testing, asphalt qc, asphalt & pavement design, innovation. BE(Civil), MTech, GradDipMgt, MIPENZ.

Nigel Preston

Bitumen Technical Manager, Shell Co of Australia
T: +61 3 8823 451 M: +61 419 564 597
E: nigel.preston@shell.com

Interested in perpetual pavements, binder technology and binder testing. Accelerated testing of aged materials

7 years with Shell UK working as their asphalt engineer. 12 years with Shell Australia as their Bitumen Technical Manager. PhD Nottingham University and BENG Bradford University.



Ian Rickards

Consulting Engineer
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E: ianrickards@bigpond.com

Learn about, and encourage, the transfer of international & USA experience in pavement design, materials assessment and the introduction of perpetual pavement concepts into Australian practice.

Previously General Manager Pavements Solutions Group of PRS now consulting, participated in the development of HiPAVE and APSDS4, currently supporting AAPA in the fields perpetual pavements. Interests include advanced asphaltic material testing and associated test & production equipment.

Cassandra Simpson

State Executive – Victoria, Australian Asphalt Pavement Association
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E: cassandra.simpson@aapa.asn.au

Understand WMA experience in USA, and state of play with RAP.

1 year with AAPA, 15 years with VicRoads as construction/maintenance/surfacing engineer.
B.Eng(Civil), M.Eng(Pvt Tech)

Greg Stephenson

Senior Engineer Roads, City Assets, Brisbane Infrastructure Division, Brisbane City Council
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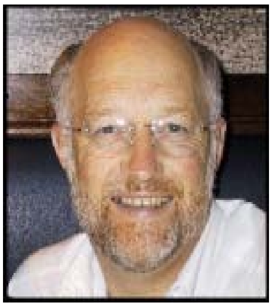
E: Greg.Stephenson@brisbane.qld.gov.au
WMA technology being of immediate interest. RAP into WMA mixes will be vital to Council's continuing use of RAP.

30 years experience working for local government authorities, federal government and consulting engineers mostly in the road and airport construction and maintenance areas. Before joining BCC, I spent 5 years at Queensland University of Technology in a range of pavement and asphalt research related activities. B.Eng.Civil, M.Sc, Ph.D in Civil Engineering



Rob Vos

State Executive – Queensland, Australian Asphalt Pavement Association
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E: robert.vos@aapa.asn.au

Learn from progress in the USA, establish partnerships for future sharing. Seek fast track on WMA introduction for all asphalts, using PP concepts & APT trials in Q, find out RAP inclusion limits

13 yrs at Cape Province Roads, 10 yrs Technical Director Sabita in South Africa. Last 10 yrs in AAPA in Queensland. BSc.Eng.Civil, MICE, C.Eng

Appendix 9.3 - Questions from Australia for the Study Tour

This document was forwarded to our hosts in California, Washington DC, Virginia, Tennessee and Alabama to give an indication of the range of the topics, and the level of detail that the study group would like addressed in the course of the various meetings and discussions. By this process we hoped to maximize the benefit of the valuable time being given by our generous hosts.

KEY VISIT THEMES

A. PP - Perpetual pavement design & performance, materials characterisation

B. WMA - warm mix asphalt implementation, lab & field validation, specifications, RAP inclusion

C. RAP recycled asphalt pavement usage and increased percentages

D. APT - Accelerated pavement testing methods, long term pavement performance and calibration of tests

While the participants will be keen to gain a general overview in all the themes approximately five of the group will be focused on the Perpetual Pavement concept and accelerated performance testing.

A. PP – Perpetual Pavements

ASPHALT MATERIALS PRACTICE

- Mix design methods – SHRP / other
  - Preferred gradation WRT maximum density
  - Binder content optimization
  - Any special requirements – aggregate / filler /
  - Design for moisture resistance
  - Permeability requirements – methods of assessment
  - SMA design methods - special requirements
  - Design special requirements WMA / RAP (covered in detail separately but current position in respect to PP relevant here)

- Binders
  - PG specification
  - Modified binders – types, purpose and application
  - Performance testing – durability, adhesion and visco-elastic behaviour
  - What are the grades of binders typically used in PP construction. Are modified binders commonly used and if so how are they considered in the context of pavement design?
  - NCAT is currently hosting trials of Thiopave. What are the early observations from these trials and how does it compare with other heavy duty pavement structures.

- Asphalt materials performance characterization
  - Adoption of the AMPT (Asphalt Mix Performance Tester)
  - Which modulus for design purposes – resilient / dynamic / with or without confinement – could also use flexural modulus from fatigue beams

  - Calibration against field performance – status (particularly FHWA trailer)
  - Sample preparation – compaction; lab / plant materials
  - Deformation resistance – wheel track / SSTCH / AMPT

- Asphalt fatigue limit / endurance limit
  - Research backing / concept validation
  - Affect of temperature / load spectrum effect of strain level used during testing on performance
  - Laboratory verification protocols
  - Is any form of laboratory fatigue testing undertaken? And, if so, is this used in design?

OTHER MATERIALS PRACTICE

- Subgrade preparation (NB no freeze thaw in Australia)
  - Drainage requirements / moisture content limits
  - Compaction standards

- Capping layers / subbase preparation
  - Material requirements
  - Compaction standards / dry-back
  - Prime
  - Performance requirements under construction traffic

- Rehabilitation of PCC pavements
  - Advances in crack retarding treatments
  - Crack and seat / rubblised
  - California I 710 case study / others

DESIGN PRACTICE

- Layered Elastic Modeling / Finite Element Modeling (NB LEM used in Australia)
- Performance verification / model calibration
- Modeling temperature / load spectrum
- What material characteristics
- Design and performance of high modulus layers in pavements – EME's
- What fatigue relationships used – Is Shell equation used?
- In Australia, pavement designs are typically done at the initial design based on generic material properties and not on "contract specific" materials. Is this approach adopted in USA.
- PP would have biggest application in heavily trafficked urban locations where there are issues with service authorities. How are these handled?

CONSTRUCTION PRACTICE - ASPHALT

- Layer thickness fn NMAS (Nominal Maximum Aggregate Size)
- Treatment to assure bond at interfaces
- Treatments to improve early life skid resistance of SMA's
- Treatment to minimize moisture ingress in base layers
- Compaction standards / conformance limits self diagnostic rollers
- Tests to measure insitu density and permeability of thin asphalt layers
- Pay factors to encourage superior delivery
- Case studies – innovative and superior project delivery

LONG TERM PAVEMENT PERFORMANCE PROJECT

- Current status
- Relationship with FHWA studies (AMPT trailer)
- Summary of findings
- Relevance to PP

US ACCEPTANCE OF PP

- What is the level of acceptance
- What are the factors that swayed supporting agencies
- Life cycling costing – maintenance diaries for PP

TECHNOLOGY TRANSFER – US, EUROPE & AUSTRALIA

- Corresponding membership of appropriate NCHRP / FEHRL committees
- Cooperative research – materials exchange and characterization studies
- Sponsored visits for workshops with agency / industry / consultant personnel
- Personnel exchange – higher degree studies
- What is the overall level of undergraduate training in pavements generally and asphalt specifically? How are any deficiencies being addressed as an industry?

B. Warm Mix Asphalt (WMA)

Processes

- What process/es of WMA have achieved adoption? Why
- Is there any framework to assess new additives?
- Are environmental issues influencing the adoption of WMA?
- Development of carbon calculator for WMA and RAP?

Use

- Any changes to handling, placing and compacting for WMA?
- Compaction temperature - specification limits if applied.
- Storage time changes?
- How is moisture content addressed with the foamed WMA?
- Why does the USA appear to have MC limits for WMA?
- Are the asphalt samples handled and compacted differently for WMA vs HMA
- Are any additional asphalt mix design tests in use? Are some redundant?
- What is the experience of using WMA in: Bitumen crumb rubber asphalt, SMA, OGA
- How does WMA cope with modified binders? Is there any pressure to move away from modified binders?
- Will there be any effects when recycling wax based WMA?
- What is the effect of WMA on the performance of the bag house?
- What steps are taken to overcome reduction in the stiffness of the binder due to lower mixing temperatures?
- Is there any experience with modified binders (i.e. PG70+) in warm mixtures? Are there considered to be any restrictions on the types of binder that can be used in WMA?
- Has the US produced SMA and Open Grade through a WMA process?

WMA and RAP

- Is the asphalt mix design re-deigned for RAP? How – binder content, class of bitumen?
- Limitations on RAP inclusion? Is this plant restrictions or field performance ?

- What is the maximum RAP used in WMA? Is there any limit on RAP quantity and quality depending on the WMA technology or process (eg. Wax and foaming)?

Acceptance by DOT

- Which DOT allow WMA?
- Under what conditions? Warranties? Is the option of HMA/WMA up to the supplier?
- Used with PMB?
- Any specific layers of asphalt pavements?
- How was WMA introduced to the DOT? Did they run projects?
- How is WMA specified in contracts

Project reports

- Are project reports of WMA available?
- Is data available for bitumen testing, asphalt performance tests, field performance data?
- Are there comparison projects? HMA and WMA
- What is the impact of WMA technologies on bitumen chemistry (eg. Modifiers such as SBS)?
- Are there any changes to testing/confirmation requirements (eg. Lowering preparation and testing temperatures)?

Impact on asphalt performance

- Any stiffness/fatigue issues – good or bad ? since less oxidisation may give longer service life
- Cold temperature with cracking
- Hot temperature with ‘softer‘ binder – softer binder may be an advantage in low traffic applications where oxidisation is the terminal condition.
- Is there any difference in performance between WMA produced by different methods – is all WMA treated the same?

C. Recycled Asphalt Pavement (RAP)

- What % of RAP are in use
- For RAP at higher %:
    - are there requirements for stockpile management?
    - different tests for the RAP
    - re-design for the mix
    - binder class of the mix
    - tests to measure effect of comingling of virgin with aged binder?
    - lab protocol for preparation of high RAP mixes
- Any restrictions on the layers for use of RAP
- DOT specifications
- Does the asphalt supplier or DOT do the mix design?
- What other sources of recycled materials such as crushed glass are used in asphalt? And how common is this?
- Recycling mixes with RAP – how many times can it be recycled?
- How is the RAP stockpile managed? What tests? Why?
- How is moisture content addressed with high RAP?
- How are RAP mixes treated in design – if considered at all! Such as stiffness and fatigue relationships – are these different to virgin mixes?
- Are there any restrictions on different binder types in recycled asphalt.

- What proportion of the binder content in RAP is taken into account in the overall percentage of bitumen in the mix?

D. APT – Accelerated Pavement Test Methods

- Current status of HVS at U Cal; summary of findings and implementation
- Current status of ALF at FHWA Turner Fairbank
- Full scale test track NCAT / MnROAD (NB participants will visit NCAT)
- Status other APT equipment (Texas, FAA Atlantic City etc)
- Instrumentation developments
- Construction issues – how representative are test tracks of actual constructed pavements? (Tolerances and Quality Control may be higher than routine pavements.)
- Environmental controls – properties of AC are temperature and load duration dependent. How are these controlled/monitored and interpreted?
- Test tracks can accelerate the actual traffic loading. How are long term material changes – such as bitumen hardening – considered?
- Methods - data collection and analysis
- Equivalencies to convert tri and quad axles to ESA's – any impacts due to rapid repeat loading of multiple axles compared to single axle loads.
- Has there been any attempt to validate/confirm the WMAPT concepts.
- What are the US experiences with accelerated ageing tests for bitumen. Is there a recognised test method to mimic the long terms ageing characteristics of bitumen? How is low temperature performance of bitumen measured?

Miscellaneous

The following are miscellaneous topics that we will attempt to cover during the Study Tour.

General

- How is texture depth on Dense Graded Asphalt (DGA) wearing course specified or managed for high speed traffic roads (eg. 100 kph)?
- What is/are the best product(s) for reinforced asphalt? What is the reason for using reinforced asphalt? Is there any best practice guidelines for constructing reinforced asphalt pavements? Specialised equipment etc?
- Are they considering performance based asphalt specifications or staying with the 'recipe based' philosophies?
- Is there any development in terms of automated real time monitoring of asphalt on site (i.e. temperature and compaction records)? If yes, has this resulted in better site management?
- Are there any developments/facilities which produce on-line conformance information at asphalt production plants?
- How common is foam stabilisation used in the US? What grade of binder is normally used in foam stabilisation and what type of wearing surfaces are placed on top of stabilised pavements?
- What is the US experience of the PG system of specifying binders particularly with PMBs (PG70+ binders).
- The US sources bitumen produced from a variety of crude types. Is there regional evidence of any difference in performance of binders and emulsions or are such effects dwarfed by climatic and traffic influences?

Sprayed sealing

General statistics of sprayed sealed roads in the US. What proportion of the US network is sealed and what sector of the road network generally receives sealing treatments as opposed to asphalt?

- *Emulsion*
    - Inverted or non-ionic emulsions in sprayed sealing?
    - What type of emulsion is generally used for sprayed sealing?
    - What type of polymer is most commonly used in the manufacturing of Polymer Modified Bitumen (PMB) Emulsion?
- On low traffic volume streets, deterioration is caused by oxidisation over time. Is there an optimum level of oxidisation of asphalt that can be considered for a low cost treatment (rejuvenate or thin PMB emulsion spray surfacing)? If so, how is it measured?
- Are cutback binders still used for sprayed seals or are all seals emulsion? What type of emulsions are typically used in sealing operations?
- *Scrap rubber*
    - What is the size and particle size distribution of scrap rubber for use in sprayed sealing and asphalt. What is the production method for obtaining the scrap rubber?
    - Is there a preference for how to incorporate scrap rubber into bitumen?
    - What measures are in place to reduce fuming when blending and spraying CRB?
- *Aggregate*
    - Steel furnace slag or similar materials in sprayed sealing?
    - Is graded aggregate used in sprayed sealing? How is this designed? Specifications?
    - How do they measure shape? (i.e. proportion calliper, ALD, AGD, etc?)
- *Resurfacing*
    - Acceptability of spray seal in urban areas
    - Options for resurfacing spray seals in urban areas where a spray surface is not accepted

Appendix 9.4 - USA Acronyms, State Abbreviations, Conversions & Quotes

USA Acronyms

Acronym	Definition and notes	Introduced / Used by
AASHTO	American Association of State Highway and Transportation Officials	
AMPT	Asphalt modulus performance tester (new name for the SPT)	
APCS	Automated pavement condition survey	
APA	Asphalt pavement analyser (like a wheeltracker?)	
APT	Accelerated pavement testing	
ASR	Alkaline silica reaction, in concrete	
ATIRC	Advanced transport infrastructure research centre, at the University of California	UC Davis
AUPP	Area under pavement profile	Marshal Thompson
BCP	Budget change proposal (like a contract variation)	UC Davis
BMP	Best practice management	UC Davis
BPS	Best performance standard	Granite constructions
CA4PRS	Construction analysis for pavement rehabilitation strategy	Caltrans
Caltrans	Californian department for transportation, see http://www.dot.ca.gov/	
CalME	Caltrans mechanistic empirical pavement design method?	
CAPA	Carolina asphalt pavement association	
CC	Creep compliance	
CIR	Cold in-place recycling	
CR	Crumb Rubber	
CRC	Continuously reinforced concrete	
DAT	Evotherm DAT ® = Evotherm Dispersed Asphalt Technology	
ESAL	Equivalent single axle load	
ETG	Extra task group	FHWA
FEL	Fatigue endurance limit	
Gmm	Theoretical maximum specific density	RICE test
Gsb	Bulk specific gravity	RICE test
Gse	Effective specific gravity of aggregate	RICE test
GPR	Ground penetrating radar	
HMA	Hot mix asphalt	
HVS	Heavy vehicle simulator (the South African model)	
ITS	Indirect tensile test	
JPC	Jointed portland concrete	
ksi	Kips/square inch	
Kip	1,000lb force	
LCA	Environmental life cycle assessment	UC Davis
LCCA	Life cycle cost analysis – see Caltrans website	
LCNWP	Longitudinal cracking not in the wheel path	

Acronym	Definition and notes	Introduced / Used by
LCWP	Longitudinal cracking in the wheel path	
LTPP	Long term pavement performance	
MC	Moisture content	
ME-PDG	Mechanistic- Empirical pavement design guide	
MMPT	Mean monthly pavement temperature – Marshal Thompson suggests at 4/10th of the pavement depth	
NAAQS	National Ambient Air Quality Standards (NAAQS) are standards established by the United States Environmental Protection Agency under authority of the Clean Air Act .	
NAPA	National Asphalt Pavement Association	
NCDOT	North Carolina department for transportation	
NCHRP	National Cooperative Highway Research Program	
NGCS	New generation concrete surface	
NMAS	Nominal maximum aggregate size	
OGFC	Open graded friction course	
Pb	Percent binder	
PCC	Portland concrete cement	
PCC-O	Portland concrete cement – open grade	
PerRoad	'perpetual road' : Mechanistic-Empirical perpetual pavement design and analysis tool	
PPA	Poly phosphoric acid	
P^3	Perpetual pavement preservation	Dave Jones
PG	Performance grade of/for bitumen	
PMA	Polymer modified asphalt	
PMS	Pavement management system	
PSS	Permanent shear strain	
QA	Quality assurance	
QC	Quality control	
RAP	Reclaimed asphalt pavement	
RICE	Rice Density Test is a test to compute the Maximum Specific Gravity (Gmm) of a loose Hot Mix Asphalt (HMA). Originally developed by James Rice, and is standardized as ASTM D-2041 in 1964. The maximum theoretical density (or Rice Density) is the unit weight of the mix if it were compacted so it contained no air voids.	
R-HMA-G	Rubberised HMA gap graded	
R-HMA-O	Rubberised HMA open graded friction	
RSST	Repeat shear strain test	
RTFOT	Rolling thin film oven treatment	
R-WMA-G	Rubberised WMA gap graded	
SMA	Stone mastic asphalt	
SPT	Simple performance tester, now called AMPT	
TI	Traffic Index (No. ESALs *period of time / constant = a number around 5 – 15 to input into Caltrans design)	
TRL	Transport research laboratory, UK	
TSR	Tensile strength ratio. From AASHTO T283 Resistance of compacted asphalt mixtures to moisture-induced damage	
TTI	Texas transportation institute	

Acronym	Definition and notes	Introduced / Used by
TWG	Technical working group	FHWA
UC	University of California	
UCPRC	University of California pavement research centre	
VTRC	Virginia transport research centre	
VVA	Virginia asphalt association	

USA state abbreviations

AK	Alaska	KY	Kentucky	NY	New York
AL	Alabama	LA	Louisiana	OH	Ohio
AR	Arkansas	MA	Massachusetts	OK	Oklahoma
AZ	Arizona	MD	Maryland	OR	Oregon
CA	California	ME	Maine	PA	Pennsylvania
CO	Colorado	MI	Michigan	RI	Rhode Island
CT	Connecticut	MN	Minnesota	SC	South Carolina
DC	District of Columbia	MO	Missouri	SD	South Dakota
DE	Delaware	MS	Mississippi	TN	Tennessee
FL	Florida	MT	Montana	TX	Texas
GA	Georgia	NC	North Carolina	UT	Utah
HI	Hawaii	ND	North Dakota	VA	Virginia
IA	Iowa	NE	Nebraska	VT	Vermont
ID	Idaho	NH	New Hampshire	WA	Washington
IL	Illinois	NJ	New Jersey	WI	Wisconsin
IN	Indiana	NM	New Mexico	WV	West Virginia
KS	Kansas	NV	Nevada	WY	Wyoming

Conversions

Temperature

°F	30	50	55	60	100	200	220	230	240	250	260	270	280	290	300	320	340	360	380	400
°C	-1	10	13	15	38	93	104	110	115	121	127	132	138	143	149	160	171	182	193	204

Mass

1 short Ton (2,000 lb) = 0.907 metric tonnes

Pressure / modulus

1 ksi = 1 kip/square inch = 1,000 pounds force/square inch = 6.89475728 MPa

1 pascal is equal to 1.45037738007E-7 kip/square inch.

Length

1" = 1 inch = 25.4 mm

0.10' = 1/10th foot = 30.5 mm (used as a nominal HMA mix size in California)

1 mile = 1.61 km

Volume

1 US gallon (liquid) = 3.79 L

1 US gallon (dry) = 4.4 L

1 imperial gallon = 4.55 L:

Speed

55 MPH = 90 kph

Sieve sizes

American	Metric
½ inch	12.5 mm
3/8 inch	9.5 mm
No. 4	4.75 mm
No. 8	2.36 mm
No. 30	0.60 mm
No.100	0.15 mm
No. 200	75 μm

Quotes – *compiled by Kym Neaylon*

The USA consists of 50 individual countries united by a common currency

Information does not cross State lines

California has 12 different Kingdoms (regions)

The coldest winter I ever had was a summer in San Francisco

We haven't been sued about that yet (answer when asked why a particular research topic had not yet been funded)

Road deterioration is like boiling a frog. Slowly increase the temperature and the frog doesn't notice.

You've got to educate the public, before you ask them a question

It's another bullet for your gun (where we would say 'it's another string to your bow')

California…..the land of fruit and nuts.

Don't mess with old men. They didn't get old by being stupid

We are not smarter than anybody else; we are just 200 mistakes ahead of anybody else

Our mobility is our freedom

Our customers don't want our equipment – they want to make money

Before we save the planet, let's make sure it meets our specifications. (on RAP and WMA)

We are going to lead aggressively, from the rear

Our house is protected by the good Lord – and a gun

USA……..the land where too much, is barely enough

Appendix 9.5 - References

In the electronic version of this report the references are included and can be accessed below.

Pretour

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02-California_Partnered_Research_Program_Appendix_E_Nov09_Dave_Jones_Joe_Holland.pdf
03-Granite_Construction_details_ex_NAPA_website.pdf
04-High_percentages_of_RAP_Virginia_case_studies_2007_Trenton_Clark.pdf
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California – Sacramento

1-Granite_Construction_AAPA_Study_Tour_2010_PPT.pdf
1-Granite_Construction_AAPA_Study_Tour_2010_PPT_x6.pdf
2-WARM_MIX_PRODUCT_APPROVAL_CRITERIA_FOR_NEW_PRODUCTS_DJ_08-11.pdf

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1-UCB_I-710_presentation1_AAPA_Study_Tour_Group_8-10-2010_PPT.pdf
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3-UCB_CM_AAPA_8-9-10_HMA-EL_PPT_x6.pdf
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Washington

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06-PS_FHWA_RAP_increasing_usex6.pdf
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08-HVQ_Mechanistic_Design_2010-08-10.pdf
08-HVQ_Mechanistic_Design_2010-08-10x6.pdf
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R02_WMA_TNDOT_qualprodlist.pdf
R03-WMA_ALDO_Lii27_Approved_List.pdf
R04-WMA_ALDOT_2008_GASP_09_10_09_page 100.pdf
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R06-WMA_FLDOT_DCE03-09.pdf

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South Carolina

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Alabama

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Post Tour

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AAPA is a representative industry association for the flexible pavement sector. It was formed in 1969 as a non-profit organisation to promote the economic use of asphalt and bitumen bound products based on sound technical and commercial grounds.