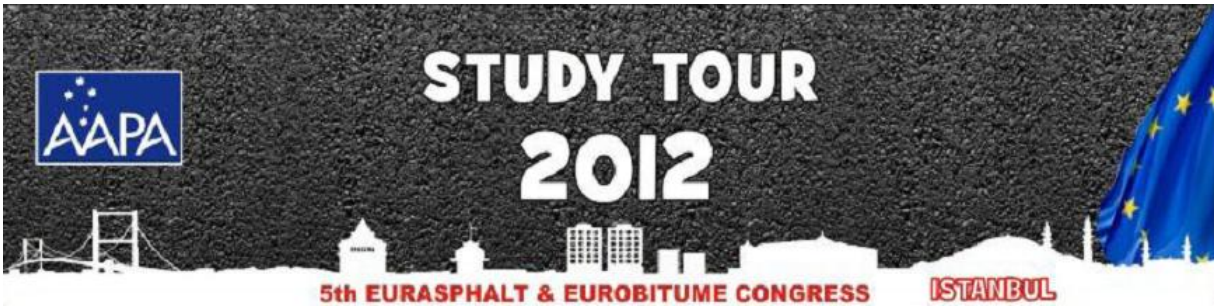

Australian Asphalt Pavement Association

Study Tour 2012

France, Belgium, Netherlands, UK, Germany, Turkey

2nd to 21st June 2012

GROUP REPORT

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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. The most recent tours have been held in 2010 to the USA and to South Africa & CAPSA in 2011, returning to present the findings across Australia.

Five key topics were selected to address:

- Long life pavements
- Sustainability
- Procurement systems
- High performance asphalt & binders
- Health & Safety

To gain detailed feedback on the country, hosts were contacted across Europe to set up meetings in the two weeks before the congress and in the few days after. Organisations and international colleagues acted as hosts in France, Brussels, The Netherlands, United Kingdom and Germany.
As on previous study tours, a comprehensive set of questions were drawn for each topic, based on feedback from colleagues and tour members, and then sent off to the host to gain a head start on providing the answers to the over 150 questions!

This AAPA 2012 Study Tour Group Report answers the questions raised in detail, includes bservations on the topics and makes recommendations for actions to benefit Australia. The recommendations are highlighted as follows:

Long life pavements
Consider the use of the endurance strain in Australian pavement design; don't rely upon performance data other than from the UK's TRL and TUDelft in The Netherlands; get local pavement performance from rehabilitation projects.

High performance asphalt & binders
Investigate the use of EME in Australia as a premium asphalt base with known performance properties; review ways of improving asphalt performance through better packing of the aggregate matrix.

Sustainability
Treat sustainability as an opportunity; use whatever RAP is available; don't put rubbish into asphalt; seek improved durability from flexible pavements.

Health & Safety
Review risk management guides on the use of bitumen; communicate the hazard and exposure methodology; promote the reduction in temperature of bituminous products; promote the use of lane shifting and contra-flow to improve quality; increase safety and reduce costs.

Procurement systems
Promote the formation of an Australia-wide system to support innovation; support the transfer to function or performance related specifications; compare Australian greenhouse gas calculator tools to those in Europe.

5th Eurobitume & Eurasphalt Congress
Sustainability as an opportunity – not threat, use more durable pavements, use cost-effective products that lower CO2 and energy, preserve non-renewable materials through recycling and reuse, don't use asphalt or binders as a "dump".

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.

This report summarises the observations and combined feedback of the personnel who participated in the study tour of Europe in June 2012. Prior to embarking on the tour, five topics of current interest to the Australian paving Industry were identified and for each of these European experience and perspective would be sought. The key topics were:

- Long life pavements
- Sustainability
- Procurement systems
- High performance asphalt & binders
- Health & Safety

Chapter 3 of the report provides a collection of the recommendations offered and actions that could be pursued in Australia following the tour. Chapters 4 to 9 provide greater detail of the feedback and learnings from our European colleagues on each topic.
Chapter 10 contains a list of appendices covering the itinerary of the tour, the participants, the questions posed and a list of useful acronyms and abbreviations.

3. RECOMMENDATIONS

3.1 Long life pavements

Recommendations

1. Australia would benefit from consideration of endurance strain levels in the design of flexible pavements and this should be further investigated (as also recommended after the 2010 AAPA study tour and some initiatives taken).
2. Any local development should not rely on a significant amount of information from Europe and the UK, as it is unlikely that the ELLPAG group will soon produce specific LLP design procedures. However, progress in Europe and the UK should be monitored, with a specific focus on work being done at the TRL and Delft University.
3. The best source of information to calibrate local models would be the performance of existing pavements, especially ones which had been rehabilitated (for which information on past traffic, pavement composition and failure mechanisms should be available).

3.2 High performance asphalt & binders

Recommendations

1. Investigate the use in Australia of EME, being a dense graded with a high structural stiffness, superior permanent deformation resistance through the use of hard bitumens with a penetration value between 10 and 25, and good fatigue resistance through high binder contents.
2. Review the potential in Australia for an asphalt mix based upon high density packing of aggregates, using a binder with low content but modified with SBS, with the aggregate gradings altered to achieve a double gap grading.

3.3 Sustainability

Recommendations

1. Sustainable development offers opportunities and is not a threat.
2. Higher percentages of RAP should be promoted.
3. Waste products added to asphalt should not reduce quality or the ability to recycle.
4. Durability should be sought through higher quality production and paving.

3.4 Health & Safety

Recommendations

1. Review the Australian risk management guides on the use of bitumen
2. Communicate the hazard and exposure methodology in the safe use of bitumen
3. Promote the reduction of temperature in the use of bituminous products
4. Promote the use of lane shifting and contra-flow to improve quality, increase safety and reduce costs.

3.5 Procurement systems

Recommendations

1. Promote, and seek methods of establishing, a national system to support innovation in cost reducing road products and systems and their commercialization.
2. Support and motivate for the transfer to functional specifications and contracts.
3. Evaluate the Australian greenhouse gas calculators in comparison to the European tools to assess their value in comparing industry products and systems.

3.6 5th Eurobitume & Eurasphalt Congress

Recommendations

1. Treat the requirement for more sustainable practices and products as an opportunity and not a threat.
2. Improve sustainability through more durable pavements.
3. Improve sustainability by using cost effective products with lower CO2 and energy footprints.
4. Preserve non-renewable natural materials by maximising their reuse and recycling.
5. Do not use asphalt or binders as a “dump” for undesirable materials.

4. LONG LIFE PAVEMENTS

Overview of reasons

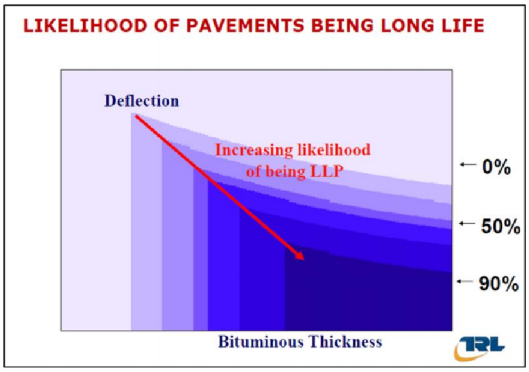
- A revision to the Austroads pavement design guide is required to keep flexible pavements competitive against rigid pavements
- The proposed revision will take into account the 'perpetual pavement concept' underpinned by the asphalt fatigue endurance limit and healing which is widely accepted in the literature (mainly NCAT test track findings)
- A number of issues hinder implementation in Australia, e.g.
    - evidence of successful implementation by Road Authorities
    - proven structural and material design procedures
    - appropriate laboratory testing and criteria (moduli and fatigue properties)
    - specification, construction and quality control requirements.
- European performance data will facilitate the validation and calibration of the limiting cumulative distribution of asphalt strain for long life pavements.

Feedback from

Feedback directly related to long-life pavements was obtained from :

- The French Administration (IFSTTAR & SETRA) and LCPC (in France)
- The University of Delft and the Rijkswaterstaat (in The Netherlands)
- The Highways Agency and Transport Research Board (in the UK)
- Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt) and German Asphalt Pavement Association (DAV) (in Germany).
- Colas (in France), Kraton polymers (in The Netherlands) and BP (in Germany)
- The 5th Euroasphalt and Eurobitumen (E&E) congress proceedings (in Turkey).

Background



From the TRL presentation (Ferne)

Many papers at the E&E congress dealing with thin asphalt (functional) surfacings referred to longlife, sustainable or durable pavements materials. They are not pertinent to the discussion. It is therefore important to clearly define what is meant by long-life pavements (LLP). The formal European definition is given further on in this report. For the purpose of this discussion, the design
of LLP covers:

- The thickness design (a function of the design traffic, design period or threshold strain and material properties)
- Structural properties of bituminous material used (mainly as base, since this layer determines the structural life).

The findings from a 2010 AAPA study tour to the USA and work by the European Long-Life Pavement Group (ELLPAG), as well as recent Austroads reports are relevant to this discussion and the salient issues are summarised below.

Findings from 2011 AAPA Study Tour to the USA

An AAPA tour to the USA in 2010 studied, amongst others, Perpetual Pavement, PP (the marketing term used in the USA to describe long-life pavements, LLP) concepts. The main observations were:

- The concept of PP or LLP has been accepted in the USA, but not widely implemented.
- The Fatigue Endurance Limit (FEL) is an accepted concept and full scale field trails at NCAT have provided evidence that a FEL exists and o that
    - o FEL is not a single value, e.g. the distribution of the strains (percentage below and above) affects the performance
    - o Laboratory FEL may not directly translate to the FEL in the field
- If the pavement structure is sufficiently thick so that the FEL is not exceeded, a long life or so called "Perpetual Pavement" becomes a reality. The field calibration of asphalt fatigue is difficult since a distinction can often not be made between structural (bottom-up) and topdown cracking.
- Typical FEL values obtained from various sources during the visit
    - o 90 to 300 µm with average of 125 µm (Thompson)
    - o 75 to 200 µm for a 95% lower prediction limit and the higher values related to SBS polymer modified materials (NCHRP report 646)
- 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.
- 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 which provide an approach to designing perpetual pavements. However, these programs currently (in 2010) do not form part of accepted design practice in the USA.
- "Rich bottom" or high fatigue asphalt base layers is widely being researched.
- The concept of effective crack healing is not accepted by all researchers.
- There was general agreement that pavement support conditions should be sound and that material and construction quality control should be effective.

The following recommendations were made:

- Australian flexible pavement design practice should investigate the opportunities for inclusion of Fatigue Endurance Limits into local practice.
- Contact should be maintained with US colleagues to facilitate the above through industry, State Road Authority, academia, consultants, ARRB personnel and the Austroads Pavement Structures Reference Group.
- 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.
- A "library" of the performance Australian pavement materials should be developed to provide input into local predictive models.
- 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.

European experience

Discussions about long-life pavements are not new in Europe and the UK. A large number of European countries have been involved in the sharing of information and in related research since the 1990s.

The European Long-Life Pavement Group (ELLPAG) was established in 1999 as a FEHRL (a registered international association formed in 1989 as the Forum of European National Highway Research Laboratories) and Conference of European Directors of Roads (CEDR) Working Group. Core membership of the Group comprises representatives of the research institutes (FEHRL members) and the UK Highways Agency. ELLPAG is chaired and co-ordinated by TRL (UK). The objectives of ELLPAG are:

- In the short term - to carry out state-of-the-art reviews of the current European knowledge on the design and maintenance of long-life fully-flexible, semi-rigid and rigid pavements.
- In the medium term – to undertake a series of workshops/seminars to promote the understanding and use of long-life pavements in Europe.
- In the long term - to produce a user-friendly comprehensive best practice guidance note on long-life pavement design and maintenance for all the common types of pavement construction used in Europe.

A long-life pavement was defined by the Group as "well designed and well constructed pavement where the structural elements last indefinitely, provided that the designed maximum individual load and environmental conditions are not exceeded and that appropriate and timely surface maintenance is carried out".

Also relevant is the definition of deterioration or failure as " whatever the network manager considers important, e.g. significant cracking or (progressive) deformation in the structural layers of a fully-flexible pavement".

Funding was obtained in 2002 for phase 1 (short term as mentioned above) which covered the review of the current knowledge on the design/maintenance of long-life fully flexible pavements. As a result, "A guide to the use of Long-life Fully-Flexible Pavements" (FEHRL Report 2004/1 ELLPAG PHASE 1), was produced in 2004 that covered the definition, new pavements, assessment and upgrading, maintenance, economic analysis and research needs. The components directly relevant to the 2012 AAPA Study Tour Report are the design and maintenance of long life pavements. The situation among the participating countries was summarised in the report as:

- Many countries permit the design of pavements for periods in excess of 20 years, e.g. France, Germany, The Netherlands, Hungary and the UK.
- Fatigue Endurance Limits (FEL) had not been established, but values of 70 µm and 50 µm have been mentioned in the UK and the Netherlands, respectively.

For heavily trafficked pavements, design traffic can be expressed in traffic class, cumulative traffic (with or without a capped level) and traffic flows derived at a certain time in the life of the pavement.

- No special provision is generally made for the treatment of the subgrade for long-life pavements. A number of approaches are used, such as minimum bearing capacity, specific strength, superior modulus, classes of support (in cases depending on traffic level) and minimum capping layer thickness.
- Some countries use special surfacings and fatigue resistant lower layers. The best example is France where high modulus and modified binder layers are regularly used.
- Only one country (the UK) applied a maximum asphalt layer thickness based on a notional threshold strain below which structural deterioration is unlikely to occur.
- In general, improved quality and quality control are required during construction.
- Maintenance entails treatments to restore the functional characteristics rather than improve the structural capacity, e.g. inlays, resurfacing, surface patching, surface dressing and rejuvenation of the surfacing.
- Maintenance of LLP is important and best practice involves:

(e.g. The Netherlands, UK, Austria and Hungary)

  - The measurement of the relevant condition parameter (mainly cracking and surface deterioration)
  - Appropriate warning and intervention levels (to initiate interventions)
  - Pavement management systems and prediction models (to process information and prepare intervention programs)
  - Appropriate maintenance actions
  - Whole of life analysis with financial, environmental and safety considerations

The following recommendations were made in the FEHRL Report 2004/1 ELLPAG PHASE 1 for further research:

  - Develop monitoring methods to accurately determine the degree of surface deterioration in long-life pavements.
  - Conduct research to identify the rate of deterioration and to quantify the risk of sudden, unforeseen developments in deterioration occurring in such a way that the structure of the pavement may be affected.
  - Identify intervention levels for non-structural deterioration.
  - Develop an integrated maintenance strategy of monitoring and treatment so that the whole-of-life costs of long-life pavements after construction are minimised.

Although these recommendations had been made in 2004, none of them have yet been developed further.

Austroads reports

Two recent Austroads reports, and also the 2012 Austroads Guide, contain information relevant to the discussion of LLP:

- Austroads AP T199-12, Development of a Nonlinear Finite Element Pavement Response to Load, 2012. One of the pavement design areas identified for improvement was that related to the ability to predict asphalt fatigue life of thin (<150 mm) asphalt layers, as feedback from "experienced engineers" was that the current method which under-estimates the life of thin asphalt layers. Nonlinear finite element theory (APADS software) was used, instead of the linear elastic model (CIRCLY software), to compare strains at the bottom of the asphalt layer. The results indicated that the multi-layer theory calculated different strains than those using the finite element theory and that the differences depended on the asphalt thickness and subgrade CBR, i.e.
  - For 50 mm asphalt, the APADS calculates higher strains than CIRCLY for cases where the subgrade CBR is more than 2%

- For 100 mm asphalt, the APADS calculates higher strains than CIRCLY for cases where the subgrade CBR is more than 6%
- For 150 mm asphalt, the APADS calculates lower strains than CIRCLY

• Austroads AP-T131/09, Asphalt Fatigue Endurance Limit, 2009. The report contains findings of field studies by Ross, AAPA and Tsoumbanos which confirmed the findings by Nunn on UK roads that the pavements were in "sound structural condition and meeting functional requirements despite many having, at the time, already exceeded the design life predicted " (p.19). Tsoumbanos specifically found that "three of the four sites selected for detailed investigations generally exhibited behaviour expected of long-life pavements based on asphalt thicknesses typically exceeding 210 mm, cracking mostly limited to the top 40 to 60 mm of the asphalt, deflection testing identifying very strong pavement structures, and no structural intervention during service life to date" (p16).

• The latest Austroads, GUIDE TO PAVEMENT TECHNOLOGY PART 2: PAVEMENT STRUCTURAL DESIGN (2012) addresses the endurance limit, i.e. "There is increasing recognition of the notion that asphalt mixes have endurance strain limits for asphalt fatigue, such that below a given applied strain repeated cycles of loading no longer result in fatigue damage. For instance, as a result of the work by Nunn et al. (1998), the UK procedure for design of asphalt pavements was revised to include a minimum asphalt thickness, corresponding to minimum threshold pavement strength, for the most common asphalt mixes beyond which the pavement should have a very long but indeterminate structural life, so-called long-life pavement structures.

Currently, field performance information is insufficient to incorporate a strain endurance limit for use with the Equation 11 fatigue relationship. It is anticipated that future research will enable this concept to be incorporated in the mechanistic design process."

From the references above it is clear that there is a general acceptance (in the USA, Europe, the UK and Australia) of the merits of LLP and that a FEL is relevant, but specific structural design procedures and design criteria have not yet been developed to a point where they are routinely used.

1. Usage and performance records

The objectives of this component of the study tour were to obtain information about:

- Examples and case studies
- Composition, traffic, deflection history
- Typical maintenance

Information gathered

ELLPAG Phase 1 report contains valuable information on the utilisation of long-life fully flexible pavements in Europe and the UK. Figure 1 depicts the designs for maximum traffic volumes in each of a number of European countries (and the USA), with only 3 countries utilising heavy traffic thresholds.

European designs for 1E+08 ESAs are shown in Figure 2. This shows a large variation (to be expected, given the differences in traffic loading patterns, type of asphalt and the environment). As reference a typical full depth asphalt design for 1E+08 ESAs in Queensland (Brisbane region with WMAPT of 33^{o}C) comprises 50 mm surfacing, 50 mm binder layer, 270 mm asphalt base on a working platform (subgrade CBR of 5%). This gives a total thickness of asphalt of 370 mm, which is slightly higher than thicknesses in the UK, France and Germany (but at a higher temperature).

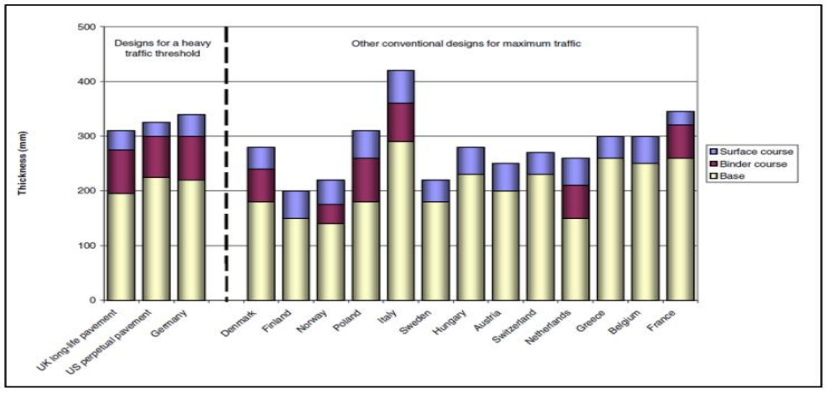


Figure 1: Pavement designs for national maximum design traffic levels (ELLPAG Phase 1 report)

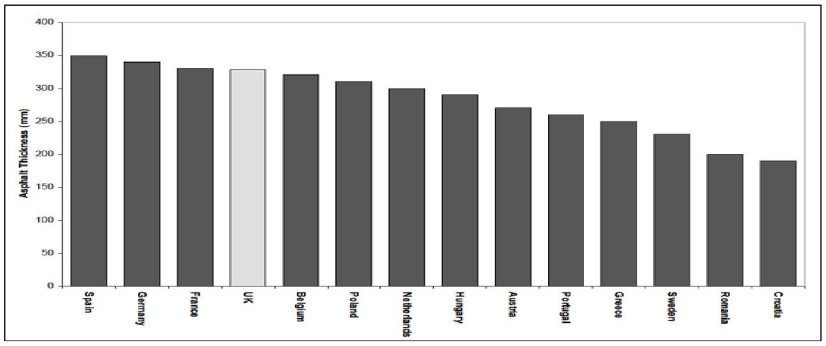


Figure 2: Asphalt design thicknesses for 100msa$_{so}$ design traffic (1E+08 ESAs) (ELLPAG Phase 1 report)

None of the road authorities visited could provide very detailed information about the usage or performance (e.g. examples and case studies, traffic, deflection history and typical maintenance).

The British approach is based on research by Nunn in the 1990s (initially reported in TR 250) which showed that thick (>250 mm), well built flexible pavements did not deteriorate structurally as previously expected. For such pavements, rutting was confined to the upper surface layers and cracking initiated at the surface (with no evidence of "bottom-up" fatigue cracking) as shown in Figure 3.

Figure 3: Photographs depicting the cracking from the UK study

This study resulted in the British LLP design now limiting the thickness to that which would be required for 80 MESA (8E+07 ESA), which would result in a maximum thickness of 320 mm for hard bitumen base (EME2) or 380 mm for soft bitumen base (DBM50/HDM). The bituminous base is typically supported by a foundation layer, Class 2 (E ≥ 100 MPa) or better, and 150 mm bound subbase. The maintenance is normally an asphalt overlay with the thickness determined by the pavement deflections and expected traffic loading.
A deflection of less than 0.25 mm (at 20^{o} C) is considered to indicate a long-life pavement in Britain. The Highways Agency indicated that 80% of the fully flexible motorways and 20% of the All-Purpose Truck Roads (APTR) meet the long-life deflection and thickness criteria.
Deflection measurements, (previously with the Deflectograph and now with the Travel Speed Deflectometer, TSD) on the British road network are done annually (covering about a third of the network per annum), but the deflection histories were not available for the assessment of the identified long-life pavements. In the Netherlands FWD deflections are only done on project level.
The Dutch refer to long-life pavements as "eternal" pavements, i.e. pavements that are strong enough not to fail until functional repair is done. Functional repairs are defined as overlays to replace surfacings and to correct deformation. This is normally done at 10 to 15-year intervals (open grade asphalt which is replaced every 11 years in the slow lane and 15 years in the fast lane). A typical design comprises:

- 50 mm porous asphalt (with no waterproofing layer below)
- HMA base of 230 to 300 mm (4.5% bitumen, 6% voids, E= 8,500 MPa at 20^{o}C)
- 2% cement modified base of 250 to 300 mm (cement concrete waste, E = 400 to 500 MPa)
- Typical subgrade CBR of 10%

Typical German designs for high traffic loading (>32 MESA) comprise a 120 mm binder and surfacing layer on a 220 mm base layer supported by an appropriate foundation.
The French are currently monitoring 58 pavement sections, including 3 sections with thick asphalt which could be considered LLPs. Information reported include age, cross-section, drainage, pavement structure, details of asphalt mix designs, rehabilitation, cumulative traffic since construction (but using a method different from Austroads), Deflectograph deflections and condition.

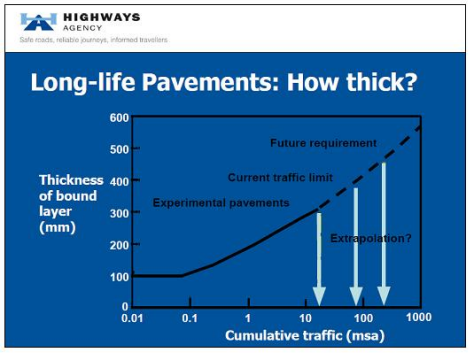
Conclusions

- LLP is accepted in Europe and the UK as a pavement design option and considered important enough to have created the ELLPAG to investigate. A report was published in 2004 with a summary of the situation in the UK and Europe and recommendations for further research, but
  none of these recommendations have yet been implemented
- Most information on the past performance of full depth asphalt pavements comes from UK studies in the 1990s. No documented recent case studies could be made available by the agencies visited.
- Maintenance, involving the replacement of the surfacing layer only, is important for the performance of LLPs and should be based on a sound selection and design methodology.
- Long-life pavements are designed in the UK (maximum design traffic loading of 8E+07 ESA), Germany (maximum design traffic loading of 3.2E+07 ESA) and the Netherlands (standard low maintenance design for their traffic loading) by applying some form of limiting criteria. However, the formal theoretical models with limiting criteria (e.g. fatigue endurance level) are not used.
- High modulus asphalt base layers are used in France to produce long-life pavements. The fatigue relationships have been developed for these materials and are used in a mechanistic design process.

2. Design aspects

The objectives of this component of the study were:

- To evaluate the design procedures
- To determine the most appropriate approach - either mechanistic or catalogue-based
- Prioritisation of focus – either design models or construction



From the Highways Agency presentation

Information gathered

The Highway Agency uses either a series of graphs limiting the thickness to that of a pavement for a loading of 8E+07 ESAs (HD26/6 and TR 250, see Figure 4) or a mechanistic procedure (TR1132, e.g. fatigue criteria of 79 µm and shift factor). The latter (use of shift factor) is only used where there is a departure from the standards, but this does not seem to happen often. The BISAR program is used in the analysis with bituminous layer design stiffnesses (moduli) at a reference condition of 5 Hz and 20^{o}C (e.g. 2,500 MPa for the surface course). Subgrade design properties are defined as moduli (measure with Light FWD). The maintenance actions selected are in line with design, i.e. no structural failures, only replacement and / or rejuvenation of the surfacing.

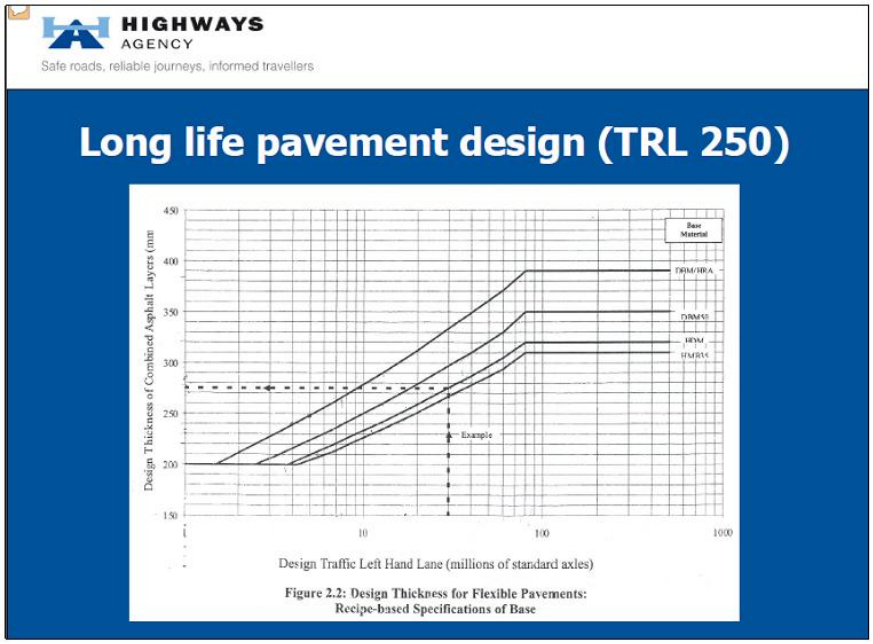


Figure 4: UK Highways Agency design

Dutch pavement thickness design method has been adapted to the harmonised European Standards for asphalt and follows a fundamental approach of fatigue failure for asphalt concrete (tensile strains at the bottom of the layer), shear failure of the road base (stress/strength ratio), fatigue and compressive failure of cemented layers (tensile stresses at the bottom and compressive stresses on top of the base) and permanent deformation of the subgrade. The reliability is 85%. Other material properties are specified to control resistance to permanent deformation and water resistance of the asphalt concrete.

The approach used in the design of long-life pavements entails the following considerations (see Figure 5)

- Pavement is designed to be free from structural deterioration by keeping the stresses and strains below fatigue limits. Specific fatigue limits were not made available, but laboratory values specified for the HMA base layer material (were indicated as appropriate) to be used.
- Materials must be insensitive to deterioration from climate, environment, endogenous processes, etc.
- Overlaying will further reduce stresses and strains. The overlay is also used to correct defective profiles.
- No special material is used as HMA base, but requirements set in terms of rutting, failure and stiffness.

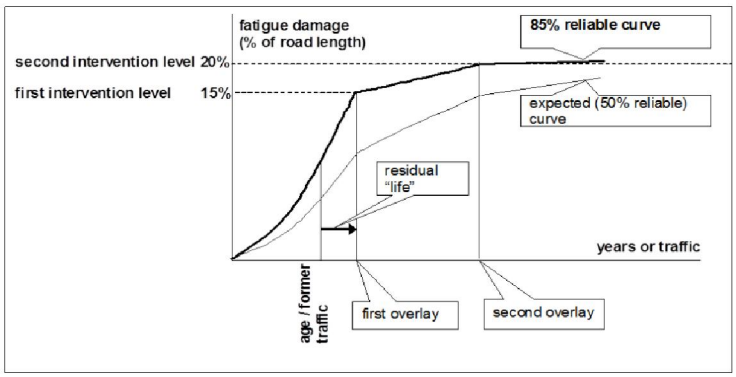


Figure 5: Dutch design approach

The BISAR M-E program is used for non-standard designs. Laboratory determined asphalt fatigue relationships are multiplied with a factor of 10 (4 for healing and 2.5 for other factors) are to be used in the M-E design, but these non-standard designs are not often done.

The German designs are presented as catalogues in the pavement design manual in 7 categories ranging from <3E+05 ESA to > 3E+07 ESAs (see example in Figure 6).

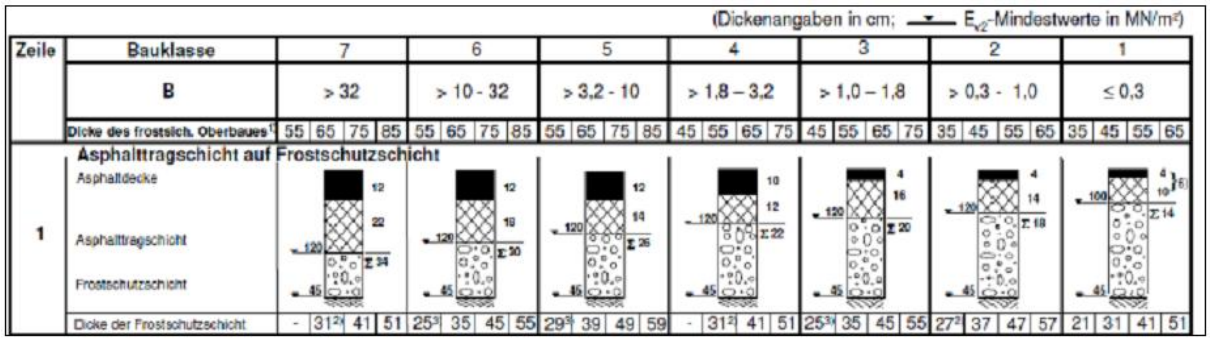


Figure 6: Example for German design

Only one paper (from Denmark) at the E&E congress touched on the long-life pavements by means of a case study. A few papers addressed fatigue testing and a number of papers covered aspects of the long-life of pavement surfacing materials. None of these papers presented specific thickness design methods.
The ELLPAG group identified three options for the development of design procedures for LLP, i.e.

- The extrapolation of current design curves (thicker pavements using conventional materials),
- The recognition that above a certain strength (threshold strength), pavement wear does not accumulate,
- The use of improved materials and/or design to prevent the expected modes of deterioration occurring (e.g. use of an anti-fatigue layer as the lower base layer).

The use of improved materials, preventing expected modes of failures, was identified as the referred option as shown in Figure 7.

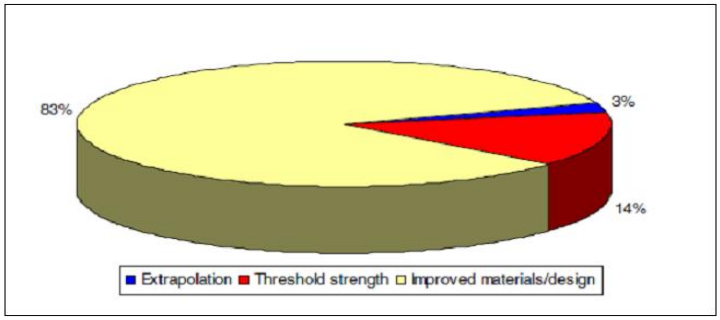


Figure 7: The preferred way approach to developing a long-life design method (ELLPAG Phase 1 report)

Mr Brian Ferne (from TRL, and the coordinator of ELLPAG Phase 1) provided further useful insights into issues related to the design of LLPs, i.e.

- Threshold levels seem to exist, but have not been defined. Threshold levels determined in the laboratory and in accelerated loading facilities do not necessarily apply to the real network, i.e. there is a mismatch between lab and field performance.
- There is uncertainty about the relevance of the traditional parameters, i.e. horizontal strain at the bottom of asphalt and vertical strain at the top of subgrade, to predict pavement life. Horizontal tensile strain below the HMA may not be the governing stress/strain, i.e. failure is not caused by bending.
- Top down cracking develops due to change in viscosity with depth and not loading.
- Validated M-E models do not exist for the design of LLP in Europe and the UK. Development of these models should include an assessment of existing pavement performance.

Conclusions

- There is general acceptance of the concept of a threshold value, but it has not been defined.
- Validated M-E models do not exist for the design of LLP in Europe and the UK. As a consequence, there is no uniform design method. Horizontal tensile strains below the HMA may not be the governing strains, since failure of thick layers may not be caused by bending.

The conversion of laboratory test results to field performance is problematic. The use of existing pavement performance to calibrate the models was suggested as the most effective way of calibrating models or developing laboratory–field conversions.

- The focus in Europe for future development is on improved materials and related design.
- The preference of the road authorities visited seemed to be for catalogue design rather than M-E designs for routine LLP designs.

3. Material Properties

This component of the study had as objectives:
- Types of materials typically used
- Relevant material properties
- Measurement of material properties
- Laboratory curing and testing
- Incorporation of "non-standard" materials, e.g. PMB, EME, RAP Information gathered

A significant amount of work is being done by various road agencies and bitumen suppliers to improve the structural and durability properties of asphalts and bitumens.
More work has, arguably, been done in France than any other European country on the use of high modulus asphalts, i.e. " Enrobés à Module Elévé" (EME) with a proven track record of more than 20 years. The EMEs have excellent deformation resistance and outstanding waterproofing properties. In France it is produced with 0/10 mm, 0/14 mm and 0/20 mm aggregate and target binder content of around 5.7%. It has a high modulus (14,000 MPa at 15^{o}C and 10 Hz) with a high resistance to fatigue (130 µm at 10^{o}C and 25Hz). Tables 1 and 2 contain the French classifications and specifications for the standard (GP) and the high modulus (EME) mixes. Saving in thickness of up to 35% can be expected if an EME is used instead of a GB material.

Table 1: French classification

Type	Max Aggr size	Binder	Binder Content (%)	Void content %	Thickness (cm)
GB	14 et 20	35/50 20/30	4 to 5	6 to 8	8 to 16
EME	10-14-20	10/20	4.5 to 6.2	3 to 6	6 to 15

Table 2: French specifications

Type of mix	Giratory. (Voids %) C80 (D 10mm) C100 (D 14mm) C120 (D 20 mm)	Water sensitivity r/R ratio	Rut depth (60°C-100 mm) * 10,000 cycles (%) ** 30,000 cycles (%)	Stiffness modulus (15°C-10Hz) in MPa	Fatigue – admissible strain (@1 million de cycles)
G.B Class 2	≤ 11	≥ 0.65	≤ 10*	≥ 9,000	≥ 80.10^{-6}
GB Class 3	≤ 10	≥ 0.7	≤ 10*	≥ 9,000	≥ 90.10^{-6}
GB Class 4	≤ 9	≥ 0.7	≤ 10**	≥ 11,000	≥ 100.10^{-6}
EME Class 1	≤ 10	≥ 0.7	≤ 7.5**	≥ 14,000	≥ 100.10^{-6}
EME class 2	≤ 6	≥ 0.75	≤ 7.5**	≥ 14,000	≥ 130.10^{-6}

The French design method for EME mixes are depicted in Figure 8.

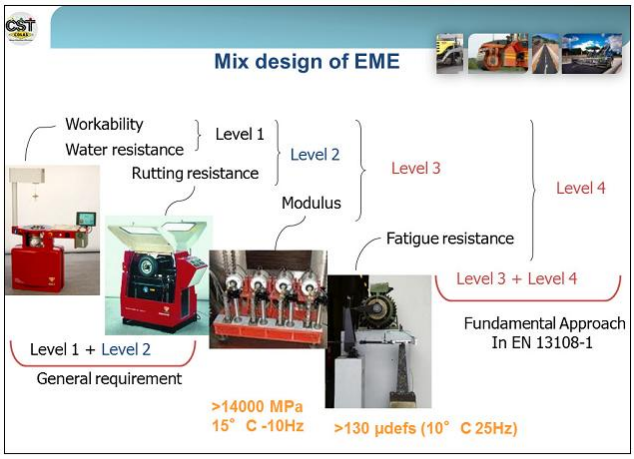


Figure 8: French EME mix design approach

EMEs were introduced in the UK in 2006 and the standard French specification is used. The EMEs are not always more cost-effective than "traditional asphalts" due to high binder contents, but the design charts are considered to be conservative estimates of properties and thus under-estimate the structural benefits of the EMEs. Binder properties are considered to be critical. The UK Highways Agency recommends a 10/20 grade bitumen as binder for use in EME base/binder coarse asphalt mixtures, targeting a penetration of 15-20, and in accordance with EN 13924 (as elaborated in Annex A of the Draft Specification Requirements given in TRL Report 636). During production of the EME2, the binder content must not be less than 0.3% below the design target binder content, nor more than 0.6% above. The target binder contents are 5.6% for EME2 0/10, 5.4% for EME2 0/14 and 5.2% for EME2 0/20. EME2 must be compacted on a subbase with an initial minimum foundation surface stiffness modulus of 120MPa.
Currently PMBs are not accounted for in UK design methodology.

The Dutch do not specify non-standard materials for an HMA base. The properties typically specified in design and construct (D&C) contracts are

- Creep/permanent deformation (triaxial test) – maximum of 1.4 mm (local roads) and 0.2 mm (high traffic volume roads)
- Fatigue at 10^6 cycles(4 point bending test) – maximum strain values of 100 µm (local roads) and 90 µm (high traffic volume roads)
- Stiffness at 20^{o}C and 8 Hz (4 point bending, frequency sweep) – minimum of 4,500 MPa (local roads) and 7,000 MPa (high traffic volume roads) and maximum of 11,000 MPa (local roads) and 14,000 MPa (high traffic volume roads)
- Water resistance – Indirect tensile strength (ITS) ratio

Typical properties for binder (base) and wearing courses in Germany (German Standard 2012) are

- Binder Course (base) AC 22 BS and AC 16 BS
    - Bitumen, 25/55-55 or 30/45 or 10/40-65
    - Wheel tracking not specified but must be documented
    - Voids 3.5 % to 6.5%
    - Binder content, 4.2 % (AC 22 B S) and 4.4% (AC 16 B S)
    - Grading according to TL Asphalt-StB 07
- Wearing course (SMA8S or SMA 11S), 2.5 to 3% voids (Marshall 50 blows), 6.6% (SMA11) and 7.2% (SMA8) binder, fibres added.

Conclusions

- The benefits of higher quality (in terms of higher modulus, better deformation resistance, longer fatigue life and / or durability) material is recognized.
- Large amount of work is done both in Europe and the UK to develop and utilise higher quality HMA materials, e.g. EMEs.
- No uniform European / UK design procedure exists for the non-standard materials, but all use the similar structural properties, e.g. stiffness, fatigue and deformation resistance.
- RAP is widely used in standard mixes, but not in high modulus and / or high fatigue resistant mixes.

Laboratory fatigue properties specified in France and in the Netherlands range between maximum strain values of 90 and 100 µm for conventional asphalt mixes and 130 µm for EME2 mixes (for the specified test method and temperatures).

4. Fatigue and healing

The objectives of this component were to investigate European and UK views and experiences related to:

- Definition of fatigue/failure
- Fatigue testing and the determination of endurance limit
- Correlation between laboratory test results and field performance
- Effect of binder type on fatigue/endurance
- Healing of asphalt mixes – testing, effect of traffic loading frequencies

Information gathered

Fatigue testing was not discussed in any detail during any of the visits to the road authorities and TRL, except as mentioned as one of a number of tests conducted and by Prof Molenaar (Delft University). Four different tests are used by European and UK road agencies to determine the fatigue resistance, i.e.

- 4 point bending – used in Netherlands
- 2 point bending – used in France and Belgium
- Indirect tension – used in the UK
- Direct tension

In addition to the different tests, the sample test temperature and loading pattern also differ from country to country. The standard measurement of flexural bending fatigue is when a stiffness of 50% of the original is reached. These differences and the consequences thereof were highlighted by Prof Molenaar (Delft University) in his presentation in which he conveyed the following:

- Fatigue resistance is a specimen related, not only a material property.
- Reported applied strains are dependent on how the test is performed (full sine vs. half sine).
- Reported number of load repetitions to failure is dependent on the type of test (4 point, 2 point, indirect tension and direct tension), slab dimensions and if the test is load or displacement controlled.
- Strain, under which no fatigue develops, could be around 37 to 44 µm at 10 million cycles and 20°C (depending on slab thickness).
- Reported endurance limits are in fact specimen shape and equipment configuration properties.
- Substantial adjustments are needed to convert laboratory tests to field performance (confirming Ferne's views reported earlier). A factor of 10 (4 to convert from laboratory to field performance and another 2.5 to accommodate for the effects of healing) as shown in Figure 10.

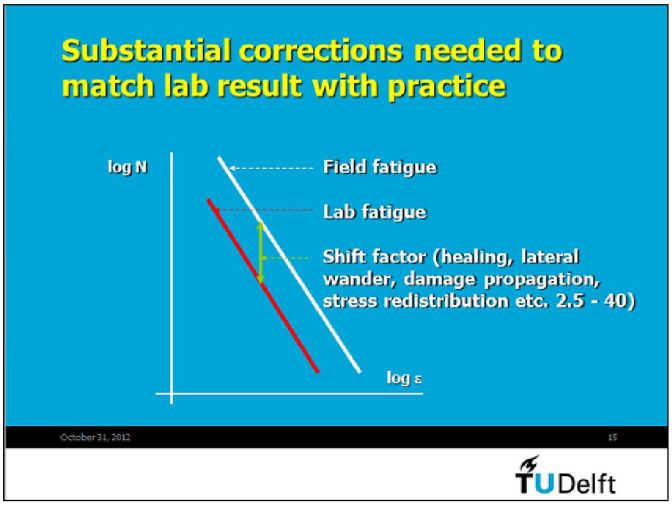


Figure 10: Conversion of laboratory to field performance (Prof Andre Molenaar presentation)

Further information on fatigue testing of asphalt samples was presented at the visit to BP in Germany and in E&E congress papers. These emphasized the complexity of fatigue testing and the difficulty relating that to field performance.

As in the case of fatigue testing, healing was not discussed in depth with any of the road agencies visited. However, Prof Andre Molenaar reported on work done at the Delft University on healing of asphalt samples. The main conclusions in his presentation were:

- Healing entails the recovery in strength (fatigue) and not stiffness.
- Test properties (e.g. temperature, frequency, binder type) influence the quantification of the healing of stiffness and stiffness recovery is most likely due to thixotropy.
- Healing of asphalt mixtures is mainly a flow driven process.
- Long rest periods are beneficial but only at elevated temperatures.
- Temperature is more important than time in the healing process.
- Healing (strength recovery) of asphalt mixtures is limited.
- The healing of asphalts is complex to define and difficult to measure. It depends on a large number of factors, e.g. temperature, healing time and type of binder (Figure 12).

Conclusions

- A number of test devices, loading applications and test temperatures are used to determine failure resulting in differing fatigue values. Failure is generally defined as 50% of the original stiffness. Since different test devices and protocols are used, the results must be used with circumspection. Conversion from laboratory tests to field performance is problematic and no standard value or uniform conversion protocol exist (the Dutch use a value of 4).
- Fatigue tests have not been used to determine FEL values for use in the structural design, but minimum laboratory strain values for HMA bases are specified in France and the Netherlands.
- The healing of asphalts is complex to define and difficult to measure. While healing is accepted as occurring, standard test procedures and conversion factors have not yet been developed (when healing is accepted a value of 2.5 is used in the Netherlands, but it can be as high as 40). Indications are that temperature is more important than time and healing only takes place at high temperature.

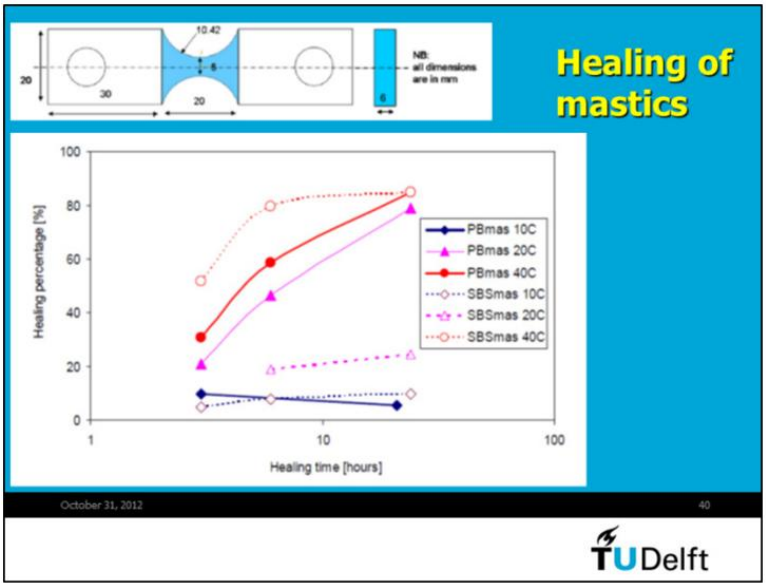


Figure 12: Healing of mastics (Prof Andre Molenaar presentation)

5. Contract and construction

Two specific aspects were addressed:

- Initial construction cost – flexible vs. rigid
- Specification requirements in D&C contracts

Information obtained

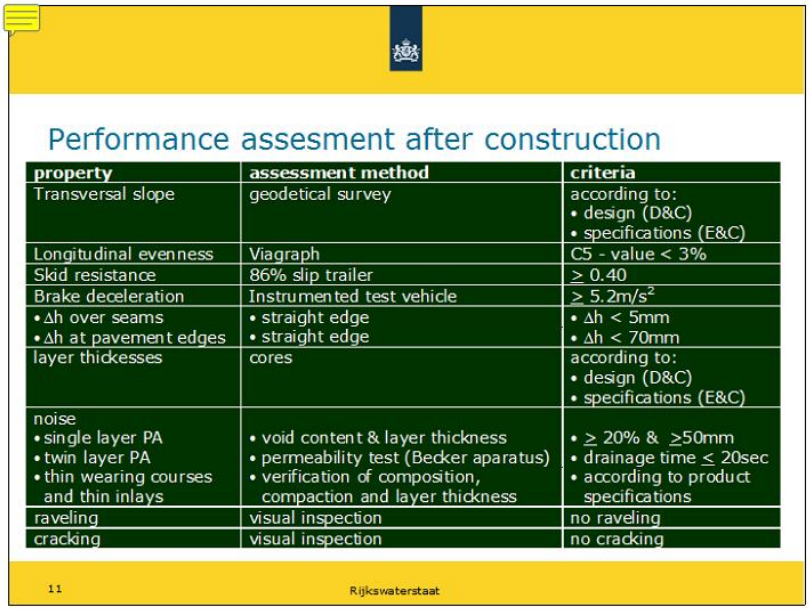
Contracting models were only explicitly discussed during the visit with the Rijkswaterstaat, while the importance of effective quality control in the construction of LLPs was raised in all the discussions. There were

no discussions on initial construction cost comparisons. It is reasonable to assume that pavement option cost comparisons are done for all major projects, but that the outcomes would depend on the country, the traffic, etc. and not be readily be transferable.

Types of functional contracts in the Netherlands:

- Performance contracts for routine maintenance (grass mowing, cleaning of traffic signs, emptying garbage containers at service areas, etc.) (no design component)
- Engineering & Construct contracts for maintenance of wearing courses of pavements (limited design component)
- Design & Construct contracts (D&C) contractor has a design responsibility (new design, widening, strengthening); usually with 7 to 10 years of warranty
- DBFM – contracts; contractor is not only responsible for the design but also for the maintenance of his work for 20 to 30 years

Figures 13 and 14 display properties typically used by the Dutch Road Agency as performance criteria after construction and during the warranty period, respectively. These are applicable to the D&C contracts in the Netherland.



Performance assesment after construction

property	assessment method	criteria
Transversal slope	geodetical survey	according to: • design (D&C) • specifications (E&C)
Longitudinal evenness	Viagraph	C5 - value < 3%
Skid resistance	86% slip trailer	≥ 0.40
Brake deceleration	Instrumented test vehicle	≥ 5.2m/s²
• Δh over seams • Δh at pavement edges	• straight edge • straight edge	• Δh < 5mm • Δh < 70mm
layer thickesses	cores	according to: • design (D&C) • specifications (E&C)
noise • single layer PA • twin layer PA • thin wearing courses and thin inlays	• void content & layer thickness • permeability test (Becker aparatus) • verification of composition, compaction and layer thickness	• ≥ 20% & ≥50mm • drainage time ≤ 20sec • according to product specifications
raveling	visual inspection	no raveling
cracking	visual inspection	no cracking

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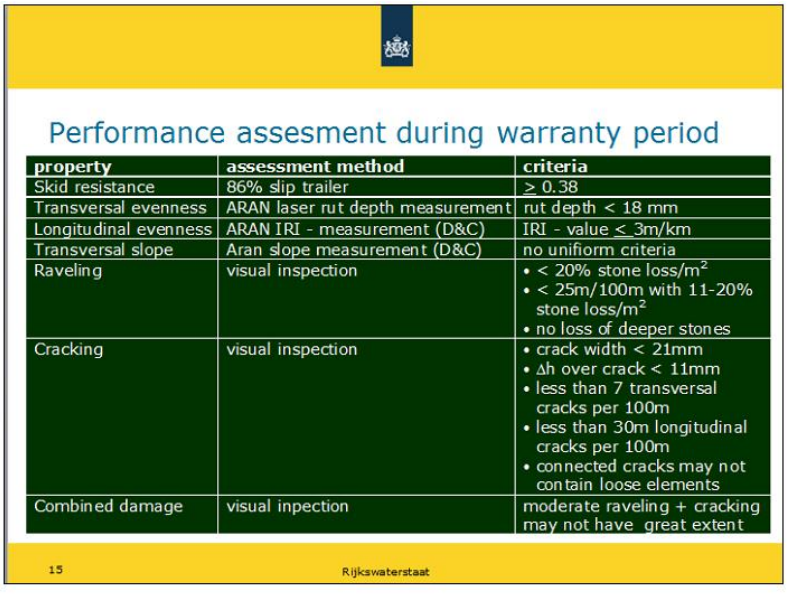
Figure 13: Performance criteria after construction



Performance assesment during warranty period

property	assessment method	criteria
Skid resistance	86% slip trailer	≥ 0.38
Transversal evenness	ARAN laser rut depth measurement	rut depth < 18 mm
Longitudinal evenness	ARAN IRI - measurement (D&C)	IRI - value ≤ 3m/km
Transversal slope	Aran slope measurement (D&C)	no unifiorm criteria
Raveling	visual inspection	• < 20% stone loss/m² • < 25m/100m with 11-20% stone loss/m² • no loss of deeper stones
Cracking	visual inspection	• crack width < 21mm • Δh over crack < 11mm • less than 7 transversal cracks per 100m • less than 30m longitudinal cracks per 100m • connected cracks may not contain loose elements
Combined damage	visual inpection	moderate raveling + cracking may not have great extent

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Figure 14: Performance criteria during the warranty period

Conclusions

- There were limited discussions on contracts and contracting as it pertains to LLPs, but the contracting approach seems to be similar, in general, to that in Australia.
- Information on typical contracts in the Netherlands was obtained. The D&C contracts have a warranty period of 7 to 10 years.

Summary and recommendations

Summary

- The concept of Long-Life Pavements (LLPs) is widely accepted in Europe and the UK, but only explicitly applied in the UK and Germany. The pavement designs for high volume roads in the Netherlands are based on no structural defects during the design life (referred to as eternal pavements). High modulus layers are used in France to increase the life of the pavements. Most information on the past performance of full depth asphalt pavements comes from UK studies in the 1990s. No documented recent case studies could be made available by the agencies visited.
- A group, ELLPAG, was established to investigate LLP in Europe and the UK. It produced a report in 2004 with a summary of the situation in the UK and Europe and recommendations for further research. A long-life pavement was defined by the Group as "well designed and well constructed pavement where the structural elements last indefinitely provided that the designed maximum individual load and environmental conditions are not exceeded and that appropriate and timely surface maintenance is carried out". The definition highlights the important elements of construction and maintenance in addition to the structural design. The use of improved materials and/or designs to prevent the expected modes of deterioration occurring was identified by more than 80% of the group members as preferred design options. Unfortunately none of the recommendations have yet been developed any further.
- Long-life pavements are designed in the UK (maximum design traffic loading of 8E+07 ESA) and Germany (maximum design traffic loading of 3.2E+07 ESA). The LLP designs are based, to a large extent, on past experience and not on specific structural analyses, laboratory testing and material properties.
- The existence of a fatigue endurance limit (FEL), or threshold value, is recognized, but no specific values have been developed. However, validated M-E models do not exist for the design of LLP in Europe and the UK. As a consequence there is no uniform design method.
- Maintenance, involving the replacement of the surfacing layer only, is important for the performance of LLPs and should be based on sound selection, asset management and design methodologies.
- A number of test devices, loading applications and test temperatures are used to determine failure resulting in differing fatigue values. Failure is generally defined as 50% of the original stiffness. Conversion from laboratory tests to field performance is problematic and no standard value or uniform conversion protocol exists. The use of existing pavement performance to calibrate the models was suggested as the most effective way of calibrating models or developing laboratory–field conversions. There is also recognition that horizontal tensile strains below the HMA may not be the governing strains since failure of thick layers may not be caused by bending.
- While healing is accepted as occurring, the definition and testing are complex and standard test procedures and conversion factors have not yet been developed (a value of 2.5 is used in the Netherlands, but it can be as high as 40). Indications are that temperature is more important than time, and healing only takes place at high temperature.
- The benefits of higher quality (in terms of higher modulus, better deformation resistance, longer fatigue life and / or durability) material is recognized. Large amounts of work are done both in Europe and the UK to develop and utilise higher quality HMA materials, e.g. EMEs. But no uniform European / UK design procedure exists for the non-standard materials, but all use similar structural properties, e.g. stiffness, fatigue and deformation resistance. Also, RAP is widely used in standard mixes, but not in high modulus and / or high fatigue resistant mixes. Laboratory fatigue properties specified in France and in the Netherlands range between strain minimum values of 90 and 100 µm for conventional asphalt mixes and 130 µm for EME2 mixes (for the specified test method and temperatures).
- The latest Austroads, GUIDE TO PAVEMENT TECHNOLOGY PART 2: PAVEMENT STRUCTURAL DESIGN (2012) addresses the endurance limit, i.e. "There is increasing recognition of the notion that asphalt mixes have endurance strain limits for asphalt fatigue, such that below a given applied strain repeated cycles of loading no longer result in fatigue damage….. Currently, field performance information is insufficient to incorporate a

strain endurance limit for use with the Equation 11 fatigue relationship. It is anticipated that future research will enable this concept to be incorporated in the mechanistic design process."

- The findings were commensurate with those of the 2010 AAPA study tour to the USA, except perhaps that the concept of the FEL not being a single value did not come out as strongly.

Recommendations

1. Australia would benefit from consideration of endurance strain levels in the design of flexible pavements and this should be further investigated (as also recommended after the 2010 AAPA study tour and some initiatives taken).
2. Any local development should not rely on a significant amount of information from Europe and the UK as it is unlikely that the ELLPAG group will soon produce specific LLP design procedures. However, progress in the Europe and the UK should be monitored, with a specific focus on work being done at the TRL and Delft University.
3. The best source of information to calibrate local models would be the performance of existing pavements, especially ones which had been rehabilitated (for which information on past traffic, pavement composition and failure mechanisms should be available).

Long life pavements - Questions & Responses

Usage and performance records

1. Do you have examples of old LLP on heavily trafficked roads which have been periodically deflection tested over an extended period of time?

No examples provided and there seems to be very little recent information available.

2. If so, is it possible for AAPA/Austroads to obtain information about their pavement structure, past traffic loading and performance of these pavements and who would be best person to contact to obtain this data?

N/A.

3. Are there case studies available on the benefits of using long life pavements?

No specific case studies, but the FEHRL Report 2004/1 ELLPAG PHASE 1 contains useful information on the situation and views in Europe and the UK.

4. In what context are long life pavements used? What requirements are there for the pavement and foundation/subgrade as a whole?

In countries were LLPs are used, they are used for high trafficked roads (> 8E+07 ESAs in the UK and >3.2E+07 ESAs in Germany). Pavement design procedures (mainly graphs and catalogues) and foundation/subgrade requirements are used.

5. What is a typical maintenance schedule for a long life pavement?

Normal maintenance of the asphalt surfacing, e.g. reseal every 10 to 12 years. In addition efficient pavement maintenance management procedures are recommended.

Design aspects

1. Can you provide an example design of a long life asphalt pavement?

Yes, see write-up.

2. What is the design procedure adopted for long life asphalt pavements in your country?

Graph (in the UK), catalogue (in Germany) and standard design (in the Netherlands).

3. For how long has the current pavement design procedure been in place?

Not specifically answered, but probably more than 5 to 10 years (in the UK).

4. What are the inputs to the mechanistic design procedure (e.g. moduli as a function of temperature and frequency, asphalt fatigue characteristics)?

The mechanistic design procedure is only used in special cases (in the UK and the Netherlands). Then only stiffness (at a reference temperature) and "standard" fatigue relationship (i.e. same relationships that had been used for a large number of years) are used.

5. In multi layer construction, how is the binder course and wearing course incorporated into the design process?

In the UK as part of the bound layer for thickness design purposes. In the Netherlands and Germany as layers with specified thicknesses on a bound base, i.e. thickness of base only determined (but considered to be structural layers).

6. Is a catalogue of designs a more realistic solution (i.e. it recognises the enormous uncertainty in modeling; avoids the silliness of solutions which are designed primarily to give a commercial edge at bid time; it ensures parity in bids; it has an empirical basis)?
Yes, that was the impression we got.
7. Certainly design models need to be refined for the long life pavement – the empirical evidence indicates designs are far too conservative and this is due to fatigue endurance and healing factors. Considering the complexity of the pavement structure and its environment, is it realistic to expect to hone the thickness design other than by climatic zone?
This was not explicitly discussed, but no specific adjustments in the UK, the Netherlands (climate reasonably uniform) and Germany (but subgrade frost considered) design procedures.
8. In research, where is the "best bang for the buck" given the extremely limited resources in Australia;
a) refining and honing thickness design models or;
b) refine construction detailing, specification and auditing to ensure high construction quality or;
c) other?
Not specifically discussed, but ELLPAG report 1 indicates a preference for the use of improved materials and/or design to prevent the expected modes of deterioration occurring. High quality construction considered by all to be important.

Material properties
1. What materials are used in long life pavements in Europe?
In Australia, some areas have effective long life pavements with slag road base layers, with 100-150mm AC on top.
Our study focused on fully flexible, i.e. asphalt surfacing, binder and base layers. A variety of materials are used below that - crushed stone, hydraulic (the UK), recycled building rubble (the Netherlands), cemented capping layers (France).
2. How are different asphalt mixtures accounted for in pavement designs (e.g. high modulus / EME / modified asphalt / RAP / WMA etc.)?
It varies, but all available materials are not covered in the design. The UK design procedure prescribes different thicknesses for different types of materials (RAP and WMA not yet included), while the Dutch uses a standard mix (and therefore thickness).
3. What testing is carried out on sub-bases prior to paving of asphalt layers?
No detailed information provided, but density (the Netherlands) and light falling weight deflectometer tests (the UK) mentioned [subgrade only?].
4. How have the material properties used in the design procedure been validated?
No formal validation procedure mentioned. Mix laboratory properties defined on projects. Not clear how they relate to the structural design properties.
5. Are the apparent laboratory performance gains in PMB materials implemented in thickness design?
Demonstrated in laboratory (research) tests, but not included in the standard UK and Dutch designs.
6. How is the modulus of asphalt mixtures measured?
Frequency sweep.
7. Has work been done in Europe correlating dynamic modulus with indirect tensile modulus, and the relationship to insitu modulus?
Not addressed in the discussions. Some work could have been done at Delft University.
8. The lack of good data and modeling somewhat precludes the opportunity to introduce exotic binders. For instance, do we know enough about the lab/field fatigue relationship, fatigue endurance and healing and long-term performance of PMB mixes, to determine if we can offset the added cost of the PMB by thickness reduction and still offer overall savings?
A large amount of information is available (e.g. at Delft University and BP in Germany), but none of the road agencies (except perhaps in France) incorporated it into their design procedures. Mainly due to the complexities of testing and conversion from laboratory test results to field performance.
9. Is there any on-going monitoring of material properties?
Nothing formal presented.
10. How is curing taken into account in terms of design moduli?
The Dutch increases the fatigues relationship by a factor of 2.5.
11. Can RAP and other construction waste or crushed concrete be included in the design and construction of long life asphalt pavements?
None of the road authorities visited had done that (except perhaps in laboratory studies).

Fatigue & healing

1. How can fatigue testing be used to determine the endurance limit for asphalt mixes? What are the influences of test method and specimen size? Should the standard test method be modified?

Fatigue testing had not been used to develop endurance limits for structural design, but fatigue limits are defined for base materials on high trafficked roads. The test method and specimen size have a significant influence on the results. Different test equipment and protocols are used in Europe and the UK, which makes a comparison of results impossible [difficult/cumbersome?].

2. Fatigue testing – what is the definition of failure and how is it related to field performance?

Failure is defined as a sample reaching 50% of its original stiffness. The only formal conversion from laboratory to field performance presented was in the Netherlands, i.e. a factor of 10.

3. Do the specific binders used have an impact on reducing the fatigue strain and hence increase the life of the long life pavement?

Yes, demonstrated in many laboratory studies.

4. Healing of asphalt mixes, what is the influence on very long life flexible pavements and how would you incorporate it into a design procedure?

The effect of healing was recognized, but the influence neither quantified nor incorporated in designs.

5. Has the endurance limit and healing of PMB mixes been evaluated?

In laboratory studies, e.g. at Delft university.

6. Will the axle loading, triaxle vs. single axle and frequency of loading affect the healing of asphalt?

Prof Molenaar found that temperature is the main contributor, i.e. more than loading frequency. That means the effects of the axle loading configuration may be small.

7. Australia usually employs a 'fatigue layer' at the underside of the bound materials. Is there any equivalent in Europe?

High modulus layers used in France, the UK and Germany which could achieve the same results, but the term "fatigue layer" not mentioned.

Contract and construction

1. At the tender stage of a project, how are flexible pavements compared with rigid pavements?

Not discussed, but presumably on whole-of-life costs and environmental effects.

2. In Design and Construct contracts, is there experience in Europe of specifying perpetual pavement characteristics? What are the specified requirements?

This was only raised in the discussions with Rijkswaterstaat officials.

3. For roads designed and constructed according to this design procedure, are all roads still structurally sound? Has there been any monitoring of the network in the succeeding years post construction?

Not formally to document performance.

Reference Material

List of the presentations or other materials gathered during the tour.

1. FEHRL REPORT 2004/01 ELLPAG PHASE 1: A Guide to the Use of Long-Life Fully-Flexible Pavements
2. HA design method 26/6 Design Manual for Roads and Bridges, 2006
3. TRL 1132, The Structural Design of Bitumen Roads, 1984.
4. Richtlinie für die tandardisierung des berbaues von erkehrsflächen, 2011 (in German)
5. Pavement design manual (in French) - CATALOGUE DES STRUCTURES TYPES DE CHAUSSÉES NEUVES, 1998
6. LPC Bituminous Mixtures Design Guide, Sept 2007.
7. Austroads AP T199-12, Development of a Nonlinear finite Element Pavement Response to Load, 2012.
8. Austroads AP-T131/09, Asphalt Fatigue Endurance Limit, 2009

5. HIGH PERFORMANCE ASHALT & BINDERS

The Long live pavements report in Section 4 covers the back ground to pavement design across the countries visited in Europe. With its long performance history and well defined range of pavement materials, the selection methodology relieves heavily on experience. This means a typical pavement is less likely to be designed to M-E theory and more likely to have prescribed traffic loading inputs and selection from know pavement and material options.

An example is give of the practice in France and their pavement design considerations for high performance asphalt. A catalogue design system is available in the selection of high modulus asphalt (EME2) in France. It is used:

- For new construction where two base layers under the surfacing layer use EME2, (French pavement catalogue, 1998)
- As a rehabilitation treatment for heavy duty lanes where the existing layer is replaced at the same thickness but with a stiffer improved asphalt mix resulting in improved pavement performance.

Generally catalogues play a major role in pavement selection and charts for EME2 are as illustrated in Figure 2.

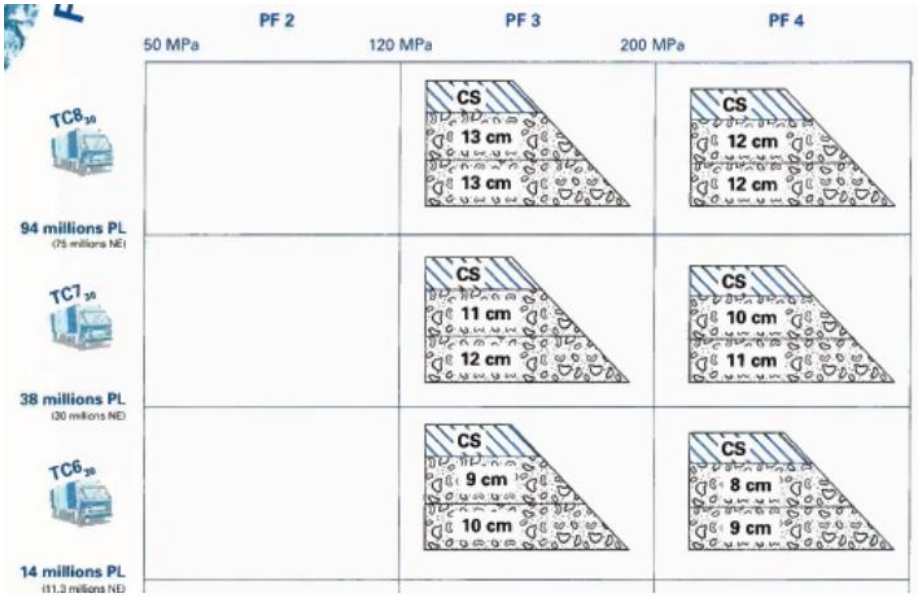

Figure 2: Catalogue Pavement Design using EME2/EME2

The French apply a level of service to their mix designs, with emphasis placed on capability against severe winters. This is also reflected in their catalogues, with standard designs for 20 and 30 years. The French also apply cement capping layers between supporting base course and high modulus pavement which provides a strong platform for the functioning of these stiff layers.

2. High performance asphalt (EME) technique

High modulus asphalt, is also known as EME (Enrobés à Module Elevé), was first developed in France in the early 1980s to reduce pavement thickness. In the 1990s, the HiMA technique evolved to strengthen binder and wearing courses (BP 2012).

The aim of EME is to provide a dense graded asphalt mix using standard good quality crushed aggregates with a high structural stiffness. The mix combines superior permanent deformation resistance through the use of hard bitumens with a penetration value between 10 and 25, and good fatigue resistance through high binder contents.

Note that the binder properties have been given in pen units (dmm). Specific data on the viscosity at 60 degrees for these binders is very limited as this property is not measured in Europe.

The design process commences with the selection of aggregate, sand and filler materials targeting a dense mix grading curve with binder content based on a minimum richness factor, similar to binder film thickness used in Australia. The performance testing commences with samples compacted in the gyratory compactor where a minimum air voids content is to be achieved and provides a measure of workability of the mix. These samples

are then subject to the durability test, followed by the remaining tests of rut resistance, modulus and fatigue. These steps are provided in Section 5.5.

EME comes in two classes, being EME1 and EME2, with EME2 being for heavy traffic. EME2 requires a Richness modulus of 3.4 and binder content of around 5.1% (2.65 t/m3 density) for D = 10 and 14. The binder details are provided in Table 1 (Denneman et al).

Table 1: Summary of EN Binder specifications

Property	Test method	Unit	Penetration grade		
			10/20	15/25	20/30
Before RTFOT					
Penetration at 25 °C	EN 1426	0.1 mm	10-20	15-25	20-30
Softening point	EN 1427	°C	58-78	55-71	55-63
Viscosity at 60°C	EN12596	Pa.s	>700	>550	>440
After RTFOT					
Increase in softening point	EN 1427	°C	< 10	< 8	< 8
Retained penetration	EN 1426	%	-	> 55	> 55
Mass change		%		< 0.5	< 0.5

Note the Viscosity values are minimum values and not indicative of supplied bitumen. For hard paving grade bitumens refer to EN 13924. In conclusion, the EME mix has definite benefits for Australia and builds on the extensive experience of use on French roads but requires availability of special hard binders. Questions remain on its implementation into Australia, the relationship between French performance tests to those used in Australia and the recyclability of this mix.

3. High performance asphalt : Innovation and packing theory

France, the UK and the Netherlands have systems encouraging innovation in road building materials (Charte d'Innovation, Avis Technique, HAPAS, Innovation Test Centre). In France this has stimulated the development of new materials, products and systems.
An example of such a proprietary system is GB5, registered to a French road construction group. The principle behind the product is maximising the use of lower cost aggregate through improving the aggregate packing. Use is made of fundamental packing theory and gyratory compaction to determine the best proportions of the aggregate sizes for lowest binder content. Achieving the required engineering properties is achieved through the modification of the bitumen binder. The product GB5 is in a trial stage and its proprietors believe it can be an alternate to EME2. Over the last two years 250,000 tonnes have been placed on the road networks being administered through the proprietor (Francois Olard).

Fundamentals of aggregate packing theory

To be economical the design is based on a standard binder at a low content of around 4% and modified with SBS, with the aggregate gradings altered to achieve a double gap grading. This later aspect results in asphalt bases that are easily compactable, as they contain low air voids but high granular interlock and hence high modulus with the binder modification providing the fatigue resistance.

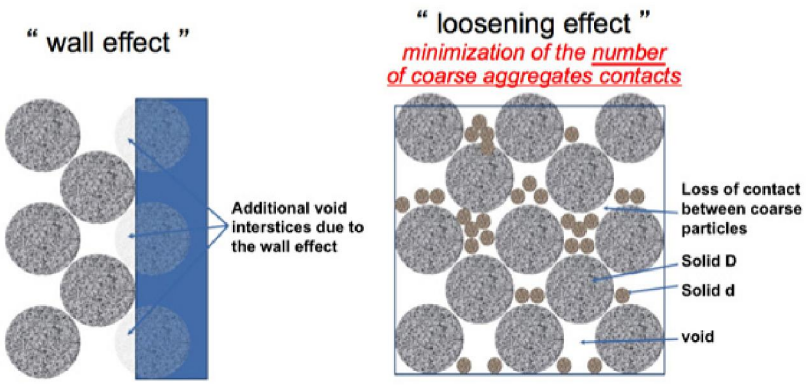

Figure 3: Packing Schematic showing wall effect

The packing of aggregates requires solid ‘d’ particles to fit inside the solid ‘D’ particles, where ‘d’ is required to be 0.22 times ‘D’ (0.22 from Bailey method) for adequate packing. Note the effect that the wall has on increasing voids. This occurs in practice on both top and bottom of a layer. Packing of fine and course aggregates at a range of proportions in a gyratory compactor (at 20 cycles) results in the experimental curve on Figure 4. The purple area is indicated as a deviation from the experimental curve due to the wall effect, while the yellow area is where the packing results in interference and an increase in air voids.

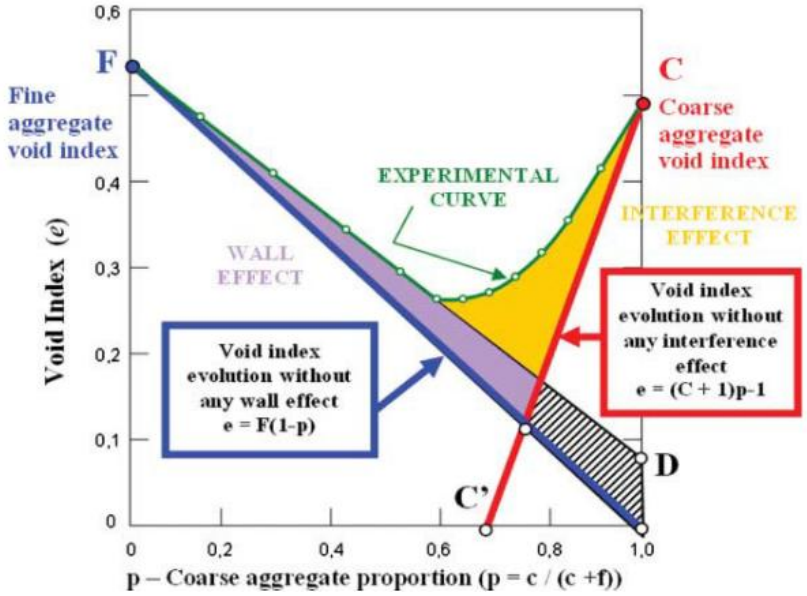

Figure 4: Aggregate Packing Curve including wall effect

The packing curve above is simplified to that of Figure 5, with equations shown in legend as being equations 2, 4 and 3 respectively.

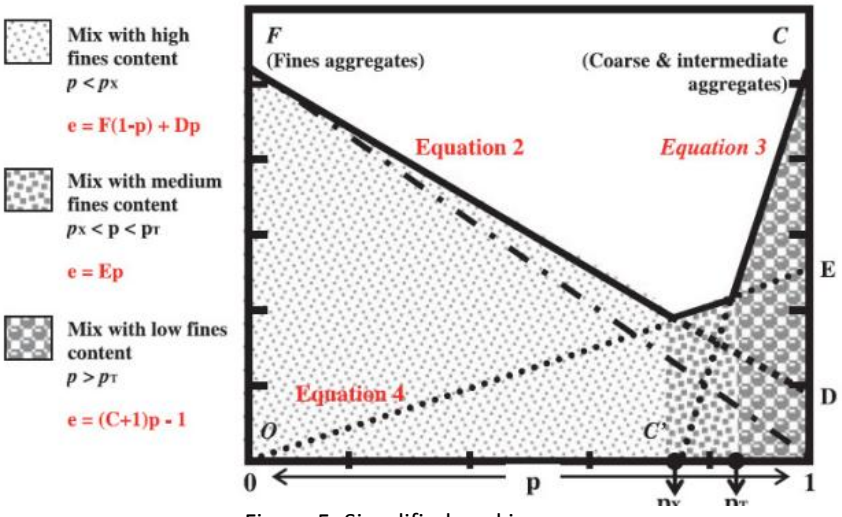

Figure 5: Simplified packing curve

The point on the horizontal axis marked by pT is a critical point where additional sensitivity testing is carried out. Its use can be seen in the example below, where 10/14 aggregate is combined with 0/4 aggregates, which in turn the 80% (20% fine) is added with the 0/2 aggregate and optimum combination (64%/16% & 20%) with filler to optimise at 13.5% filler. The size of materials used fit inside each other as seen by the steeply sloping curve of the gyratory compaction.

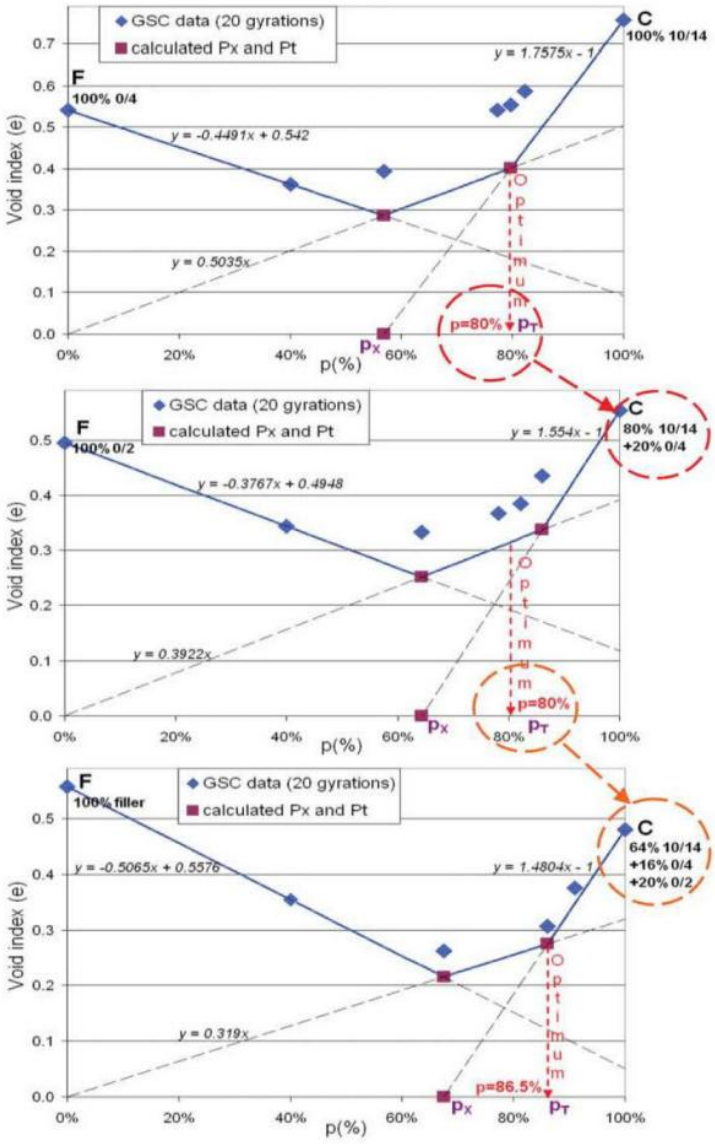

Figure 6: Aggregate Packing Optimization Curves Example

The resulting combination for the above packing optimization is shown in Figure 7 where the double gap grading is evident. Note that this mix is on the dense grade side of the SMA grading envelope.

The performance testing is carried out as per Section 5.5, and this mix has shown the following benefits:

- Flexural Stiffness master curve shows improved stiffness at low rates of loading, an important benefit for Australian loading conditions,
- Fatigue is enhanced through use of SBS polymer
- Rutting is also enhanced through use of SBS polymer

In conclusion, the principle of high density packing of aggregate in the mix has definite benefits for Australia. This could enable current materials and binders to be used as well as enhancing the engineering properties of this mix compared to the current dense graded mixes. Should the Australian aggregate suppliers be able to reliably deliver product to this level of reliability it might even provide a challenge to proven products such as EME2 mix.

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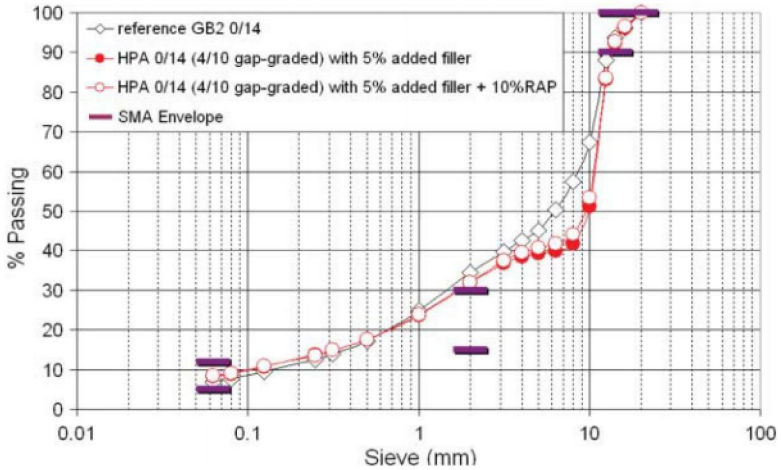

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4. High performance asphalt (GAB II) French Technique

Although this mix type may not be suitable for Australian conditions, it does provide an insight into another type of high performance asphalt mix. This mix is designed to Denmark conditions where aggregates are a premium. For the GAB II mix, 16/32 alluvial aggregates are added to approximately 65% sand so that the aggregate acts as a filler.
Tables 2 & 3 provide data on bitumen and performance test results to testing as shown in Section 5.5, including addition of RAP, with further details available in X Carbonneau et al.
Table three shows that for hard binders, the addition of RAP provides a 'softer' binder to the mix, improves fatigue resistance, lowers the modulus and increases the air voids. It is interesting to observe that the addition of RAP is lowering the viscosity of the mix while the opposite is traditional, and is another consequence of using hard binders.

Table 2: GAB II Bitumen Options

	Bitumen 40/60	Bitumen 20/30
Penetrability (EN 1426)	52	22
Ring and Ball temp (°C) (EN1427)	49,8	61,6
PI Shell	-1,2	-0,4
Complex modulus 15°C 10Hz (fresh binder) Strain 0,05%	28,5	48,5

Table 3: GAB II Performance Test Results

	GAB II	High modulus GAB II	High modulus GAB II 15 % RAP
Air void content	8.5	3.9	6.5
Modulus at 15°C 0.02s (MPa)	6,260	12,100	11,130
Fatigue resistance at 10°C 25Hz	88	109	116
Air void content	10	6.3	6.5

Note that the above mentioned paper also provides commentary on fatigue testing carried out using two methods, one of trapezoidal specimens (French standard) and flexural beams for IPC four point bending.
In conclusion, the GAB II mix is probably of no benefit to Australia and its climatic conditions, but is another example where hard binders are used to advantage, and in this case, for the local conditions in Denmark.

5. High performance asphalt: Performance Linked Mix Design

The French method of asphalt mix design is shown in Figure 8. It indicates the progression through four levels, with the first checking for aggregate and grading suitability through compaction and workability, as well as water sensitivity check. This is followed by the performance tests of rutting, stiffness and fatigue.

This design approach is used to develop the required performance properties of the mix when high performance asphalt, such as EME, is required.
Workability in Level 1 (Figure 8) is the most important key step in the design of EME.

Good quality control of sample preparation in the laboratory, such as composition, voids and homogeneity of mix, requires accurate and relevant tests corresponding to in situ materials.
Equipment used in laboratory testing includes:

1. Mixer BBMAX 80 (EN 12697-35)
2. Plate compactor (EB 12697-33)
3. Vertical gamma Bench (EN 12697-7)

The main properties specified for base course mixes (EN 13108-1) are summarised in tables 4 & 5. In general, pure bitumen with low penetration value of 10/20 at 25 °C is used to manufacture HiMA/EME. Such hard grade bitumen can be manufactured by using special refinery processes. These processes have a strong impact on the chemical composition and colloidal structure of bitumen manufactured − the rheological and ageing properties of the bitumen can thus be varied enormously (BP 2012).

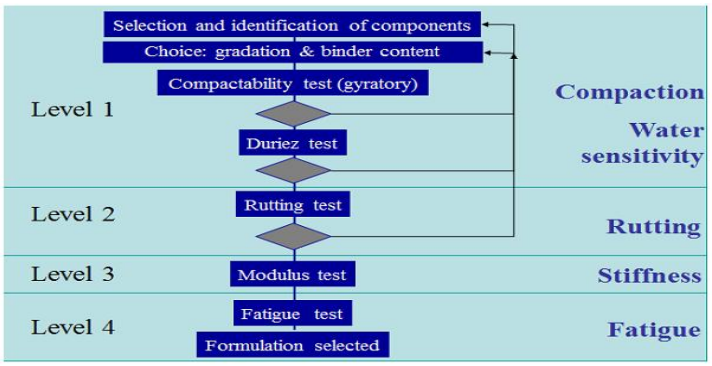

Figure 8: Overview of design steps for high modulus asphalt
Source: Yves Brosseaud (2012), PowerPoint presentation on "French methodology for hot bituminous mix design', AAPA 2012 study tour

The change in physical and chemical properties of the hard grade bitumen can be quantified usingthe Penetration Index (PI) (Read & Whiteoak 2003) and Colloidal Instability (CI) Index. Note that the CI index is also referred to as the Gaestel index (GI) in many other references (e.g. Gaestel et al. 1971, Oliver 2006). ARRB uses GI as an indicator of bitumen compatibility and propensity to segregation of PMBs (e.g. Oliver et. al, 2012, Oliver and Khoo 2012). Information on the CI/GI values of a large number of Australian and some overseas bitumens is given in a series of Austroads technical reports (e.g. Austroads 2007, 2009, 2011a, 2011b, 2012). It was found that as the PI and CI increases, the change of performance of the hard grade bitumen used to make HiMA/EME are (BP 2012):

- Resistance to low temperature cracking↑
- EME fatigue resistance↑
- EME rutting resistance↑
- Ageing resistance↓
- Healing capacity at ambient temperature↓
- EME stiffness↓

Table 4. Specification of key properties for aggregates and binder used in HiMA/EME

Type	Max Aggregate Size (mm)	Binder (pen)	Binder Content (%)	Void content %	Thickness (cm)
GB	14 - 20	35/50 20/30	4 to 5	6 to 8	8 to 16
EME	10-14-20	10/20	4.5 to 6.2	3 to 6	6 to 15

Table 5. Specification of key properties for base course mixes of HiMA/EME

Type of mix	Gyratory. (Voids %) C80 (D 10mm) C100 (D 14mm) C120 (D 20 mm)	Water sensitivity r/R ratio	Rut depth (60°C-100 mm) * 10.000 cycles (%) ** 30.000 cycles (%)	Stiffness modulus (15°C-10Hz) in MPa	Fatigue – admissible strain (@ 1 million de cycles)
GB Class 2	≤ 11	≥ 0.65	≤ 10*	≥ 9,000	$\geq 80.10^{-6}$
GB Class 3	≤ 10	≥ 0.7	≤ 10*	≥ 9,000	$\geq 90.10^{-6}$
GB Class 4	≤ 9	≥ 0.7	≤ 10**	≥ 11,000	$\geq 100.10^{-6}$
EME Class 1	≤ 10	≥ 0.7	≤ 7.5**	≥ 14,000	$\geq 100.10^{-6}$
EME class 2	≤ 6	≥ 0.75	≤ 7.5**	≥ 14,000	$\geq 130.10^{-6}$

Specified requirement for each design level (Figure 8) are listed at below:

1. Gyratory compactor test : 4% void (e.g. MLPC gyrator shear compactor EN12697-31)
   Water sensitivity (Duriez test): Ratio r/R (and % voids) > 0.75. The test result aids in decision on the use of an adhesion agent. Indirect tensile test is also specified in the European standard (EN12697-12)
2. Rutting resistance (Test at 60°C) for base for EME1&2: 30 000 number of cycles with max. 5% in rut depth
   Test conditions: smooth tyre, pressure at 0.6 MPa, Load = 5 kN, speed = 1 cycle/s, controlled temperature = 60°C (EN12697-22 ex NFP 98-253-1)
3. Modulus (stiffness at 15°C, complex (10Hz) or tensile (0.02s)): minimum 14 000MPa
4. Fatigue (Admissible strain @ 10°C and 25Hz [μ]strain): minimum of 130με (NF EN12697-24 Annex A)
   - Compatibility characterisation
   - Some factors affecting rutting resistance include binder type, sand nature and void content

   are shown in Figure 9.

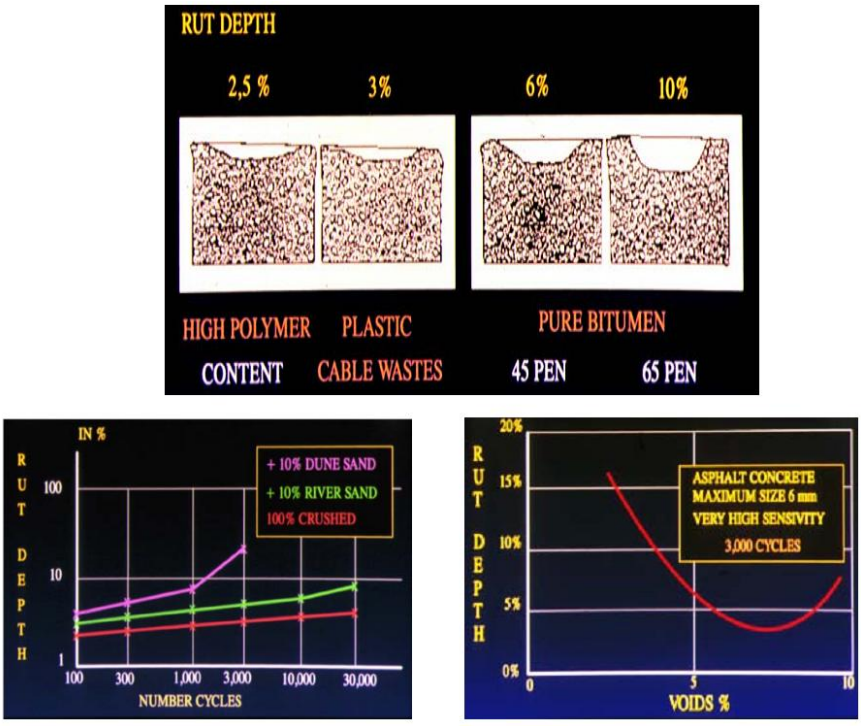

Figure 9: Effects of binder type, sand nature and void content on rutting resistance

Table 6. Usage of HiMA/EME and RAP in Europe and USA in 2010 (Harry Roos, VBW-Asfalt, 2012)

Country	HiMA production (million tonnes)	RAP in HiMA (%)
Spain	39	3
France	39	7
Austria	8	5
USA	327	17
Germany	45	26
The Netherlands	10	32

6. Development of HiMA/EME technology

It was reported that (BP 2012):

- Good performance on various surveys of EME road projects
- Only one key cracking failure due to the use of a very hard binder HSB (Pen=5). This product has now been excluded from the market
- The EME technology was successfully implemented in Switzerland (HMT) in the early 90s and was transferred to The Netherlands and UK in the late 90s. No change in the French formulation nor the HSB originally imported from France was required.
- SANEF Motorways Agency requested use of recycled asphalt in EME. Trials (up to 50% of recycled asphalt) have been constructed. (Refer BP pdf slide 'Bitumen', page 16)

7. European Specifications for Bituminous Binders

The grading of bituminous binders in Europe is based on penetration at 25 °C (Eurobitume 2011). The harmonised specifications, as administrated by 'Comité Européen de Normalisation' (CEN), are based on physical properties only. Working Group 1 deals with paving binders and includes paving bitumens (EN 12591 & EN 13924), polymer modified binders(EN 14023) and industrial bitumens (EN 13304 and EN 13305). Working Group 2 is concerned with cutback and fluxed bitumen and bitumen emulsions.

The bituminous binders Technical Committee (TC336) reviews the specifications on a rolling 5-year cycle(cf. AS 2008). The EN specification only categorises the properties of the binders, not the grade of the binder to be used. It is a flexible means for users to specify the properties they require. It is then up to the contractor / supplier to produce product that meet users' criteria, i.e. this requires the user to understand the effect of properties on performance.

Some challenges encountered for the specification include:

- asphalt: conditioning procedures for aged asphalt, WMA (foamed); specification for cold mix
- binder: adhesion, consistency of quality and long term aging

EAPA has looked into ways of categorising binder adhesion, but in vain. An industry committee has advised that adhesion is a very complicated topic, e.g. different aggregates give different results. Even if the same aggregates are used, surface aggregate A will be different to aggregate B (Personal communication, Elgert Beuving (EAPA), 6 June 20120).

The harmonisation process in Europe resulted in a collation of all the different country based specifications for bitumen. Consequently, each country can still use its own specifications and test method with the potential of selecting additional tests from the overall specification (EAPA).

European contractors emphasized that road authorities have the responsibility of clearly stating what their requirements are. Thus road authorities need to ask for quality – the contractors will not deliver what is not specified. The device to measure the resistance to shear stresses is interesting and such a device would be useful for assessing the effect of PMBs on shear resistance in asphalt and seals in Australia.

However, the cost of the French device is likely to be very high. An Australian approach could be developed or the work of New Zealanders who are looking at a similar problem, might provide a lower cost solution.

Recent developments in binder specifications (B11)

The process of achieving harmonisation is described in one of the reference documents given out on the tour. The document is entitled "Position Paper: Performance Related Specifications for Bituminous Binder, January

2012”and is the collective viewpoint, on the development of performance related bitumen specifications contributed to by bitumen industry members.

First generation specifications

Following agreement to develop common European standards and specifications to replace those of individual members of the European Community, work was undertaken to produce a first generation bitumen standard. Over the period 1990 – 2005, existing national bitumen standards were harmonised and a common European standard, EN 12591 (bitumen and bituminous binders – specifications for paving grade bitumens), was published by CEN in 1999.

This first European bitumen standard is based on conventional test methods such as softening point (ring and ball test) and penetration at 25°C. This is in contrast to the Australian Bitumen Standard which in 1977 changed to viscosity grading for binders. Revision of the standard commenced in 2005 to comply with the Construction Products Directive which stated that harmonised technical specifications should be performance based.

Development of second generation performance-related standards

Work on the second generation standards is the responsibility of CEN Technical Committee TC336 Bituminous Binders. The standards of particular interest to binder suppliers and users in Australia are the paving grade bitumens (EN 12591) and polymer modified binders (EN 14023).

Preparation of the standards is a complex process. Therefore, two projects were set up in parallel to provide data for the second generation standards in particular:

- The Bitumen Test Validation (BitVal) project was setup by FEHRL (the Forum of European Nationa Highway research Laboratories). The project is concerned with developing correlations with field performance. These will assist in producing recommendations for specifications.
- The Data Collection Framework examines new test methods. It also collects test data on commercially marketed binders. These data will be incorporated into the Eurobitume database.
- In considering the use of Performance Related Specifications (PRS) for bituminous binders, the European binder industry binders should be defined as simple or complex. It considered that a new specification is only required for rheologically complex materials such as PMBs and hard paving grade bitumen. It suggested that rheologically simple bitumen meeting EN12591 does not require new specifications.

The main criteria in developing future specifications should be to maintain the trust of road users and authorities whilst providing the opportunity to improve binder performance. Future specifications will therefore differentiate between binders used for standard asphalt mixes and binders use for more intensive traffic and special applications such as porous asphalt and EME.

Future binder specifications

The EU Construction Products Directive states that tests must be performance related where at all possible. In considering this, an industry task force reviewing the first generation bitumen specifications, recommended that binders should be defined as simple or complex. This would impact on specification changes as follows:

- simple binders would be covered by the current (empirical) specifications (EN12591) and test methods. However, a review is to be undertaken in 2014 as required by CEN.
- new specifications are needed for complex materials such as PMBs and hard paving grade bitumen. Performance parameters would have to be developed for these materials.

Conclusion

- The work of developing performance related specifications began in 1995.
- This was a very difficult task because of the wide range of tests, cultural and language differences between countries.
- Eventually a first generation of harmonised specifications was produced in the period 1999 to 2005. These were, basically, traditional tests (such as penetration at 25 °C and Softening Point) that could be accepted by all countries.
- However, it is recognised that these tests are not suitable for PMBs and will not meet CEN requirements that tests must be related to performance.
- A second generation of tests is under development. However, this may be a slow process as budgetary difficulties appear to have arisen.

8. PMB testing: conclusion and recommendation

Recent work reported by Robertus et al (2012 – paper A5EE 402) at the Eurobitume & Eurasphalt (E&E) Congress suggested that non-recoverable creep compliance (Jnr) calculated in the Multiple Stress Creep Recovery test (MSCRT) was the best indicator of permanent deformation in wheel tracking specimens . Table 6 gives a summary of R2 values for the correlation of Softening Point, Zero Shear Viscosity (ZSV) and Jnr against wheel tracking rate at 60°C for 20 binders. The creep compliance (Jnr) gave a better correlation than Low Shear Viscosity (LSV) and ZSV. The three rheological parameters (Jnr, LSV and ZSV) were measured using a Dynamic Shear Rheometer (DSR).

Summary and recommendations

Australia has the potential to benefit from the adoption of high performance asphalt base mixes. These high performing base mixes can be achieved through a range of techniques, with three listed below:

- EME is a dense graded asphalt mix using standard good quality crushed aggregates with a high structural stiffness. The mix combines superior permanent deformation resistance through the use of hard bitumens with a penetration value between 10 and 25, and good fatigue resistance through high binder contents. The EME mix has definite benefits for Australia and builds on the extensive experience of French use as a high performance asphalt base mix use for heavy duty roads. However, this requires the availability of special hard penetration grade binders. Questions remain on its implementation into Australia, the relationship between French performance tests to those used in Australia and the recyclability of this mix.
- Innovative options exist for the use of aggregate packing theory to achieve a much higher densely graded asphalt mix using a binder at a low content of around 4% and modified with SBS, with the aggregate gradings altered to achieve a double gap grading. This later aspect results in asphalt bases that should be easily compactable, containing low air voids but high granular interlock and hence high modulus with the binder modification providing the fatigue resistance. The proprietary GB5 mix highlights the potential benefits for Australia and would enable current material and binders to be used to achieve high performance asphalt base mixes, as well as enhancing the recyclability of this mix.
- GAB II is an asphalt mix designed for Denmark conditions where aggregates are a premium. The GAB II mix uses 16/32 alluvial aggregates and approximately 65% sand so that the aggregate acts as a filler. Hard binder is used to achieve its high modulus value. The GAB II mix is probably of no benefit for Australia and its climatic conditions, but is another example where hard binders are used to advantage, and in this case for the local conditions in Denmark.

Recommendation

It is recommended that Australia investigate the use of high performance asphalt base mixes based on high modulus values as a means to potentially reduce asphalt layer thickness or to improve performance for heavy duty roads. The types that need to be investigated are:

1. EME, being a dense graded with a high structural stiffness, superior permanent deformation resistance through the use of hard bitumens with a penetration value between 10 and 25, and good fatigue resistance through high binder contents. Questions remain on its implementation into Australia, the relationship between French performance tests to those used in Australia, the availability of hard bitumens and the recyclability of this mix.
2. Review the potential in Australia for an asphalt mix based upon high density packing of aggregates, using a binder with low content but modified with SBS, with the aggregate gradings altered to achieve a double gap grading. This later aspect can result in asphalt bases that are easily compactable, containing low air voids but high granular interlock and hence high modulus with the binder modification providing the fatigue resistance.

High performance asphalt & binders

- Questions & Responses

Asphalt (EME/ HiMA)

1. Does EME work, how long has it been used and is it cost effective?

(Yves Brosseaud, IFSTTAR, 2012):

EME was first used in France in 1980 to reduce pavement thickness. The evolution of EME technique was as below:

1980 : firstly applications , companies' processes
1985 : generalization in reinforcement maintenances
1988 : guide EME for urban rehabilitations (minimum complex modulus of 11 000 Mpa at 15°C and 10 Hz was specified)
1990 : new construction on RRN
1996 : new pavement on motorways – Scetauroute pavement catalogue
1998 : RRN pavement catalogue
2007 : EME (EN standard)
2010 : 200 kt 10/20 – 4 Mt EME (10% enrobes)
HiMA has been used for 25 years in France without significant signs of thermal cracking, stripping of binder and Modulus evolution by hardening

2. What are the key issues to be addressed to allow the EME approach to be used in other countries?
Good performance of various EME road projects were reported (BP 2012). Only one significant cracking failure was reported due to application of hard bitumen with a Penetration value of 5. This product has been removed from the market. The only significant issue for Australia is how to adopt the full French requirements.
Other countries that use EME include: Belgium, Czech R., UK (introduced in 2006), Ireland, Switzerland, Brazil, Algeria (3 MT, 3 years), Morocco (400 km motorway, 7 years, recycling 20%)
Countries that are interested in EME: Romania, Columbia, USA, Argentina, Mexico, China
Development of HiMA in Poland: 9 years ago near POZNAN with others applications, regulations June 2010 (thermal cracks – February) resulting from Polish-French Cooperation – 2003: HiMA- Technology transfer
- *Key to success of EME (Yves Brosseaud, IFSTTAR, 2012):*
- *Stiff enough sub-base*
- *Performance check (lab and application controls)*
- *Respect of the thickness*
- *Protect with wearing course (texture, climate, etc.): joint quality, equivalence coefficient (Alize pavement design, new polish version)*

3. Can EME be produced to a standard specification or is a proprietary system required?
A standard specification would be suitable for EME use.
4. How are the performance parameters of EME established – laboratory tests, field links?
Mix design of EME in France is based on the following key parameters in order:
- *workability (compaction test using gyratory) and resistance to water (Duriez test) – these are the two key design steps to identify and select suitable components, gradation and binder content in meeting the two requirements.*
- *rutting,*
- *modulus (stiffness)*
- *fatigue resistance*

The Marshal test is not recommended (Yves Brosseaud, IFSTTAR, 2012)
5. For EME, what requirements are there for the pavement and foundation/subgrade as a whole?
As for question 2, a stiff enough base is required. Figure 2 is a pavement catalogue example indicating three supporting pavement alternatives. PMB's are only used for wearing courses, and high textured mixes include open grade and stone mastic asphalts.
6. What level of contractor sophistication is required to successfully deliver EME?
Contractor needs to have a quality mix design laboratory capability, as it is vitally important to respect the laboratory performance tests, control quality constituents (hard bitumen), composition, voids, thickness and homogeneity.

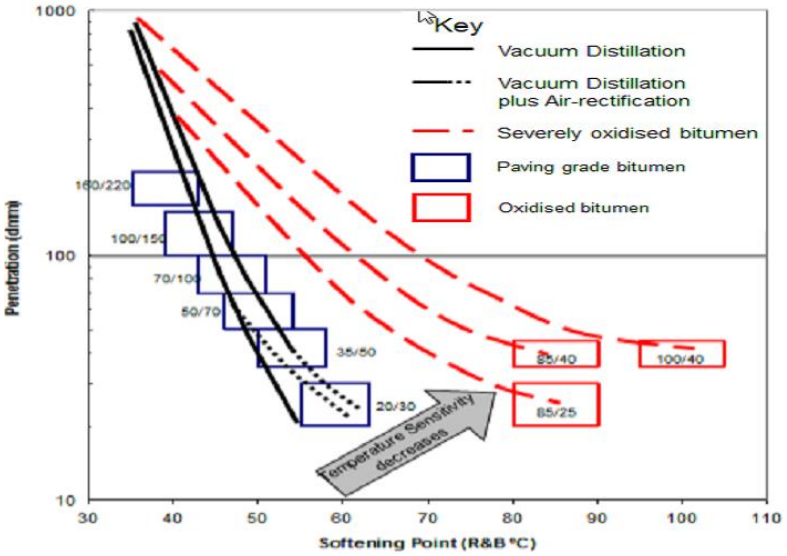

Figure11: Eurobitume differentiation between air-rectified and oxidised bitumen Long life pavements (construction of pavements)

7. Can high percentages of RAP assist in meeting the modulus criteria for EME?

The RAP binder is 'softer' than the hard binders for EME, and thus modulus would be compromised with high percentages of RAP. RAP has been used in HMA up to about 50% RAP (10 -20 mm). COLAS conducted a trial using high RAP content in 2009.

8. How carefully should the EME binder be selected? What are the manufacture routes for producing EME binders other than by refining?

Refer to Figure 11. Hard grade bitumen can be manufactured by using special refinery processes. These processes have a strong impact on the chemical composition and colloidal structure of bitumen manufactured – the rheological and ageing properties of the bitumen can thus be varied enormously.

9. Is having 'high modulus' the only goal of EME? Can having more resilience be aimed for instead? (i.e. aim to have a material which last longer under the same deflection). For example, use of elastic polymers would exhibit longer lasting life, not because it is stiffer (high modulus) but because it can endure much more deflection.

High modulus is EME's aim, but with stiff supporting pavement. The GB5 mix could be a candidate to improve flexural resilience as it does utilize a PMB binder.

10. How would high modulus asphalt be best used on thin pavements?

Refer to question 9.

11. What are the key binder parameters to achieve a performing EME?

Refer to Table 1.

12. Are there any key placement/construction considerations regarding EME that we should be made aware of (and if yes, what are they)?

No additional information was provided apart from achieving all the mix design steps that includes the assessment of mix workability using gyratory compaction.

Asphalt (Performance)

13. Are there 'rut resistant' mixes specifically designed and used for intersections and high stress areas and, if so, how are they performing?

Nil Information.

14. What AC properties / products show best performance in snow and de-icing salts?

High textured surfacings are preferred, with porous asphalt preferred in Netherlands and Stone mastic in Germany and France.

15. AC needs to inhibit reflected cracking – what mixes and binders offer this?

Nil Information.

16. Products like Lo-Noise in Australia have been prone to damage from shear forces – intersections, braking zones – is this European experience?

Nil Information.

17. Performance characteristics of reinforcing interlayers, or geotextiles like Tru-Pave?

Nil Information.

18. What design method can be used to determine AC layer thickness and properties to resist reflected cracking, given a predicted strain value from underlying cracks – either cemented granular layers, or for rehabilitation of concrete pavements?

Nil Information.

Asphalt (Reinforced)

19. Design parameters for reinforced AC layers?

Nil Information.

Asphalt (Modified Binders)

20. What new modifier combinations are available?

The only modified binder discussion was on the use of PMB for base course mixes.

21. Are high polymer modified binders providing additional benefits to match the increased cost?

Refer to Question 20

22. What is the polymer concentration used in Europe? What are the advantages and disadvantages of higher concentrations?

Generally, the polymer additives range from 1 % to 3 %, to as much as 7 % for some applications (Eurobitume, 2011). Disadvantages are Moisture Susceptibility (measurement, tests & approaches) and Porous Asphalt maintenance and performance.

23. What is the life of PMB asphalts in Europe, particularly Southern Europe with higher temperatures like Australia?

Nil Information

24. Why are PMBs used instead of bitumen - rutting prevention, fatigue/cracking resistance, longer life, etc.? Have long-term performance trials been undertaken to assess the advantages?

PMB's are being used in base layers to achieve the high performance pavement criteria, and principally to meet fatigue requirements. Refer to GB5 discussion.

Asphalt (Construction)

25. What aids are being used to improve the construction of asphalt pavements? GPS controlled compaction – direct feedback on compaction results?

Nil Information

26. Has there been a move to place dense graded asphalt at lower air voids and what are typical in situ void values?

Both EME and GB5 are placed at low air voids, achieved using high binder contents and double gap graded curves respectively.

27. Are seals placed under asphalt wearing courses to prevent moisture ingress into under-lying layers? What measures are undertaken to prevent moisture penetrating open graded asphalt in the under lying layers.

Nil Information.

Asphalt (SMA)

28. What countries use SMA and what service lives are being achieved?

Refer Question 14.

29. Low noise SMA treatments, are there generic specifications and what performance experience is there?

Nil Information

30. What types of overlays are used over existing Stone Mastic Asphalt (SMA), if any? For instance is SMA over SMA acceptable practice and, if so in what circumstances?

Nil Information.

Asphalt (Moisture Susceptibility)

31. Is moisture damage an issue in your pavements?

Moisture damage is a big issue, with adequate resistance checked in mix designs and achieved through use of low voids in base mixes. UK experienced moisture damage in some EME base layers. Severe winters are a continual problem for longevity of pavements in France.

32. What measures and tests are performed on asphalt to determine its sensitivity to moisture ingress i.e. stripping potential?

The Duriez test is used in France and is discussed under 5.5 above.

33. What actions to contractors (both manufacturers and paving contractors) to address moisture sensitive material?
Refer to Question 32.

Asphalt (OGA/PA)

34. How is Open Graded Asphalt (OGA) / Porous Asphalt maintained and/or rehabilitated? What methods are used and how are these performing? It is understood that in some places Dense Graded Asphalt overlays are placed on OGA. If this is true, then what issues have been encountered and how are they performing?
Nil Information

Specifications and Test Methods

35. How does the industry manage proprietary mix designs? Do agencies attempt to emulate the properties in specifications?
Both the UK and France offer product approval schemes based on laboratory testing and field trials to demonstrate performance.
36. What is the status of binder specification harmonisation in the EEC?
The harmonisation system, as administrated by CEN, is mainly based on physical properties rather than chemical properties. Method agreed by European standardization for HiMA/EME:
- *road material mix design, laboratory characterization tests*
- *in future : pavement design procedure (harmonization to be done)*

37. Are polymers still the major type of modifiers? What type of polymers (elastomer, plastomer) are in general use? Does the specification identify them by type? What relative percentages of the polymer modifiers are used?
UK: Currently PMBs are not accounted for in UK design methodology. Risk based approach via a Departure from Standards procedure (Donna James, Highways Agency)
38. Test methods: has there been agreement on standardised equipment and what has been chosen?
The general result of harmonization across Europe is that several test types may be allowed to be used for the same property. But further work still needs to be done to determine if further harmonization is possible and the effect of different test configurations to produce different results. Refer to discussion with Andre Molenaar under Long Life Pavements Section 4 in relation to Fatigue testing.
39. Appropriate laboratory test methods: Laboratory testing can be very useful in testing alternative/new mixes (also in QC) – what use is made of that?
The basis for a high modulus mix design is demonstrated using laboratory testing meeting minimum specification (maximum for rutting) requirements which can be quite onerous prior to application in the field.
40. Are there any laboratory binder test methods which can correlate the low temperature performance of different material?
Nil Information
41. Limits of change in Softening Point and Elastic Recovery after RTFOT are specified in EN 14023:2010 – what are the purpose, benefit and effectiveness of these limits?
Purpose is to ensure binder durability and limit the ageing potential of the binder.
42. Apart from specification of storage stability and limits of changes in PMB properties (Softening Point and Elastic Recovery) after RTFOT, how is segregation and degradation of polymer modified binders (PMB) controlled?
Nil Information.

Binders

43. Is the concern for climate change temperature rising impacting on the choice of binders?
Nil Information
44. Are there concerns about the potential decreasing availability of local binders and are bitumens being extensively imported into Europe?
Examples were provided where lack of bitumen supply was creating issues for contractors.
45. Are there any concerns about the quality and general characteristics of (imported) bitumens being different to what they used to be?
Nil Information.
46. What level of testing is required on the binder at point of manufacture, at the asphalt producer's plant and in the field?
Nil Information.

47. What attempts are being made to correlate design practices with field monitoring/performance i.e. are they getting the expected performance and what are the key parameters they are measuring (if they are involved in this)?
All countries indicated that this was a difficult and underfunded function. The fact that design catalogues exists suggests sufficient monitoring and laboratory assessment is occurring to give confidence in pavement types and suggest that the 20 year time scale referred to for EME's use is needed to obtain suitable confidence.
48. How is the field performance related to laboratory test results, e.g. stripping potential, an easier way of testing fatigue, etc.?
Refer to Question 47.
49. To what extent is unbound material stabilised, in a plant or in situ? Is foamed bitumen used? How is it used, where and in what layers? What is included in mixes?
Nil Information

Emulsions

50. What test methods have been used to measure bituminous emulsion fundamental and performance properties (adhesion, breaking behaviour, etc.)?
Nil Information
51. Are there harmonised EN specifications for emulsions in Europe?
Nil Information
52. How and for what are sprayed bituminous polymer modified emulsion surfacings used?
Nil Information
53. Are there standard types of emulsions for use in sprayed chip sealing or slurry surfacing?
Nil Information
54. Are there performance-based specifications for bituminous emulsions?
Nil Information

Surfacings

55. Are proprietary thin surfacings providing the intended benefits cost effectively?
It was clear from all countries that for the heavy duty pavements, stone mastic and open graded asphalts are used. Nil information gained for other pavements.
56. Are thin proprietary surfacings used over concrete pavements?
Nil Information
57. What modelling is being done that can be linked to surface seals design and performance prediction?
Nil Information

Reference Material

List of the presentations or other materials gathered during the tour

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2. Austroads 2009, First national survey of Australian bitumens, by JWH Oliver & C Chin, APT124/09, Austroads, Sydney, NSW.
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7. Chappat, M, Carbonneau, X and Lefeuvre, Y, 'Analysis of the Measured Performance of High Modulus Asphalt (HMA) and Road Base Asphalt (RBA) and a Proposal for a Compensation Principle', Europeanroads, Review 14, Spring 2009
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9. Olard, F, Dherbecourt, J and Dumont, H GB5: eco-friendly alternative to EME2 for long life and cost-effective base courses. Europeanroads, Review 20, Spring 2012.
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12. Oliver, JWH, Khoo, KY and Waldron, K 2012, 'The effect of SBS Morphology on Field Performance and Test Results', Road Materials and Pavement Design, vol. 13 (1), 104-127.
13. Oliver, JWH and Khoo, KY 2012, 'Ensuring the Quality of SBS Modified Binders', ARRB Conference, 25th, Perth, ARRB Group, Vermont South, VIC.
14. Robertus C, Van Rooijen R & Thimm L, 2012, 'A comparison of binder tests that relate to asphalt mixture deformation', 5th Euroasphalt & Eurobitume Congress, Paper A5EE 402, Istanbul, TURKEY.
15. Widyatmoko, I, Hakim, B, Fergusson, C, and Richardson, J,' The use of French Asphalt Materials in UK Airfield Pavements' 23rd World Congress – workshop on Airfield Pavements, 19 September 2007.
16. Widyatmoko, I, Hakim, B, Fergusson, C, and Richardson, J, 'The Use of French airfield asphalt concrete in the UK'. Europeanroads, Review 13, Fall 2008.

6. SUSTAINABILITY

Overview of reasons - Challenges

- Climate Change – Green House Gases
- Future Carbon Tax
- Increasing Demand - Limited Resources
- Ageing Infrastructure - Rehabilitation
- Waste Reduction - Focus on Recycling
- Reduced Construction Periods – Minimise Delays
- Society's Perceptions and Funding Constraints

Feedback from

- The French Administration (IFSTTAR & SETRA) and LCPC (in France)
- The University of Delft and the Rijkswaterstaat (in the Netherlands)
- The Highways Agency and Transport Research Board (in the UK)
- Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt) and German Asphalt Pavement Association (DAV) (in Germany).
- Colas (in France), Kraton polymers (in the Netherlands) and BP (in Germany)
- The 5th Euroasphalt and Eurobitumen (E&E) congress proceedings (in Turkey).

Observations

Promoting a sustainable environment is a very high profile political commitment in Europe. The road sector is fully aware of that expectation and is actively engaged in reducing greenhouse gas production and energy usage.

Initiatives range from economic models and tools to evaluate and price, greenhouse and energy impacts of road, asphalt production and supply, long term maintenance and end of life removal / recycling. These tools are used in a number of European states to assess tenders and to trigger changed behaviour in the infrastructure construction and maintenance sector.

The asphalt industry has recognised the high value areas such as recycled asphalt pavements, warm mix asphalt technologies and the use of cold in-situ recycling. Climate change and the requirements for sustainable use of natural materials will continue to drive innovation, improvements in quality and durability including the achievement of longer service lives of the bituminous product industry and its products.

1. Sustainability- General

Global warming – climate change – greenhouse gases – carbon footprint – exploitation of fossil fuels, these are our greatest challenges. Mankind uses natural resources from the environment. As the developing countries aspire and strive towards higher standards of living, the earth cannot support this load unless real change takes place. Sustainable development is seen as one of solutions to this issue.

Sustainability is the term that has been used recently and more frequently than the word environment. This reflects that the scope has become wider. Sustainability has three dimensions or pillars namely: Environmental, economic and social well-being for today and tomorrow.

Modern society inevitably needs natural resources and these come from the environment.

Whatever we do has an effect on the environment, but the question is how can we do this so that we consume nature as little as possible and give nature the possibility to renew. We should act in an "environmentally" sustainable way.

The economic aspect acknowledges that in order to act in a responsible way towards the environment and to carry a social responsibility, industry must be healthy. A company making losses year after year cannot be thought of as sustainable. A healthy business performance is what society needs and it is the basis for positive environmental development. However, many sound "environmentally" sustainable practices such as recycling make good economic sense.

Our Common Future, also known as the Brundtland Report, from the United Nations World Commission on Environment and Development (WCED) published in 1987 included an excellent definition for sustainability. "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Society has already started to take actions to improve the situation.

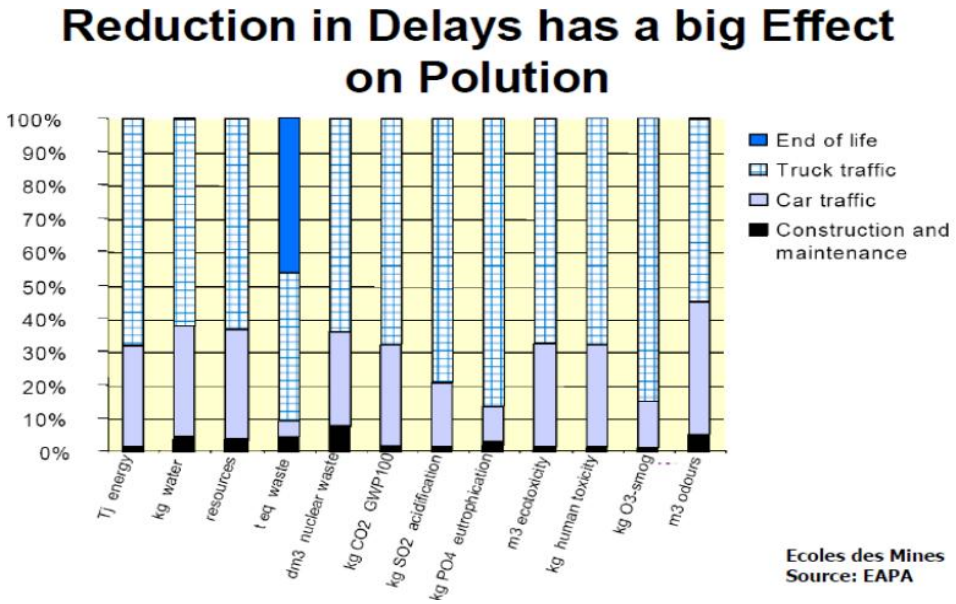
2. Sustainability in Europe

European Union has set a goal to reduce primary energy use by 20% by 2020, the reference year being 1990. One of the ways to get there is the EU's Emission Trading Scheme, where CO2-licences are sold. This sets a price to carbon emissions.
The UK has gone even further and set a target to reduce greenhouse gases to 80% of the 1990 levels by 2050. The intermediate target is 34% cut by 2020. UK decision makers have stated that this policy is not an obstacle but an opportunity for the local industry. The development of new technologies establishes a competitive advantage in a most rapidly growing sector and generates jobs and export opportunities.

Sweden has set a 40% reduction target by 2020 with the 2050 target being "zero" net emissions.
These targets are extremely challenging when considering the European recession and financial crisis in many of the European countries. The problem for a decision maker is that the strategies with the lowest capital or whole-of-life cost may not be those with the lowest carbon footprint.
Sustainability is also recognised in the European standardisation work where the new Construction Products Regulation has introduced a new essential (basic) requirement which is "sustainable use of natural resources". CEN TC350 Sustainability of Construction Works states that the construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable. Environmental product declarations (EN 15804) contain core rules for the product category of construction products. The key words will be recycling, durability and environmentally compatible raw materials.

3. Sustainability in Road Construction

Sustainability is one of the most important aspects of asphalt road construction. All the requirements for asphalt roads are summarized by this term. Asphalt roads should last for a long time and the maintenance works should be reduced to a minimum. This saves construction costs and user costs and protects resources and the environment. A sustainable development can combine the needs of people, of nature and economy. Sustainability is not only an aspirational target, it is the core value and leads directly to durability and performance of the pavement.



Sources of Environmental Loads During Road Life Cycle

Ensuring high quality construction was identified as a key to sustainability. Areas requiring stronger focus were the quality assurance during the asphalt production and paving as well as the need for well trained workers with good knowledge of asphalt as a construction material.
Due to the long life cycle of a road, the main environmental loads come from the use of the road, not from the initial investment.

Some early experimental work has shown that it is possible to save 3-5% in fuel consumption by having low rolling resistance of the pavement. The project has been doing fundamental research into the tyre-pavement interface and seeking consistent methods to measure the actual rolling resistance. The practical result will be a novel pavement type with low fuel consumption.
Preliminary results indicate a small aggregate grain size in the order of 6 – 8 mm should be used. This requires a very strong, age resistance mortar and close attention to grading to ensure skid resistance. A low surface roughness of 0.9 m/km (IRI) is also important.
The typical proportions of CO2 generated in constructing asphalt pavements are:

- 44% Production and transportation raw materials
- 31% Production of the asphalt mixture
- 18% Transportation and laying/compacting asphalt mixture
- 7% Maintenance/milling

The greatest potential for reduction in environmental emissions is during the production of the raw materials and the asphalt manufacture. The main strategies are increased use of Recycled Asphalt Pavement (RAP) to reduce the demand for raw materials and Warm Mix Asphalt (WMA) techniques to reduce the energy demand during asphalt production.

4. Recycled Asphalt Pavement (RAP)

In some European Countries, recycling is done on a large scale and has become common practice. In Austria, Germany and Netherlands over three quarters of the available RAP, is used for hot and warm recycling. Over two-thirds of the new hot and warm mix production in The Netherlands contains some reclaimed material. However, for many other countries, the values are much lower.

Some useful definitions and aims for the use of RAP are:

- 1st goal is Recycling of RAP - same function as in the original application (adding the eclaimed asphalt to new asphalt mixes)
- 2nd option is Re-use of RAP - utilisation as a lesser function than in the original application (reclaimed asphalt as foundation, fill or base course material)

In The Netherlands, the allowable amount of RAP depends on the type of mix:

- Stone Mastic Asphalt Nil
- Porous Asphalt Concrete 20%
- All other mixtures and layers 50%

Country	available reclaimed asphalt (tonnes)	% of available reclaimed asphalt used in				% of the new hot and warm mix production that contains reclaimed material
		hot and warm recycling	half warm recycling	cold recycling	unbound layers	
Austria	500.000	80		8	12	
Belgium	1.500.000	57				47
Czech Republic	1.650.000	15		35	20	10
Croatia	75.000			35		
Denmark	350.000	56			44	39
Finland	1.000.000					65
France	7.080.000	40	no data	no data	no data	no data
Germany	14.000.000	82			18	60
Greece	0	0	0	0	0	0
Great Britain	4.000.000					
Hungary	44.580	12		15	40	10
Iceland	15.000				25	2,5
Ireland	100.000	40	0	0	60	2,0
Italy	11.000.000	20				
Luxembourg	200.000					
Netherlands	4.000.000	75				67
Norway	750.000	15	13	12	60	8
Poland	110.000	4				0,2
Portugal	2.100	15	0	5	20	25
Romania	40.000	40	15	20	25	<5
Slovenia	26.160		30	20	50	
Spain	1.590.000	56	9	16	19	11
Sweden	1.100.000	70	5	5	20	60
Switzerland	1.450.000	52	19	18	11	21
Turkey	2.420.000	19			81	10
Japan						72,9
U.S.A.	66.500.00	84			12	
Ontoria-Canada	4.000.000	85			15	85

Use of Recycled Asphalt Pavement (Source EAPA)

It is predicted that the allowable amount of RAP will increase in the future and mixtures made of 100% RAP have been produced.
In France, in March 2009, there was a voluntary commitment of the stakeholders in the design, construction and maintenance of road networks and urban public spaces to improve the environmental performance of the industry's contractors. This includes participating in the development of research and innovation through new modes of technical partnerships. The Institut Des Routes, des Rues et des Infrastructures pour la Mobilité (IDRRIM) was formed as the peak body as part of this relationship. Some of the goals are to preserve unrenewable resources by aiming to reach 100 % recycling roads and increase the percentage of aggregates recycled in asphalt from the current 20 % to 60 %.
Research has been undertaken to study blending of fresh and aged binders, and try to answer the question: is RAP aggregate a black rock or can the aged RAP binder actually blend with fresh binder? Effects of RAP on mix or binder properties have been mainly studied at the laboratory level. The main results are the following:

- The current standard manufacturing protocols are insufficient. To achieve the same target temperature for the mix when RAP is used, the temperature to which the virgin aggregate is heated must be increased as the proportion of RAP is increased.
- Blending between virgin and reclaimed binder does occur when sufficient mixing time is maintained at about 240 sec. This parameter is the number one factor for blending efficiency.
- The mixture stiffness modulus is highly dependent on recycling rate, production temperature and mixing time, and some other HMA characteristics. However, the effect on dynamic modulus is more pronounced for the binder than for the mix, particularly at higher temperature (above 40^{o}C).
- Fatigue resistance is dependent on all parameters, particularly the mixing time. In some cases, positive effects have been observed even at 70% RAP. However, the maximal fatigue resistance is usually observed at 30-40% RAP, and then tends to drop at higher rates.
- Fatigue resistance highly depends on the RAP origin – for example SBS RAP behaves better at higher strain levels.

However, despite this research, questions remain about the performance and durability of the asphalt containing RAP that has been through numerous cycles of recycling.
There is nothing new about adding recycled asphalt pavement to asphalt mixtureswith over 30 years of experience of recycling in parts of Europe. Better reclaimed asphalt management is required in order to reach the next level in the future and as a means of obtaining positive results and a higher level of acceptance in surface layer. Until now, the national road administration has some reservations against the utilisation of reclaimed asphalt in surface layers due to the potential introduction of some aggregate of gravel origin, from lower bituminous bound layers, which are undesired due to frost resistance.
The subject of recycling and sustainability has inspired several transnational projects like DIRECTMAT and Re-Road under the 7th frame work programme of the EU Commission. The DIRECT-Mat project has just ended and the four year research project Re-Road will come to an end at the end of 2012.
The DIRECT-MAT project provides a good overview and insight of European national requirements and practices for recycling in Hot Mix Asphalt and Warm Mix Asphalt. The impact of European product specifications like EN 13108-8 Reclaimed Asphalt on the reclaimed asphalt and the binder mix properties detailed in EN 13108-1 Asphalt Concrete are highlighted. But in spite of European standardization, diversity still occurs. This is probably due to national conditions and traditions like tendering for road works. DIRECT-MAT also embraces the experiences collected in 15 European countries to compile best practice guides for recycling.
The Re-Road project focuses on the recycling of reclaimed asphalt in high percentages for surface layers for high trafficked roads. In order to optimize the characterisation and the utilisation of reclaimed asphalt containing polymer modified binder, a Round Robin inter-laboratory experiment aimed at binder content and properties of three different mixes including polymer modified binder was undertaken. The outcomes of this research should provide an insight into such applications.

Increasing asphalt recycling requires:

- Stronger support from the authorities and engineering community / consultants.
- Adaption within asphalt specifications
- Regulations with regard to dumping / tipping of re-useable material
- RAP should be regarded as a building material and not as a waste material
- Client stimulus to recycle
- Legislation to stimulate recycling

In The Netherlands, “Rijkswaterstaat” (RWS) has adopted a market approach to sustainability including:

- Use functional specifications and give design freedom to the market
- Do not prescribe solutions unless there is a specific reason
- Do not prescribe recycling, low energy asphalt, sustainable materials
- Challenge the market to come forward with innovations (techniques, materials, processes)

A high recycling degree givesa far bigger effect on carbon emissions than a lower production temperature. From the environmental point of view a high degree of recycling should not be sacrificed to get a lower production temperature. However, both of these can be reached at the same time with WMA-process. Trials to produce asphalt at 105°C and with 60% RAP met the performance criteria of hot mix asphalt.
For a sustainable future, RAP recycling is essential and represents major stakes for both bitumen and aggregate resource conservation. Better and more optimal RAP management is needed to fully utilise the recycling potential. French documents place strong emphasis on producing homogenous stockpiles of RAP whilst Dutch practice is to mill off and separate each different mix type individually. There is a huge potential for better RAP performances using appropriate application techniques, particularly when using aged polymer modified binders.

5. Climate Change

To ensure the promotion and development of road techniques adapted to climatic change, the project Techniques of Roads Adapted to the Climate Change (TRACC) has been conducted in Europe by institutions from three countries (Spain, France, and Portugal). Various techniques considered as potentially environmentally friendly were evaluated. It was concluded that the best technique for overall performance is cold recycling—in situ with bitumen emulsion or bitumen emulsion with a small amount of cement.

6. Waste Recycling

Recycling of wastes is going through a revival, thanks to a worldwide environmental and economics awareness. In this context, asphalt pavements are seen by many as a potential way to dispose of waste or surplus materials generated by other industries.

Following extensive laboratory evaluations, common practice in The Netherlands is to use construction and demolition waste (mixtures of concrete and masonry) as high quality base and subbase layers. The mechanical properties may be improved by foamed bitumen or cement stabilization. It appears that similar practices are not adopted in all European countries.
Recent research on using waste in asphalt has focused on:

- Slags of different kinds from the metallurgic industry.
- Ground tyre rubber (GTR) recycling has huge potentiality in terms of economics and environment. The usage has been growing worldwide lately, particularly in Europe following after the US which has had more than 25 years of experience in practice. Economically developed countries generate each year about 9 kg waste tyre /person.
- Polyolefin plastics recovered from waste streams.
- Using sulfur in asphalt has become more critical with new sulfur limits in various light petroleum products coming into play. The various “desulfurization” processes are resulting in huge sulfur stockpiles in refineries. There is therefore a growing incentive for oil companies to recycle sulfur, particularly in asphalt pavements.

There will continue to be a push to use more and more waste products in asphalt for the sake of getting rid of them. However, some, such as GTR, may be used to enhance pavement performance. Technical issues for recycling in asphalt pavements are clearly identified for most wastes. Smarter solutions to engineer waste modified binders or mixtures will come up in the near future, including more relevant analytical techniques to understand and design performing waste modified asphalt pavements by means of special processes and additives.
However, some remaining important questions will need to be addressed:

- “Re-recycling” of waste recycled asphalt pavements with respect to hazards and performance.
- Adaptation or devising new test methods / specifications / mix design / pavement design for these new materials.

The problem here is that the quality of asphalt must not be risked by solving a recycling problem of another material. Similarly, the use of waste products in asphalt should not subsequently restrict the recycling of that asphalt. For example, pavements containing coal tar binders and asbestos fibres are now placing severe restrictions on whether these materials can be recycled.
EN 13108-8 Reclaimed Asphalt concludes "Finally, non-waste status should only be able to be obtained after the waste has undergone treatment which results in a product that meets specific European quality criteria, ensuring that it may be used for the intended purpose in a safe and environmentally responsible way."

7. Warm Mix Asphalt (WMA)

The benefits in terms of reduced energy costs, reduced emissions and other potential advantages (better working conditions, less oxidative hardening, use of higher RAP contents, extended paving seasons) are well known. However, some questions remain to quantify its efficiency in terms of reduced energy consumption and environmental benefits.
Different technologies are used for the production of WMA:

- "Foaming technologies" (injected water, water contained in zeolite additives)
- Use of wax type additives
- Use of chemical (surfactant) additives.

The use of chemical surfactants seems to be the technique which fosters most interest from the research community at the present time.

PRODUCTION OF WARM MIX ASPHALT IN 2010

For this table **Warm Mix Asphalt** is defined as mixtures produced by using special techniques and/or additives to reduce the production temperature. The production temperature is between 100°C and 150°C.

Country	2010 (million tonnes)
Austria	0,000
Czech Republic	0,000
Estonia	0,000
Finland	0,800
France	1,000
Germany	No data
Great Britain	<0,5
Greece	0,000
Hungary	0,0004
Lithuania	0,000
Luxemburg	0,005
Netherlands	0,200
Norway	Insignificant
Portugal	0,000
Spain	1,250
Sweden	0,600
Switzerland	0,780
Romaina	0,000
Turkey	0,000
USA	42,600
Japan	0,120
Ontoria-Canada	0,500

Production of Warm Mix Asphalt in 2010 (Source EAPA)

Whilst many of the Warm Mix Asphalt production techniques can trace their origins to Europe, there is relatively limited use of the technologies as shown in the Table. Whilst France is shown as producing one million tonnes of WMA in 2010, total production of asphalt was 40 million tonnes so it only represents around 2.5% of the asphalt produced.
EAPA Environment Group's 2012-2014 Work Plan for Sustainability includes stimulating the use of WMA as a key activity.

The main topic is now the performance of WMA mixes as compared to their HMA counterpart. Stiffness and rutting resistance (felt to be a possible problem due to reduced oxidative ageing), as well as water sensitivity, are amongst the most frequently investigated issues. Advanced rheological tools, such as the MSCRT [Multiple Stress Creep Recovery Test] procedure and tribology experiments are sometimes applied and have shown that the particular nature of WMA additives (waxes, surfactants) does require an insight into the underlying

mechanisms of behaviour. Some research has questioned the relevance of performing some performance tests on extracted binders. With regard to binder characterization, an obvious concern is the RTFOT short term ageing procedure which should be adapted in the case of binders for WMA.

Other areas that require further considerations include:

- Low temperature performance
- Operational parameters, such as the potential modifications to asphalt mixing plants
- Low gas emission temperatures may not be seen as a problem in the course of a single industrial trial but may require special adaptations for continuous industrial production WMA technologies are often seen as offering the possibility to introduce higher amounts of RAP materials. There seems, however, to be a lack of data on the possible consequences in terms of old/virgin binder interaction, mix workability and end performance.

8. Vegetable Oils

There has been considerable research into renewable vegetable oil or other vegetal products as an asphalt mixture additive to reduce the dependency on and use of crude oils. In general, the studies show that adding vegetable oils may effectively reduce the viscosity of bitumen. Hence, it appears that using vegetable oils as rejuvenators or warm-mix additives to asphalt mixture is feasible and promising. However, long-term performance data of the mixtures produced using bitumen modified with vegetable oil are currently unavailable. In addition, cost analysis of using vegetable oil as an additive is also needed. Finally, due to the huge varieties of vegetable oils and base bitumens, extensive performance tests need to be conducted before any vegetable oil is used as an additive for a certain type of base bitumen.

Summary and recommendations

Sustainability has a wider scope than just the environment. There are three pillars: environment, society and economy, which should be in balance. Sustainable development gives opportunities; it is not only a threat. A high degree of RAP recycling has far bigger effects on carbon emissions than a lower production temperature. From the environmental point of view, the high degree of recycling should not be sacrificed to get a lower production temperature. RAP recycling is essential and represents major stakes for both bitumen and aggregate resource conservation. Better and more optimal RAP management is needed to fully utilise the recycling potential.

The use of waste products in asphalt must not reduce the quality of asphalt or subsequently restrict the recycling of that asphalt.

The main things to reduce carbon emissions are better energy efficiency, high quality durable pavements with long life and recycling. Ensuring high quality construction is a key to sustainability. There needs to be a strong focus on achieving high quality during the asphalt production and paving. This requires well-trained workers with a good knowledge of asphalt as a construction material.

Recommendations

1. Sustainable development offers opportunities and is not a threat.
2. Higher percentages of RAP should be promoted.
3. Waste products added to asphalt should not reduce quality or the ability to recycle.
4. Durability should be sought through higher quality production and paving.

7. HEALTH & SAFETY

Overview of reasons

- Australia has high expectations & legal requirements for a healthy & safe operating environment – key operating focus
- Europe is considered too aware and sensitive to this requirement
- Recent changes to the European operating environment (REACH, IARC, austerity) may have impacted and lessons learnt could be shared
- Specific issues and implications for Australia
    - Improving road work site safety
        - full closure / contraflow / automatic aids / speed
    - Increased environmental awareness & society friendly treatments
        - new developments | emerging concerns
        - impact of REACH on products and operations
        - IARC evaluations of bitumen and bitumen emissions

Feedback from

- France – IFSTTAR, USIRF, IDDRIM, Colas
- UK - Highways Agency & TRL
- Belgium – EAPA, Eurobitume
- Netherlands – VBWasfalt, DVS, TUDelft
- Germany – BP, German BITUMEN Forum, DAV

Observations

- Dropping the temperature of bituminous products to reduce fume generation are high priorities in Europe. This will likely accelerate the pace of the introduction of warm mix technologies. Particular attention will be given the use of high temperature (250°C) mastic asphalt used in Germany where agreement has been reached to limit mastic asphalt application to 230°C. When used for paving, bitumen producers recommend paving take place not higher than 200°C on the grounds of safety.
- The IARC monograph concluded that occupational exposure to oxidised bitumens and their emissions during roofing operations are 'probably carcinogenic to humans" (Group 2A). The CAS classification system does not reflect a difference between oxidized and air-rectified bitumen. However, distinction between certain materials in the same substance class may be made using certain physical characteristic e.g. PI.
- Risk management and good communication continue to be essential.
- Road worker annual fatality ranks highest in the UK when evaluated per person on the road.
- Road user and free flow of traffic through road works can be achieved through lane shifting and contra flow resulting in lower costs, increased safety and improved quality on construction.

1. Health

Australia road construction, surfacing and supplier industry to roads has a high regard for safety in the work place and for the health of those working in the sector. The Australian legal and regulatory framework has high expectations for the operating environment but there are systemic differences to what is done in Europe. Part of this section draws from an overview of the Warm Mix Asphalt – lower temperatures, lower fumes (F00 differences in Health and Safety systems and recent developments arising from the findings of the IARC Working Group evaluating bitumen and its emissions.

Both Europe and Australia are well versed in the evaluation of hazards that occur in road construction and the use of a risk assessment approach in dealing with hazards and exposure. In the case of bitumen usage, the hazards range from its use at high temperatures, and a fume containing small quantities of hydrogen sulphide (H_2S), with respiratory tract irritant potential and its possible carcinogenicity. The European approach is one of a clear identification of the hazards and then the reduction in exposure to ensure as low a risk as is possible. (05EE slides – Carl Robertus)

1.1 Using Bitumen Safely

The European approach to risk reduction was presented at the 5th E&E Congress by Dr Carl Robertus, on behalf of Eurobitume providing clarity on the implications and the status of bitumen and its safe use. The recent monograph on bitumen issued by IARC generated significant discussion and review in Europe. One of the recommendations is for additional CAS categories for oxidised bitumen / asphalt to clearly differentiate between IARC's separation into air-rectified and oxidised which currently are in the same category. This, however, is hotly disputed, and may not happen as it is expected that there will be fewer CAS classes/numbers associated with bitumen.
Other outcomes will include measures to promote communication of the impacts and to increase efforts to reduce the generation and exposure to bitumen fume.

Risks & Hazards

Using bitumen safely, requires an analysis of the hazards and exposures to determine the risk and then the reduction of the risk through reducing the hazard and exposure to reduce or eliminate the health impact.
The two systems that provide direction on this in Europe are IARC and REACH which are explained in detail later. IARC is about identifying carcinogenic HAZARD, and REACH is about RISK. (05EE slides – Carl Robertus)
The RISK based approach is best described in the table below where the measures that are required to minimise the risks from the hazards are identified and rated. In the table the key risk management measures are to control exposure through minimisation of temperature and fume generation.

Hazard	Exposure	Risk at high exposure Potential health impact	Risk Management Measures	Risk after measures
Heat / high temperatures	Dermal Contact	Skin damage … death	PPE, Equipment, Procedures	Low
H2S in fumes	Inhalation	Acute toxicity … death	Procedures, Equipment	Very Low
Cancer (due to PAH in fumes)	Inhalation, Dermal Contact	Chronic toxicity … death	Lower emissions, temperature, fume extraction equipment, etc	Very Low
Fumes (respiratory tract irritation)	Inhalation	Respiratory irritation Breathing difficulties	Lower emissions, temperature, fume extractions, etc	Very Low

Fume & emission

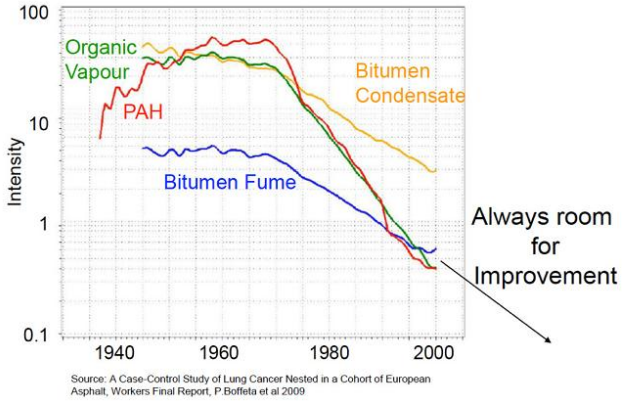
Managing emission and exposure is mainly a function of temperature control which can be achieved through:

Emission
- Aerosols and vapours from hot bitumen
- Fume condensates
- Organic vapour
- PAH (in fumes)

Exposure (Techniques)
- Systems
- Equipment
- Work duration
- Hygiene
- Quantity
- Procedures

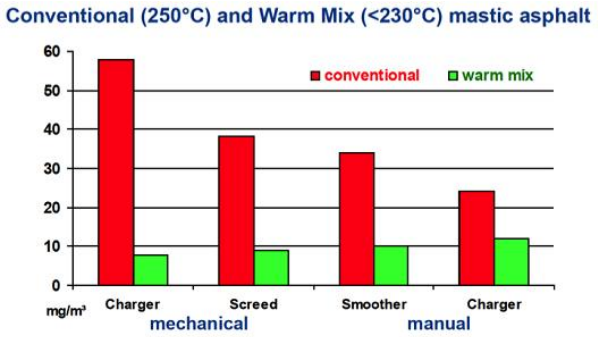
Exposure (Measures)
- Temperature control
- Innovative technologies
- Engineering controls
- Additives

These processes have been ongoing in the use of bitumen and there have been significant reductions since measurements started the 1940s. (05EE slides- Carl Robertus)



Lowering temperature

The emerging technologies of warm mix asphalt allow temperature reductions from 10 to 100°C and are increasing in usage. As part of the whole supply chain, additional reductions can be achieved through selection of raw materials and additives, modified production equipment and laying technologies and the use of improved work practices. Mastic Asphalt results from BG BAU in Germany showing the significant reduction in vapours & aerosols using Warm Mix technologies – (G003 Ruhl)



Mastic Asphalt results from BG BAU in Germany showing the significant reduction in vapours & aerosols using Warm Mix technologies – *(G003 Ruhl)*

For the mastic sealing and roofing industry, the introduction of warm mix techniques will also have a significant impact on fume exposure. The vapours and aerosol values represent the 95 percentile which is roughly double the average. Warm mix technologies temperature reduction will bring the exposure levels for mastic workers into a manageable range.

Communication

Awareness of the procedures and practices must be communicated effectively to be of value. Eurobitume and EAPA provide excellent resources through the internet on:

- Safe loading and delivery
- Transportation
- Safe handling, burns card
- Maximum safe handling temperatures
- Environmental information

These resources are then repackaged across their members to address specific local needs. Training forms part of the drive for increased health and safety which is also provided on a local basis.

Summary on using bitumen safely

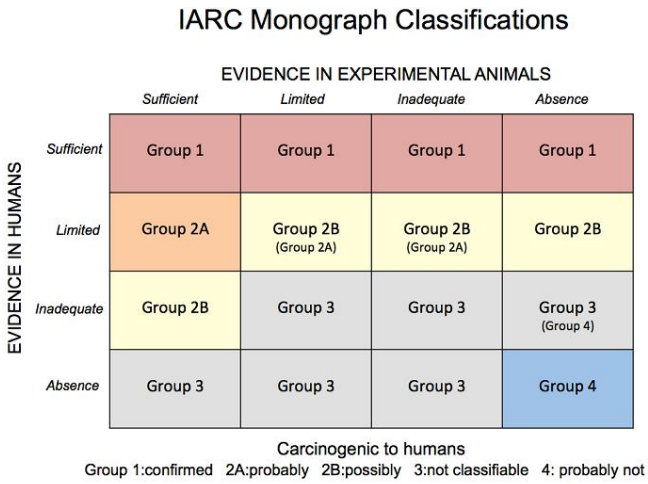
The refocus on the health and safety risks associated with the use of bitumen has confirmed that bitumen is not classified as hazardous to health or to the environment. The hazards of working with bitumen are now defined and the risks are very low and can be reduced even further through exposure reduction. Temperature control and reduction are key to reducing the level of emissions.

From a safety perspective, bitumen is usually handled and applied at elevated temperatures requiring workers to be adequately protected through training and operating to good practices and using the correct equipment (PPE). When used correctly, working with bitumen and asphalt is and remains safe.

IARC evaluation of bitumen and its emissions

"The International Agency for Research on Cancer (IARC) is an institution from the World Health Organisation. Its mission is to coordinate and conduct research on the causes of human cancer, the mechanisms of carcinogenesis, and to develop scientific strategies for cancer prevention and control. A particular task of IARC is the 'Monographs programme' which aims at identification of environmental factors that may increase the risk of human cancer. Factors considered include chemicals, complex mixtures, occupational exposures, physical agents, biological agents and lifestyle factors. Interdisciplinary working groups of expert scientists review the available scientific literature and evaluate the weight of the evidence that an agent may increase the risk of cancer. This process leads to classification of substances based on their carcinogenic hazard

potential. Although IARC classification has no formal legal status, national health agencies can use this information as scientific support for their actions to prevent exposure to potential carcinogens. It should be emphasised that the IARC evaluation itself is a hazard-driven process as it does not take into account the degree or severity of exposure." P.J.Boogaard 05EE-435



Classification framework for IARC – Human and Animal Evidence

IARC: "The distinction between hazard and risk is important, and the Monographs identify cancer hazards even when risks are very low at current exposure levels, because new users or unforeseen exposures could engender risks that are significantly higher."
REACH: EC Regulation 1907/2006
1. Ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals
2. Industry responsible for assessing and managing the risks posed by chemicals and providing appropriate safety information to downstream users.
The IARC monograph 103 is not yet in its final form but the release through the Lancet indicates that:
• occupational exposures to oxidized bitumens and their emissions during roofing operations are "**probably** carcinogenic to humans" (Group 2A)
• occupational exposures to hard bitumens and their emissions during mastic asphalt work are "**possibly** carcinogenic to humans" (Group 2B)
• occupational exposures to straight-run bitumens and their emissions during road paving are "**possibly** carcinogenic to humans" (Group 2B)

This is the identification of a cancer HAZARD even if risks are very low at current exposure levels, it is also about the occupational exposure and not the substance itself.

1.2 REACH & IARC systems

The legislation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) entered into force in the EU from June 2007. It applies to all chemicals manufactured in or imported into the EU in quantities greater than 1 tonne/year. (05EE-435 Boogaard) Bitumen is considered a chemical and is subject to REACH as an "Unknown or Variable composition, Complex reaction product or Biological material"(UVCB).
REACH requires a Chemical Safety Report (CSR) which must cover the production volume, intended uses and physico-chemical properties. The report must also include extensive data on the environmental hazards, human health hazards and hazards to man through direct exposure via the environment. Further, if classified as hazardous according to the Dangerous Substances Directive then a health assessment is to be undertaken and a Chemical Safety Assessment (CSA) submitted. CONCAWE (the oil companies' European association for environment, health and safety in refining and distribution) on behalf of the petroleum industry provided a hazard assessment of the bitumen
category comprising 9 CAS registry numbers. As part of the CONCAWE Report 11/10 "Hazardous classification and labelling of petroleum substances in the European Economic Area – 2010" bitumen and oxidized bitumen

are not classified as hazardous. Bitumen suppliers voluntarily supply Safety Data Sheets to their customers covering:

- REACH information requirements
- Safe handling information (hot product, maximum safe handling temperature, transport, H2S etc)
- Health end point: irritation of respiratory tract
- No “exposure scenario” annex is required.

REACH is a risk-driven assessment where the responsibility for the product is passed from the legislator onto the manufacturer or supplier. The regulation ensures a high level of protection of human health and the environment from the risks posed by chemicals. Industry is responsible for assessing and managing the risks posed by chemicals and providing appropriate safety information to downstream users.
For chemicals manufactured or imported in excess of 10 tonnes/year, REACH also requires the derivation and documentation of the Derived No Effect Level (DNEL) based on available data. DNEL establish a limit beyond which a person should not be exposed. The availability of the DNEL and the assessment of the working / usage conditions allow a risk evaluation “Exposure Scenarios” and provide a Risk Characterisation Ratio (RCR). If less than 1, then the risk is acceptable under REACH. A DNEL, for short term respiratory tract irritation, has been established of 2.9 mg/m^3 for bitumen fumes (THC) based on an average over an 8 hour work shift. (05EE-435 Boogaard)
The IARC evaluation of bitumen and its emissions in paving, roofing and mastic application has placed roofing(oxidised bitumen) into Group 2A. Occupational exposure to straight run bitumen and its emissions during paving is in Group 2B. Both oxidised and straight run bitumen are included in a single CAS category. There is a possibility that CONCAWE may review the situation and propose alternate CAS categories.

1.3 Health awareness in pavement materials selection

Warm Mix Asphalt

The use of warm mix asphalt technologies is limited in Europe with most States investigating its use over the last decade. Barriers to introduction include the wide range of alternate technologies available and the perceived need to evaluate each individually. The health advantage for asphalt workers is an important driver to quicker introduction of WMA and the closing remarks at the 5th E&E Congress included intentions to increase the its use.

Sanitary aspects of old asphalt pavements

Many countries have old pavements with residual tar included in their initial construction. Some, such as France, also have asbestos in their pavements. Tests to identify from previous construction records to scientific testing for presence and percentage are in place. Once identified, the potential for impact on the environment is evaluated and measures are undertaken. These range from incinerating the material, disposal in hazardous material dump sites to managed reuse, in the case of tars in France, to low temperature applications. Generally the material is rendered inert. The cost of these actions can be over €29 per tonne. This has generated resistance to the addition of “waste” material and unneeded additives into hot mix asphalt and road pavements.

IFSTTAR in France have developed a fume generator to research the implications of fume and its components to allow for the ranking of bituminous mixes against their fume generating potential. The project seeks to develop laboratory tools which can predict or forecast asphalt fume generation.

2. Safety

Safety is a high priority across Europe and individual countries address their safety issues and manage their risks matched to the local environment and their road users. Good statistics are kept by the European Union and it is possible to rank the various states for their road accidents. (B06 – European Roads Statistics).
Direct feedback was received from the United Kingdom via the Highways Agency and TRL with other input based on inspections during the tour.

2.1 Road Worker Safety

he Highway Agency, supported by TRL, has a strategy for health and safety titled “aiming for zero”. In the road work zone, it is targeted to include all likely staff and the supply chain: construction and maintenance workers, road workers, traffic officers and control room staff, office and RCC-based staff. (U02 – HA)
Road workers are acknowledged as being at high risk of fatal and serious injury especially during placing removal of temporary traffic management. Goals set for road worker safety:

- Elimination of all fatalities, serious injuries and long-term ill health to road workers maintaining the HA network, with significant reduction in carriageway crossings over the next two years with the elimination of the need for workers to be on a live carriageway by 2016.
- Highlighting the importance of road workers and the job they do, by raising the awareness of road users and influencing their behaviour at road works.
- Actively working with the HA supply chain and stakeholders to enhance the HA safety performance by sharing best practice and improving communication.

The “Aiming at Zero at the Highways Agency” program adopted a holistic approach to health and safety, not seeking “bolt-on” solutions with engagement of the whole supply chain in the process. The problems were prioritized with the biggest risks identified. (U002 – Paul Mitchell)

Category of people	Number of people	Average fatalities per year	Fatality rate
Road workers	2 000	2	1 in 10 000
Road construction	15 000	1	1 in 15 000
Road users (all roads)	30 000 000	1 850	1 in 16 000
Road users (HA roads)	8 000 000	248	1 in 32 000

Road workers were identified as a high exposure group with fatality rates at 1 in 10 000 workers per year. Four project themes were developed each containing research projects and other work streams. The project themes were:

1. Continual review of working practices to reduce risks to road workers
2. Reducing speed and improving compliance through road works
3. Improving driver behaviour through road works
4. Improving communication of road worker safety initiatives

Theme 2 has projects to:

- investigate different speed restriction methods to reduce the speed of vehicles through road works
- Improve compliance with speed restrictions at road works
- Investigate RedX (gantry signs) and hard shoulder non-compliance issues

Theme 3 includes the “Respect our Road Workers” campaign which included advertising in the press and on television. (U003 – Mark Pooley)

Completed road worker safety projects include guides on Innovative Cone taper Technique, Risk based approach to safety barrier repairs, H&S toolkit in the HA intranet, Training vehicles for use by the supply chain, Temporary barrier decision tool, Temporary traffic management simplification. These guides can be downloaded from the HA website under Interim Advice Notes. www.dft.gov.uk/ha/standards/index.html

IAN 142 Temporary Barrier Decision Tools provides a risk based evaluation of the most suitable option for the standard of temporary barrier to use. (U24-HA)

2.2 Road User Safety

Road user safety and comfort were identified including the use of ultra thin high friction surfaces which also provided noise reduction. These surfacings consist of small sized aggregate 4 to 6mm with layer thicknesses of 15 to 18mm. Ultra thin asphalt surfaces for noise reduction and skid resistance An example of this surfacing type was provided in Germany by a researcher at the Ruhr University at Bochum (G004 – Miljjovic). This surfacing has an inverted void structure with flat faces of the aggregate at the surface providing a smooth plain. Having a higher void structure below provides better sound absorption. The small aggregate size supplies many friction contact points improving the skid resistance of the pavement.

Road Work Zone separation

Providing the road user with a free flowing carriageway separate from the road construction activity was a common safety measure for the road user and road worker in Europe. Various systems were used with the attempt to better utilise the available width of existing carriageways to accommodate the traffic. Detours were noted on the routes in Germany which seem to be well planned and also used to accommodate emergency closures. In the Netherlands their pavement design and strengthening policy revolves around providing full access to the road contractor for rehabilitation on a 9 to 15 year cycle.

The experiences in Europe are captured in the photos of road works. The photos indicate the minimal impact the road construction has on the road user and the high levels of separation and safety that this approach provides to the road contractor. Cost savings, improved quality and reduced time to construction is an expectation.

Netherlands – road construction adjacent to existing dual carriageway. Cross-overs incorporated into construction allowing for the new facility on the other side.
Impact on the road user is minimal.

Germany – lane closure for maintenance with traffic lane shifted. Traffic accommodated on shoulder lane with potentially reduced lane width. Traffic speed not affected although reduced speed limits were posted
Impact on road user limited, little change to traffic flow.

Germany– contra flow single lane - two lanes provided for rehabilitation – free of traffic in work one. Over a few kilometres including a change in number of lanes.
Impact on road user limited – little change to traffic flow.

Summary and recommendations

Road worker health and safety retains its position as a key requirement of operations in the road construction and surfacing industry. Experience from Europe brings a greater awareness of the options open to promote better health and improved safety on worksites. The role played by road agencies and industry representative bodies is critical in ensuring the required standards are met and the improvements carried out.

Observations

- Dropping the temperature of bituminous products to reduce fume generation are high priorities in Europe. This will likely accelerate the pace of the introduction of warm mix technologies with particular attention to the use of high temperature mastic asphalt.
- The IARC monograph concluded that occupational exposure to oxidised bitumens and their emissions during roofing operations are 'probably carcinogenic to humans" (Group 2A). The CAS classification system does not reflect a difference between oxidized and air-rectified bitumen. However, distinction between certain materials in the same substance class may be made using certain physical characteristic e.g. PI
- Risk management and good communication continue to be essential.
- Road worker annual fatality ranks highest in the UK when evaluated per person on the road.
- Road user and free flow of traffic through road works can be achieved through lane shifting and contra flow resulting in lower costs, increased safety and improved quality on construction.

Recommendations

1. Review the Australian risk management guides on the use of bitumen
2. Communicate the hazard and exposure methodology in the safe use of bitumen
3. Promote the reduction of temperature in the use of bituminous products
4. Promote the use of lane shifting and contra-flow to improve quality, increase safety and reduce costs.

Health & Safety- Questions & Responses

Health

Impacts of IARC evaluation of bitumen on industry?

"Occupational exposure to straight run bitumen and its emissions during paving is 2B.(possibly yes - possibly no.) The cancer HAZARD has been identified. The RISK is very low. There is no scientific evidence for a causal link between cancer and the use of bitumen in road paving". (Carl Robertus)

"The recent IARC evaluation is a hazard assessment based on review of data from animals, exposed humans and on possible mechanisms of action. The final evaluations do not relate to the bitumen in situ but relate ONLY to occupational exposure to bitumen emissions during paving, roofing and mastic asphalt work. It is important to recognise that the monograph seeks to identify the cancer hazard potential of an agent not the level of risk. Based on industry evaluation of human studies and current levels of exposure to bitumen emissions, the risk to worker health is considered to be extremely low.

It has long been recognised that there is no exposure to bitumen emissions in service. Bitumen in service is inert and presents no risk to the public or the environment". (Eurobitume FAQ)

1. Has REACH impacted on the supply and use of products?

REACH has vested the risk management and product usage responsibilities onto the importer or producer of bituminous materials in Europe. This has not directly affected the supply of the usual bituminous products but may slow the process of introducing products with unknown components. No indication was given during the Study Tour that REACH limited the supply of products.

2. Drive for healthier products? What products?

Cutbacks are severely limited in availability and use. Lower temperature products and better performing binders with known additives are dominant. The wide range of temperature lowering additives make their individual selection more difficult.

3. Noise – measured, surfacing options, maintenance?

Noise is measured both in the development of products and in certain countries in their operation over time. This allows for the selection against performance and against alternate treatments. Close proximity devices are used to assess surfacing noise reduction. Noise generating test equipment can also be utilised at laboratory

development stage. Maintenance measures to retain or reinstate noise reduction benefits (and surface frictions) are seldom used.

Safety

1. Statistics – injuries & fatalities? How measured & collected?

UK feedback from Iain Rillie (U13)

- *Road users: statistics collected via STATS19 (national accident database for injury accidents / fatalities)*
- *Road workers: nationally to the Health and Safety Executive for injuries at work that cause absence of more than 7 days*
- *Highway authorities should collect details from their contractors e.g. Highways Agency in England via AIRSWeb*
- *Individual contractors collect data on everything from fatalities to near-misses using systems that invariably record slightly different data, usually in incompatible formats*
- *Highway authority data for contractor accidents is generally poor; under-reporting of even serious incidents appears to be commonplace*
- *This appears to be driven by a belief by contractors that accident records will be used as a metric for future contract award, which discourages accurate reporting*
- *Reinforced by the use of AFR as a KPI to manage safety; this has the unintended consequence of changing the behaviour of those involved with accident reporting*
- *Effective validation is key to accurate data; national data (e.g. STATS19) is always validated but validation of other data sources is carried out at point of use*
- *Point-of-use validation is difficult and time-consuming; without it, outputs from accident database analyses tend to be of questionable reliability.*

2. What are the greatest road worker risks?

High temperatures of the products used and road work site interaction with plant and public vehicles remain the biggest risks. Exposure to H2S and bitumen fume are very low level risks when proper procedures are followed. In Europe the need to move to lower temperature systems is acknowledged.

Based on input from Iain Rillie, United Kingdom (U03)

- *The risk to temporary traffic management operatives is fifteen times higher than a road construction worker.*
- *The greatest risk to any worker is associated with setting out and removing temporary traffic management equipment on a high speed road.*

3. What training is available?

There is training available in the United Kingdom through the RBA
http://www.bitumenuk.com/healthsafety-safety.asp
Safety training is largely undertaken in-house or in local jurisdictions.
Based on input from Iain Rillie, United Kingdom (U13)

- *Standard for work on high speed roads is the National Highways Sector Scheme (NHSS) which covers a range of skills.*
- *NHSS is administered by LANTRA Awards (www.lantra-awards.co.uk) and courses are delivered by both training providers and accredited in-house trainers*
- *NHSS specifies an element of on-the-job training; only one trainee is permitted per works crew*
- *Standards for urban roads are lower; under the New Road and Street Works Act, only one operative in a gang must be trained and competent.*

4. What techniques / methods for safer maintenance?

Varies by country – lane shifting and contra-flow is regularly used for rehabilitation works. Short term maintenance approaches tend to concentrate on the provision of the short term safety for separation of the traffic where the provision of the barriers carry risk. No obvious special techniques or procedures were noticed that were not already in use in Australia.

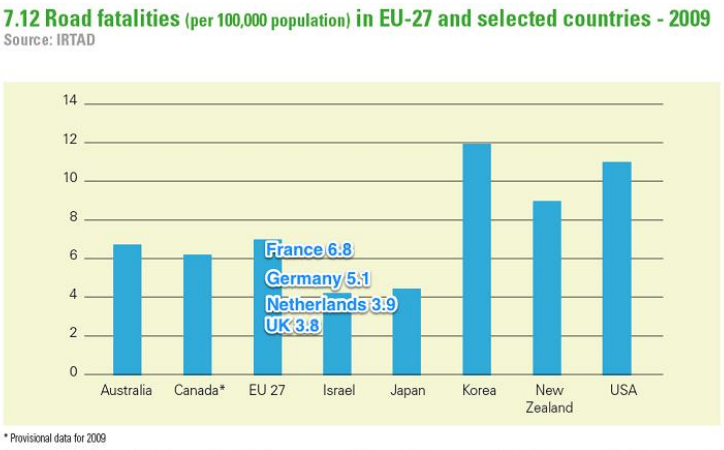
Based on input from Iain Rillie, United Kingdom (U13)

- *Emphasis is moving towards "less is more" when it comes to traffic management, adopting the approach of eliminate / mitigate / manage. For example:*
    - *ELIMINATE: don't put signs in the central reservation*
    - *MITIGATE: reduce the number of signs needed by missing some out*
    - *MANAGE: place the signs from vehicles*
- *Safer maintenance can be cheaper or the same price maintenance; achieving this means it will be embraced by all parties.*

• *Some techniques are more expensive but can deliver time savings; in this case the benefits mean they are also adopted*
• *Other approaches deliver the same function as present practices for more money; these are more difficult to sell!*
• *Risk based approaches are being adopted, enabling some maintenance activities to be delayed until they can be undertaken within scheduled works*
• *New contract terms seek to undertake less maintenance, ironically driving down the risk to road workers involved in maintenance activity*

5. Communicating road worker safety needs to the public – how?

As used locally, awareness campaigns are run along with increased law enforcement on road repair and maintenance sites. The approach is dependent on the road user profile and varies per country. The comparison between Australia, European countries and the USA indicates that each country will have a differing potential for road accidents which therefore would apply to a road construction site.



***European Road Safety Statistics – road fatalities per 100 000 population** – (B06)*

Campaigns have been undertaken to bring the importance of the road worker's role to the attention of the public and the road user as described under 2.1 Road Worker Safety.

Based on input from Iain Rillie, United Kingdom (U13)

• Issue is not restricted to the public; road worker safety has a poor level of awareness within even the road maintenance / planning professional community
• Articles in professional journals (e.g. Network Management Note from the Chartered Institute of Highways and Transportation)
• Within industry, initiatives such as the Road Workers' Safety Forum Newsletter (www.rowsaf.org.uk)
• National governmental publicity campaigns such as 'Respect Our Road Workers' (http://www.highways.gov.uk/knowledge/20639.aspx)
• Local media campaigns such as radio commercials (examples on www.rowsaf.org.uk)

6. Urban & multi accessed sites – any special safety approaches?

The typically congested sites as evidenced in Australian capital cities also occur in the European capitals. The pace of the activities appeared to be less pressured with fewer safety individuals present. Sites witnessed out of the city appeared to be separated from the traffic with fairly densely packed common activities. Site control and access appeared similar to Australian conditions. No special safety approaches were apparent apart from the traffic exclusion.

Based on input from Iain Rillie, United Kingdom (U13)

• *Urban sites need higher standards of guarding and management for pedestrians and vulnerable road users*
• *Minimum standard often applied; independent auditing of design and engagement with end-users used to ensure that needs of special groups are met*
• *Multi-access sites: site accesses need to be managed carefully to ensure that risk of traffic movement within site is regulated*
• *Identifying site access is a problem on some sites; use of innovative markers at accesses apparently helps!*

7. Are higher safety road surfacing products preferred?

Europe has a wide range of specialised thin treatments for high surface friction and noise reducing properties. Their use is common practice and their selection based upon the safety requirements of the site. The surfacings

fall into broad categories and are generally purchased against a performance category related to traffic and safety need. There did not appear to be any specific branded product which was more popular than others.

Reference Material

List of the presentations or other material gathered during the tour.

1. Evolution of Asphalt Mixes – Innovations in France, High modulus mixes – new wearing course, recycling – warm asphalt, Yves Brosseaud, IFSTTAR, presentation, June 2012 Paris, France (F009)
2. Bitumen Health and Safety, Carl Robertus, Eurobitume, 5th Eurobitume & Eurasphalt Congress, 2012 Istanbul, Turkey (05EE slides – Carl Robertus)
3. Vapours and Aerosols of Bitumen – exposures and classification, Reinhold Rühl, BG BAU, BASt, presentation, June 2012 (G003)
4. Status of bitumen under the REACH regulation, Peter J Boogaard, 5th Eurobitume & Eurasphalt Congree, June 2012 Istanbul, Turkey (05EE-435)
5. Health and Bitumen, Peter Dewez, Eurobitume, Bruxelles March 2012 (B002).
6. France's Perspective on Warm Mix: Research and Practices, Vincent Gaudefroy, IFSTTAR – France, June 2012, presentation (F004)
7. ERF European Road Statistics 2011, European Road Federation, Brussells, Belgium (B06)
8. Aiming for zero, strategy for health and safety at the Highways Agency, Highways Agency, UK, April 2010 (U02)
9. Aiming for zero at the Highways Agency, Paul Mitchell, presentation, June 2012, London UK (U002)
10. Aiming for Zero – Road Worker Safety, Mark Pooley, Highways Agency, presentation, June 2012, London, UK (U003)
11. Interim Advice Note 142/11 Temporary Barrier Decision Tool (TBDT), Highways Agency, April 2011, UK (U24)
12. LOA 5 D – Thin Noise-Reducing Asphalt, Technology & Performance, Milomir Miljkovic, Ruhr University, Bochum, presentation and paper June 2012, BASt Germany (GOO4, G04)

8. PROCUREMENT SYSTEMS

Overview of reasons

- Australia has tried to set up systems like Avis Technique & HAPAS but have been unsuccessful
- The benefits of innovation and declining skills in the road authorities point to its greater use.
- Lessons learnt, benefits of the systems used, changes to purchasing to accommodate and implications for road authority expertise is sought.
- Use of the systems to promote innovation and product development in new areas such as CO2 reduction, energy efficiency, nose reduction etc.
- The use of procurement systems from PPP, Alliancing, DBOM, ECI including normal contracts, long & short term contract maintenance systems.
    - What key performance characteristics over time?
    - How to retain the culture of stewardship in the contracting agency?
    - How to retain expertise on the road authority to manage / ensure value-for-money?

Feedback from

- Netherlands
- United Kingdom
- France

Observations

The European market is diverse and well established with systems that have been developed over decades. The forming of a common economic block and the harmonisation of standards and systems has done much to promote common approaches. It has also increased commercial competition across the states where CE-marked products can more easily shift jurisdictions.

This has also had the effect of creating completion amongst for locally developed systems – as in eco-calculator tools. More positively it has encouraged the copying of efficient systems such as the French innovation supporting Avis Technique and Charte d'Innovation by the UK and the Netherlands.

Good opportunities exist to help the move from method to performance based specifications for industry products and services. The change is not simple and does require a broad commitment to develop the skills, obtain the suitable equipment and gain the experience from those further down the path. Europe has much to offer but in where to go and how far is sufficient.

1. Innovation and product certification systems

Europe and, in particular France, has had product certification systems which were established to promote innovation and establish a process to take the acceptable innovations into the market.

The major points that are important for innovation are:

- Innovation development is done by industry. The road authority describes performance requirements (Charte d'Innovation) and is open to novel products that provide equal performance to conventional products (Avis Technique, HAPAS)
- The proof of performance is based on functional test methods, accepted construction design models etc
- The verification of performance is done by independent bodies formed through mutual cooperation between road authorities and industry
- When a product is accepted, the field of application, the performance characteristics and practical experiences are published

The introduction of European Union Construction Products Directive (EU-CPD) requires the Emarking on products which confirms that they comply with European Standards. The CE-marking only indicates that the products meet the Essential Requirements and is not a quality marking.

Where there is no harmonised European Standard, nor a mandate to produce one, a European Technical Approval (ETA) can be obtained provided the product (not system) complies with the assessment criteria. When an ETA is awarded the product may bear the CE-mark allowing it to be sold in the European Common Market area.

Four paths for development of an innovative product are described below which were drawn from the EAPA publication "Innovation Implementation in Road Contracts". (B03) During the meetings in the UK and France, it

was clear that the systems are still in use and delivering new and innovative products. The inclusion of the CE-marking does not appear to have detracted from the use of the systems.
Additionally the Netherlands has an Innovation Test Centre of the Rijkswaterstaat which provides a separate procedure to encourage innovation and to provide a process to evaluate unsolicited proposals of innovative ideas or products. Based on Carte d'Innovation and Avis Techniques, it provides: (N014)

- Validation of new materials before acceptance
- Focus on innovations that are (almost) ready for implementation
- Test facilities (locations) and validation surveys

Avis Technique

The Avis Technique system is under the control of a committee of French road administration and industry. A company applies for technical advice on a product, filing information on:

- Properties of the product on composition or performance, covering minimum mandatory criteria, typically characteristics of the binder.
- Results of tests and a list of experiments or works where the product has been applied.

The sites are inspected and the committee delivers the technical advice. The final advice covers the results relative to standard reference values, and provides indication of how the product can be used in alternate pavement design, or for an innovative product, a comparison to construction using standard products.

Also a French system, it is operated through the national road authority and has a section for road construction innovations and another for engineering structure innovations. The road authority identifies areas for innovation and contractors can propose ideas and actions. Contractors are selected to present their ideas covering:

- Description of the product, technique or material
- Description of the application method
- Results of tests and trials
- The price
- Reference to works that have been executed with the innovation

After review and acceptance by the road authority four approaches are possible:

1. Executing tests under laboratory conditions
2. Building a test section under laboratory conditions
3. Application in full scale projects for technical demonstration (partially paid)
4. Application in full scale projects for economic demonstration

After successful completion of the technical demonstration (3), the contractor is issued with a certificate of acceptable performance. When the innovation is not accepted, the contractor is informed of the conditions under which the innovation might be acceptable. The successful innovation can be used on sites to develop experience to apply for an Avis Technique.
In approach (4), if an alternate tender is offered with equal of better performance, then, if accepted, the contractor may apply the innovative product and demonstrate its performance.

HAPAS

This system is based in the United Kingdom where the Highways Agency and Country Surveyors' Society set up the "Highways Agency Product Approvals Scheme (HAPAS)" in 1995. The system is run in conjunction with the British Board of Agreement (BBA). The scheme is supported by a technical advisory committee (HiTAC) with representatives from BBA, HA, Association of Directors of Environment, Economy, Planning & Transport (ADEPT), Local Government Technical Advisors Group (TAG), Mineral Products Association (MPA), Highways Term Maintenance Association (HTMA) and the Civil Engineering Contractors Association (CECA).
The HAPAS scheme covers 10 specialist groups:

- High-Friction Surfacing Systems
- Crack Sealing Systems – Inlaid
- Crack Sealing Systems - Overbanding
- Crack Sealing Systems – Fill and Overband
- Thin Surfacing
- Modified Bitumens for Surface Dressings, Micro Surfacings and Bond Coats
- Bridge Deck Waterproofing
- Permanent Cold-Lay Surfacing Materials (PCSM)
- Coloured Surface Treatments

- Anti Corrosive Paint

Each specialist group has representatives of the Highways Authorities, the BBA and specialist producers of the products. The specialist groups develop guidelines for assessment and certification with the BBA staff undertaking the assessment. Six common steps in the assessment are:
Stage 1: Assessment of data supplied by the proprietor
Stage 2: Agreement of Quality Plan and Assessment of factory production control
Stage 3: Laboratory testing by an accredited laboratory
Stage 4: System installation trial to demonstrate practicality of the process
Stage 5: System performance trial to monitor performance in the road over two years. Survey of customers with two or more years experience with the product / system.
Stage 6: Certification and audit of the supplier and review by BBA

ETA – European Technical Approval

An ETA for a construction product is a favourable technical assessment of its "fitness for its intended use" in the meaning of the CE-marking when no European Standards are available to describe the product characteristics.
An ETA is based on the contribution made by the product to the fulfilment of the six Essential Requirements, as stated in the EU "Construction Products Directive" (CPD) for the construction in which the product is installed.
An ETA can be granted when any of the following conditions apply:

- No relevant harmonised standards for the product exist;
- No mandate for such a Standard has been given by the European Commission;
- The European Commission considers that a Standard cannot be developed (yet);
- A product deviates significantly from the relevant Harmonised Standards.

In conjunction with an "Attestation of Conformity" procedure (which is intended to ensure that the product specification set out in an ETA is maintained by the manufacturer), ETA's allow manufacturers to CE-mark their products (a CE-mark is required for all products put on the market within the EU viz. within the European Economic Area). A CE-mark (based either on European Standards or on an ETA) covers the Essential Requirements part of the product.

2. New tools for sustainable procurement

Europe has included the environmental impacts of the products and is included in tender evaluations. Consequently, Life Cycle Analysis tools have been developed which include the key CO2e, reduction in use of non-renewable natural resources, energy usage and benefits from recycling or the use of lower energy density materials.
There is no uniform approach and all are at different stages of introduction and complexity. On the tour and at the Congress three high profile tools were identified - asPECT, SEVE and DuboCalc. Each will be covered in the detail that follows. It is worth noting that there are varying levels of involvement by State Roads Authorities in each tool with and in the Netherlands use is also made of an additional tool to rank businesses against environmental compliance. This is then used in the contract award process and it allocates up to 5% in value for highest level certification.

asPECT

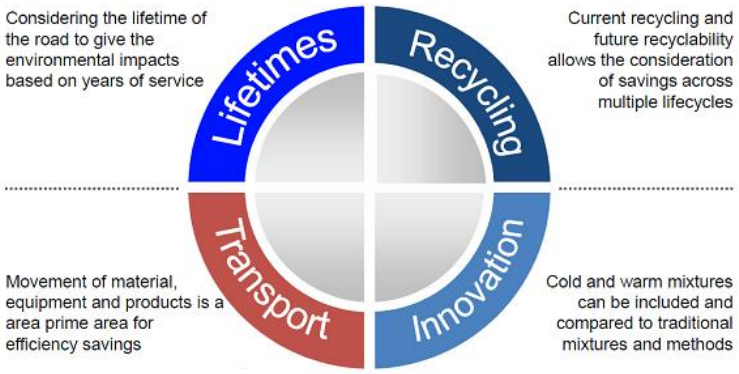
The Asphalt Pavement Embodied Carbon Tool (asPECT) was developed as a collaborative effort by the UK Highways sector: UK Highways Agency, Mineral Products Association, Refined Bitumen Association and TRL. (05EE-160)
asPECT consists of protocol documentation and software. It takes a life cycle approach that follows the Publically Available Specification PAS 2050:2008 and assesses greenhouse gas contributions from raw materials acquisition, product production, installation, maintenance and end-of-life impacts. The method is flexible enough to allow consideration of individual materials, recycling, heating and mixing energy and selected transport modes.

Life-cycle stage		Description
1	**Raw Material Acquisition**	Winning of raw materials from the natural environment with the input of energy
2	**Raw Material Transport**	Linking the winning of raw materials to processing of raw materials
3	**Raw Material Processing**	Crude oil refining, rock crushing and grading, recycled and secondary material reprocessing
4	**Processed Material Transport**	Linking the processing of raw materials to the manufacture of bitumen bound highway components
5	**Road Component Production**	Production of bitumen bound mixtures
6	**Material Transport to Site**	Delivery of bound materials to site
7	**Site Preparation, Laying and Compacting**	Included for new road construction: capping, sub-base, base, binder course, surface course
8	**Scheme Specific Works**	Installation of geosystems, traffic management etc.
9	**Maintenance**	Interventions to maintain the road. Re-surfacing, surface dressing works, patching, haunching etc.
10	**End of Life**	Deconstruction and material management

Use

Generic life cycle of road construction – *(05EE-160)*

The tool requires calibration and input from provided sources in the UK, reflecting typical or published greenhouse gas outputs such as for transport, but requires direct energy consumption data from the asphalt production by-product. This is sourced from historical records and provided as ongoing input to the model. The use of RAP and the potential for recycling the bitumen and aggregates has its benefits partially distributed to future use of the material as well as considering the potential loss from the recycling system. The tool makes it possible to discriminate between high temperature, high fines, high moisture mixes reflecting higher energy usage and the savings due to lower fines, drier input and lower temperature warm mixes.



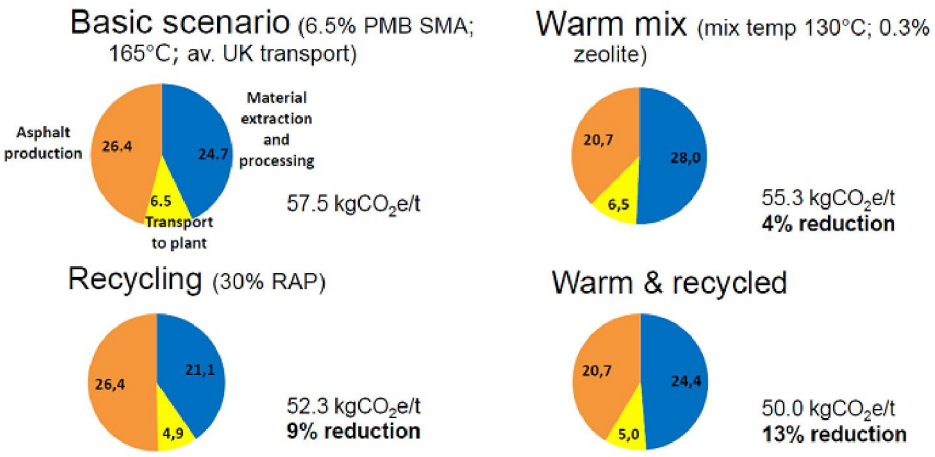
Key features of asPECT – (05EE-160)

asPECT is available for download at no charge from www.sustainabilityofhighways.gov.uk which provides access to the four components

- The protocol – a defined set of "rules" for foot-printing asphalt products and applications
- Guidance – explains the decision-making process behind the Protocol and provides worked examples
- Software – facilitates the calculation for those that choose to use it (calculations can alternately be embedded into company systems)
- Software user guide

The diagram indicates the key features that asPECT is able to address in Lifetimes, Recycling, Innovation and Transport. It provides a rapid assessment tool to determine the CO2e/t differences between mixes.

The commitments by governments to the reduction of CO2 and greenhouse gasses places the onus on industry and government departments responsible for infrastructure to clarify their position in achieving these goals. It can be expected that tools such as asPECT, and others such as DuboCalc and SEVE will be used by road funders to measure and select the best products, projects and contractors when required to meet government climate change objectives.



asPECT example – cradle to grave assessment of four options *(05EE-160)*

asPECT provides that means to measure carbon in asphalt products and highway products and is considered to be robust, transparent, easy to use and freely available.

SEVE

Rolled out in July 2010 by the French Road Builders Association (USIRF), SEVE is an eco-comparing software tool designed for use by the broader road construction industry. (A5EE-529) SEVE allows the bidding for contract process to compare environmentally friendly technical alternatives.

The program is operated on-line requiring no updates or downloads drawing from a common database of specific information. Confidential company data and mix algorithms are stored in the data base but only available to the company. Four main indicators are included in the comparison:

- Greenhouse gas emissions (in tonnes of CO2e)
- Energy Consumption (in Mega-Joule)
- Consumption of aggregates (tonnes)
- Reclaimed asphalt pavement or RAP content (in tonnes)

Life Cycle Analysis including Co2, consumed energy, preservation of natural resources, RAP usage *(A5EE-529)*

The LCA evaluation process is applied to new products to evaluate the environmental improvements, and included in contracts to quantify the advantages of alternate lower impact products. Output from SEVE is in the form of charted differences for LCA as indicated in the diagram.

Extra information is available from the internet (in French) including the manual on the operation of the "SEVE eco-comparateur" program www.seve-tp.com

DuboCalc & CO2 Performanceladder

The Netherlands has developed a two part approach to encouraging the reduction of CO2 in the production of asphalt pavements and in sustainable procurement.

DuboCalc

The first part is an LCA based tool using an international standards database for materials and energy relationships. The program "DuboCalc" utilises the database, project specific information and the environmental cost calculator for 11 environmental effects. Output is an Environmental Cost Indicator (MKI in Dutch) expressed in Euros and in tonnes of CO2e. DuboCalc is part of the sustainable procurement initiative of the Netherlands Government.

MilieuKostenIndicator (MKI) Materials and processes

Milieueffectcategorie	Items (M/P)	Equivalent unit (kg)	Env. Cost [€/kg	
equivalent]				
1. Climate change	5,8	CO_2 eq	€ 0,05	0,29
2. Effect on ozone layer	etc	CFK-11 eq	€ 30,--	etc
3. Human toxicity		1,4-DCB eq	€ 0,09	
4. Ecological toxicity, sweet water		1,4-DCB eq	€ 0,03	
5. Ecological toxicity, salt water		1,4-DCB eq	€ 0,0001	
6. Ecological toxicity, land		1,4-DCB eq	€ 0,06	
7. Photochemical reactivity Smog)		C_2H_2 eq	€ 2,--	
8. Acidification		SO_2 eq	€ 4,--	
9. Over fertilisation		PO_4 eq	€ 9,--	
10. Depletion of non renewable materials		Sb eq	€ 0,16	
11. Depletion of fossil fuels		Sb eq	€ 0,16	
			MKI	XX

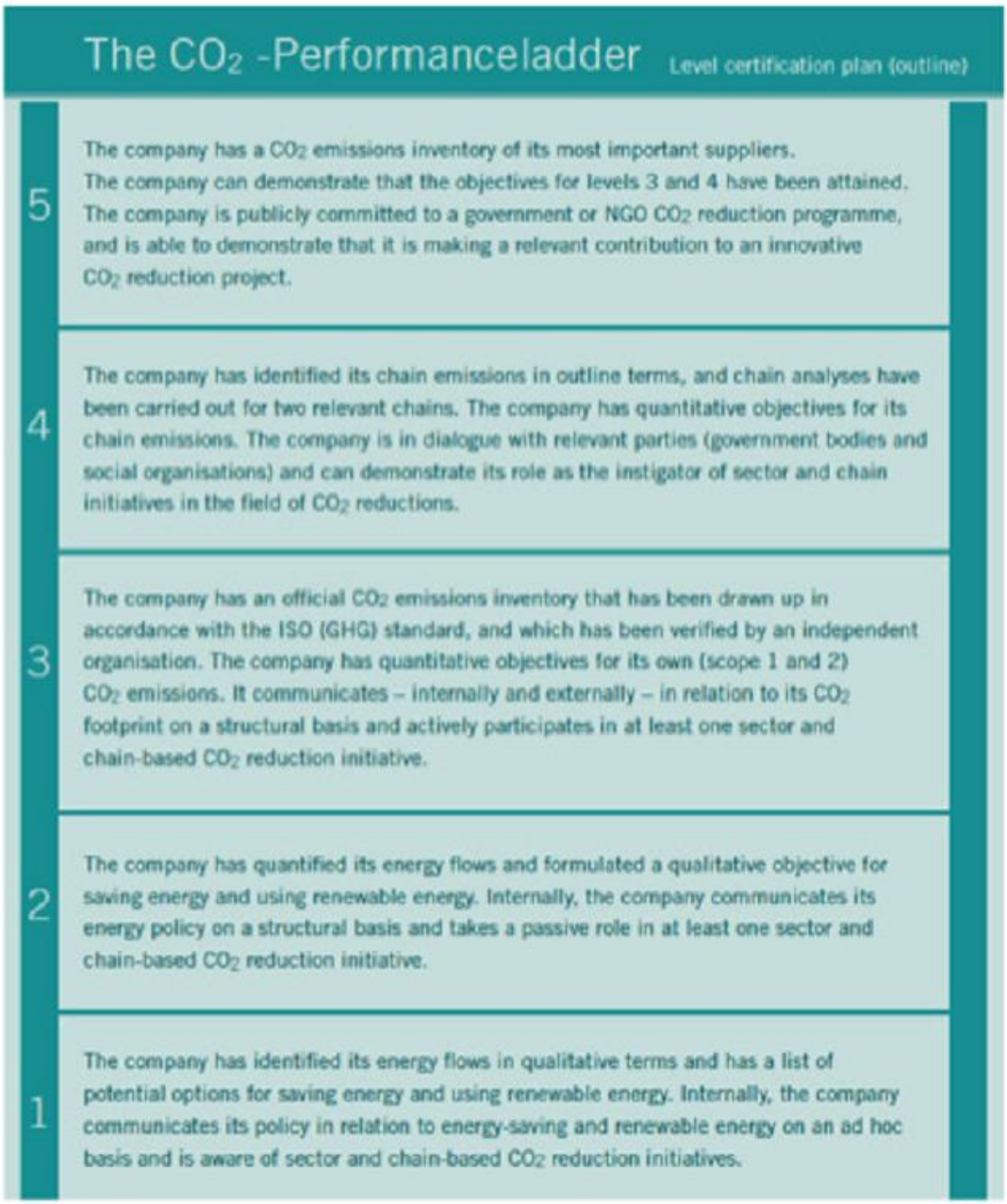
DCB= dichloorbenzeen

DuboCalc assessment of 11 environmental impacts of the project *(N007)*

As with the SEVE and asPECT, DuboCalc considers four stages during the life of the project -Building, se, Maintenance and Demolition. As the DuboCalc contains details of materials and processes as well as end of life scenarios (reuse, landfill, etc) it is possible to optimise building and design against the choice of materials, quantities and transport distances. The energy used during use of the infrastructure and the maintenance interventions can also be optimised through the life of the project.
In the contracting environment in the Netherlands, a maximum MKI value can be set, and optimisation of processes can be achieved using DuboCalc (typically for earthworks). This introduces sustainability assessment and is best included from the design stage of the project.
More details are available from
http://www.rijkswaterstaat.nl/zakelijk/duurzaam/duurzaam_inkopen/duurzaamheid_bij_contracten_en_aanbestedingen/dubocalc/index.aspx

CO2 Performanceladder

The second leg of the drive to improve sustainability is CO2e reduction aimed at the company's performance and is measured through a ladder of five rungs. The lowest level (1) is for the company itself and the highest rung (5) for innovation with partners in the supply chain.



The Rijkswaterstaat (Ministry of Infrastructure and the Environment) supports the use of the CO2 Performanceladder as a procurement tool by providing financial incentives as a percentage linked to the rungs on the ladder. From the table below up to 5% is available in the supply of engineering services if the maximum level is reached on the ladder.
http://www.rijkswaterstaat.nl/zakelijk/duurzaam/duurzaam_inkopen/duurzaamheid_bij_contracten_en_aanbestedingen/co2_prestatieladder/index.aspx

Originally developed by ProRail, the Operator of the Dutch railway infrastructure, it has been used in tenders since 2009. The tool was further developed and complies with the European Regulations and Public Procurement (Tendering Rules) Directive.

The tool operates on the basis of two important principles: attaining the best possible practical results and maximising innovation, with minimal restriction on the operation of companies. The ladder does not regulate production methods or product standards, but seeks greater scope for creativity and renewal of processes and products.

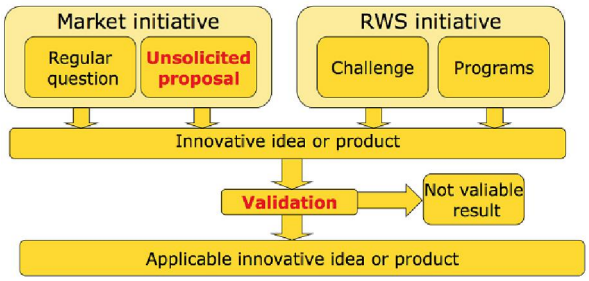
	Vanaf From	Maximale trede Maximum rungs	Aftrek per trede Reduction per rung
Prestatiecontracten, Variabel Onderhoud en Renovatie projecten Complex project, variable maintenance & rehabilitation	1 augustus 2011	3	1%
Prestatiecontracten, Variabel Onderhoud en Renovatie projecten	1 januari 2013	5	1%
Aanleg > M€ 35 Construction / addition	1 augustus 2012	5	1%
Aanleg > M€ 1,5 en < M€ 35 Construction / addition	1 augustus 2012	3	1%
Aanleg > M€ 1,5 en < M€ 35 Construction / addition	1 januari 2013	5	1%
Ingeniersdiensten > k€ 130 Engineering service	15 augustus 2012	5	1%

Motivation to use CO_2 Performanceladder

Authorised ladder-certifying organisations assess evidence provided against set criteria. Certificates are then issued with a validity of three years for the level attained. Companies can apply for higher levels of certification at any time.
The CO2 Performanceladder is operated as a private sector driven scheme and is owned by SKOA, the "Independent Foundation for Climate Friendly Procurement and Business". www.skoa.nl

Netherlands, Rijkswaterstaat (RWS) "Innovation Test Centre"

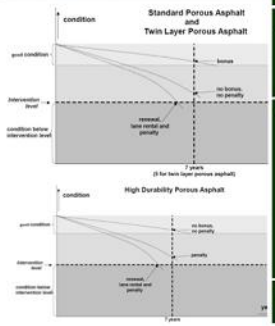
Unsolicited or challenges for better performance are addressed through an Innovation Test Centre (ITC) which is based on the French approaches of Charte d'Innovation and Avis Technique. Its goal is "to stimulate and implement innovation by the private market (sector) in order to deal with present (current) problems"(N014).
Proposals and challenges are assessed against fitness-for-purpose and are aimed at unsolicited proposals which are (almost) ready for implementation, providing test facilities and locationsalong with validation surveys. A contract is generated which ensures cooperation on obligations, responsibilities and a 50:50 sharing of the validation costs.



This supports the principle of an entrepreneur investing in an innovation which will provide a better price/performance ratio. Validation costs are shared between the entrepreneur and the RWS. After validation, the product can be used in RWS contracts. The shared win/win benefits that derive from the ITS include:

- Knowledge of market possibilities
- Client's knowledge is shared
- Mutual acceptance of the validation plan
- Test and demonstration projects
- Performance is known
- Entrepreneur determines price in a competitive market
- Client can make justified decision on tender award
- Object end report

The Rijkswaterstaat's use of the Innovation Test Centre provides encouragement to the entrepreneur to propose cost reducing ideas and products whilst providing a structure process to ensure fair assessment and use of improved outcomes.



Performance assesment during warranty period

property	assessment method	criteria
Skid resistance	86% slip trailer	≥ 0.38
Transversal evenness	ARAN laser rut depth measurement	rut depth < 18 mm
Longitudinal evenness	ARAN IRI - measurement (D&C)	IRI - value < 3m/km
Transversal slope	Aran slope measurement (D&C)	no unifiorm criteria
Raveling	visual inspection	• < 20% stone loss/m^2 • < 25m/100m with 11-20% stone loss/m^2 • no loss of deeper stones
Cracking	visual inspection	• crack width < 21mm • Δh over crack < 11mm • less than 7 transversal cracks per 100m • less than 30m longitudinal cracks per 100m • connected cracks may not contain loose elements
Combined damage	visual inpection	moderate raveling + cracking may not have great extent

3. Procurement systems options

During the tour, feedback on procurement systems was gained from two sources, the Highways Agency in the United Kingdom and the Rijkswaterstaat (RWS) Ministry of Infrastructure and the Environment in the Netherlands. Details are included in the reference material.

3.1 United Kingdom – Highways Agency

Details were formally supplied on the procurements systems used by the UK Highways Agency. This detailed their use of Public Private Partnerships in the provision of 13 large projects and the use of shadow tolling to fund the projects. Feedback is covered through the question and answers for "Contract & procurement models".

Maintenance has evolved to a new form of Asset Support Contract which is "outcome-based" and less prescriptive about how and when work is delivered, provided safety is not compromised. In the UK Major Projects have moved from Institution of Civil Engineers (ICE) design and build through Early Contractor Involvement and standard NEC works design and build contracts. The current Managed Motorways programme is being delivered through a National Framework using NEC target cost contracts. Specific contract strategies are adopted to match particular projects seeking best value and not "one size fits all".

Contractors are prequalified against scoring for capability, technical ability, financial capacity, health and safety performance as well as reference project experience.
Projects are evaluated at tender stage to identify the Most Economically Advantageous Tender with the assessment based on price and quality with the ratios varying from 50:50 to 20:80. The quality component includes six main areas: product, service, right first time, cost and time, health and safety and sustainability. Based on the evaluation Key Performance Indicators are established for the execution of the project.

Asset Management Systems are owned by the Highways Agency and populated by service providers who manage and maintain the highways. Performance data is reported to and retained by the Agency, ensuring that overall network knowledge and prioritisation remains the responsibility of the Agency.

3.2 Netherlands

The Netherlands approach to procurement systems includes functional specification methodology along with functional contracts. (N011, N012, N013) The difference in the approach is a move away from method-based

or empirical contract models and specifications to performance- based approach with outcomes to the benefit of the road user. The four main functional contract models are:

- Performance contracts
- Engineering and construct (E&C) contracts
- Design and construct (D&C) contracts
- Design, build, finance and maintain (DBFM) contracts

This provides a larger role for the private sector in construction, maintenance and management of infrastructure. The RWS role is to safeguard the interests of society, maintain its operational strength and it remains accountable and responsible to the public. Emergency issues and traffic management remain the primary tasks of the RWS.

Innovation by the private sector is promoted in the provision and maintenance of infrastructure. RWS concentrates in the "what" for design and delivery leaving the private sector to address the "how", increasing freedom to use knowledge, experience and creativity.

Performance contracts

These are used for routine maintenance (grass mowing, cleaning traffic signs, removing trash etc). They are usually for complete road districts, are simple jobs not requiring design activities, have simple functional requirements (clean signs, grass shorter than, water flows in drains, weeds, etc).

Engineering & Construct contracts

For maintenance and wearing courses of pavements with limited design component. The road owner decides on the basic design i.e. the type of maintenance treatment, the contractor does the detailed engineering, including selection of aggregates, binders, filler, mix design, planning and organisation of the work, selection of traffic systems, etc. Usually it has a 5 to 7 year warranty. This can conflict with routine maintenance by other contractors.

Performance is assessed after construction by the contractor, during the warranty / maintenance period as part of routine PMS monitoring by the RWS. At the period performance is assessed jointly by contractor and client, organised by the contractor.

If the performance does not meet the requirements during the warranty / maintenance period, the contractor has to replace the work with new work to the original requirements, has to pay for extra traffic control, pays a penalty and loses right to bonuses.

At the end of the warranty / maintenance period the performance is assessed to determine if the contractor is entitled to a bonus or should pay a penalty. Performance properties are similar to those during the warranty period, but the criteria are higher.

Design & Construct contracts

The contractor has design responsibility, is used for new design, reconstruction, road widening etc. The projects usually have a 7 to 10 year warranty period. Wearing course performance is assessed the same way as for E&C contracts. For bridges and pavement structures when the warranty period of 7 to 10 years is insufficient, the construction performance is covered by design verification.

Design Build Finance & Maintain contracts

The contractor has design responsibility, and is responsible for the maintenance for 20 to 30 years transferring a large portion of the performance risk onto the contractor. The contractor is paid on the basis of availability through a periodic "availability fee". The contractor also receives payments on the provision of new, or improvement of existing infrastructure (tunnels, bridges, roads, etc.)

The net availability fee consists of a gross availability fee minus corrections for availability and minus any performance penalty. The gross availability fee is a periodic payment with an annually indexed value. Reductions in the availability fee are determined by every 15 minute period that a lane is below the performance requirements or is unavailable due to work by the contractor (excluding accidents and events out of the influence of the contractor). The reductions are higher per time unit in the day than in the night. A bonus is paid if no penalty points are give in two successive assessment periods.

Payment is provided for new works and improvements to existing infrastructure within the contract, based on a list of required and existing infrastructure needs. Output specifications are set for the infrastructure along the lines of a D&C contract but with fewer aspects included.

One DBFM contract is operating, three are commencing, two are out to tender and three are being prepared.

Summary and recommendations

In the European construction sector the procurements systems are of similar complexity to Australia.
A number of systems have been in place for over a decade to encourage and promote innovative cost-lowering alternatives to current materials and systems. Their use has supported the shift to output or performance type specifications promoting risk taking with reward for the innovating contractors and suppliers.
The European government targets to reduce greenhouse gas production has impacted on the way projects are evaluated when funding for road infrastructure comes from government. The impact on the road pavement and surfacing sector is being handled through the development and use of Life Cycle Cost Analysis tools which incorporate substantial detail and analysis of the additional impacts of greenhouse gas, energy and climate change influences. There are four different tools available which are endorsed in different regions or states.
There are much fewer method-based or empirically based specifications being used with the systems described as providing functional performance or outcomes. There is the usual scale of risk transfer to the contractor along with the release of design and materials prescription as the duration or size of contracts increase. Long term and large DBFM / DBFO projects are regular and mobilise private sector financing and expertise. Repayments for the supply of the infrastructure include toll concessions and shadow tolling with the funds coming directly from the road agency.
The latter can be complicated if road agency budgets are cut which results in an ever increasing percentage of the road agency's budget being allocated for the long term contacts.

Recommendations

1. Promote, and seek methods of establishing, a national system to support innovation in cost reducing road products and systems and their commercialization.
2. Support and motivate for the transfer to functional specifications and contracts.
3. Evaluate the Australian greenhouse gas calculators in comparison to the European tools to assess their value in comparing industry products and systems.

Procurement systems- Questions & Responses

Systems

1. Avis-Technique systems – are they working / cost effective?

Yes, continue operating in France for decades and in UK 15+ years. Even with introduction of harmonized specification and CE-marking the products continue to be submitted for certification.

2. Lessons learnt, still promoting innovation?

Direct intervention to lead innovation in France with annual innovation awards and the road authority driven "Charte d'Innovation" system provide an innovation "pull". Products providing improved environmental outcomes are also being triggered through the use of LCA approaches including CO2e components. In the Netherlands, there are direct rewards for the introduction of environmentally beneficial products and systems.

3. How are underperforming products addressed?

Underperforming products are declassified or the certification is removed. As the certification has time limits and regular review is required, little used products will not be put up for recertification or monitoring.

Functional and performance requirements

1. Are performance-based specifications used?

Yes, often called functional specifications. Greater use is made as the overall responsibility for the performance of the road passes to the road contractor. At the extreme of Design Build Operate and Maintain (and Finance), the performance requirements shift to the provision of service and "up-time" access to the road.

2. What test methods are used to measure performance / proprietary?

Test methods vary by intended use of the product or system. Wearing courses and base courses would be assessed against engineering properties for traffic demand, loadings, usage category and durability. Standard function evaluation such as cracking, deformation, bleeding, ravelling and skid resistance would also normally be included. Binders would be assessed against performance-related tests, generally in Europe with the DSR for modified binders.

3. Functional specifications and fitness-for-purpose assessed over time – how is this done?

Refer to the report – Netherlands functional specifications and contracts (N011, N012, N013)

4. How are environmental / traffic loading changes included in the assessment?

Refer to the report – assessment tools include LCA with inputs for environmental inputs. Traffic loading changes are covered in the pavement design policies and modeling within their design models. Changes to axle masses were not raised as a significant issue. Standard axles range from 8 to 13 tonnes across Europe.

5. Define what a "warrantee" means, for how long, end state?

The issue of warrantee / warranty was not discussed in depth as the requirement for performance is built into most of the procurement systems as a requirement for payment or bonus. Used interchangeably with guarantee, the expectation is that a product will perform to certain functional characteristics to be acceptable. The only distinction arises when a method specification with empirical requirements is used. The presumption is that the specification is there to duplicate a product with known acceptable performance. In those cases, the requirement is simply compliance with the method / empirically based specification.

There is a movement in European specifications to move away from empirical measures to properties able to be more directly linked to performance.

Detail is provided in the report on the specific warranty approach used in the Netherlands. It appears that most long term contracts and non-standard products carry some form of warranty.

6. Can proprietary product systems replace performance-based specs?

Yes, provided there is validated experience of usage under the expected conditions.

7. Can "green procurement" requirements fit into the system (C02, energy)?

Yes, see details in the report

Product sourcing and life cycle assessment

1. Has REACH impacted on the product selection and use in Europe, are there benefits?

Not directly on product selection through REACH. Existing products have been assessed against the REACH responsibilities and the requirements for safe use conveyed to the downstream users. Some products with greater environmental impacts (cutbacks etc) have been used in decreasing quantities across parts of Europe. This is driven by user decisions and not as a consequence of REACH. The major benefit deriving from REACH is the transfer of responsibility for safe use from the regulator to the supplier of the product.

2. Are there any "responsible sourcing" influences on product selection?

Not directly, the SEVE, DuboCalc, CO2 Performanceladder, asPECT all give "credit" for improved environmental outcomes including reuse of products (RAP) and reduction in the use of nonrenewable natural resources – that is "responsible sourcing".

3. What methodologies and inputs are used to assess Whole of Life Cost (WOLC) for pavements?

See the details in the report and attachments. Normal LCA inputs are used plus the addition of a variable range of environmental concerns or targets of government. The analysis is still expressed on a cost basis but is limited where non-cost quantifiable variables are important and more difficult to mode. (noise, time delays, visibility, etc).

Contract & procurement models

1. Are PPP widely used to fund and deliver European road projects?

Answer received from the UK Highways Agency – the attached reference (U11 PFI Briefing) provides a listing of the projects across the UK being delivered under the Design, Build Finance & Operate (DBFO) approach.

Launched in 1992 to promote collaboration between private and public sectors with Government committed to the principles of Public Private Partnerships (PPP). The Highways Agency commenced the procurement of road services through DBFO projects with the objectives:

- *to ensure that the project road is designed, maintained and operated safely and satisfactorily so as to minimise any adverse impact on the environment and maximise benefit to road users;*
- *to transfer the appropriate level of risk to the private sector;*
- *to promote innovation, not only in technical and operational matters, but also in financial and commercial arrangements;*
- *to foster the development of a private sector road-operating industry in the UK; and*
- *to minimise the financial contribution required from the public sector.*

The contracts are funded by shadow toll payments where the Highways Agency provides payments against usage and traffic, and the payments are discounted or increased based on the provision of infrastructure improvements, maintaining availability of road space, providing safer use and ensuring other functional properties of the road infrastructure. The routes are not tolled. The details of 13 DBFO projects are included in the reference.

2. Do PPP affect the products chosen and warrantees required?

Answer received from the UK Highways Agency (U10)

The DBFO company maintains and operates the route for 30 years. In that period, it is their liability to maintain the route in accordance with maintenance standards as set down in the contract. It is up to the DBFO company to fund, plan and programme their maintenance work over the life of the contract. The DBFO company takes the risk for maintaining the route in accordance with the standards set down in the contract. When the route is handed back to the Highways Agency at the end of the 30 years there are firm requirements set down in the contract for the condition of the asset at handback which the DBFO company must meet.

BFO companies should be in a position to plan maintenance better as they have a longer term view and more control over long term budgets. Currently, many of the first Tranche of DBFO projects are approaching the stage where the DBFO company needs to consider major maintenance for the first time. This has resulted in them exploring potentially innovative alternatives to major maintenance, such as the use of Rhinophalt, which acts as a carriageway surfacing preservative and extends the life of the surface, delaying the need for major maintenance. This will see them "sweating" the asset to get the maximum from it and timing their major maintenance to meet handback requirements.

3. What are the dominant contract models used for purchasing products and services from the road sector? Are non-price criteria used and if so how big an environmental component is included?

Answer received from the UK Highways Agency (U10)

The Highways Agency primarily uses a model of directly contracting with a main contractor for the provision of its road maintenance and construction projects. Maintenance is procured using a Term Service Contract and Major Projects are procured using an Engineering and Construction Works Contract. Both of these forms of contract are based on the NEC 3 form of model contract published by the Institution of Civil Engineers.

As the Agency is a public body supplier, selection is governed by the Public Contracts Regulations. These prescribe a formal framework of procedures and processes. The Agency ordinarily employs a "Restricted Procedure". This entails advertising the contract throughout Europe and employing a pre-qualification process to arrive at a tender list of typically five companies. Prequalification will assess and score capability, technical ability, financial capacity, health and safety performance and may seek access to reference projects.

The five highest scoring suppliers are then invited to tender. The tender process is designed to identify the Most Economically Advantageous Tender (MEAT). This is an assessment based on price and quality. The ratio of price to quality is varied based upon the risk profile of the particular procurement. Typically, values vary from 50:50 to 20:80 (price:quality). The quality submission is divided into six main topic areas: Product, Service, Right First Time, Cost & Time, Health & Safety and Sustainability. Depending upon the specific procurement, different emphasis can be placed on each of the criteria. Note that the same topic areas are measured as Key Performance Indicators during execution of the project.

4. What contract models are used to purchase proprietary products?

Answer received from the UK Highways Agency (U10)

The Agency does not normally purchase such products directly. They are normally procured through the Main Contractor. However, as part of a Category Management initiative, a Pavements & Concrete national framework was awarded in spring 2012 directly to "Tier 2" suppliers. The framework will enable the Agency to benefit from aggregated demand across its Tier 1 Contractors, both for Maintenance and Major Projects. It is unlikely that the Agency will itself award contracts under the framework. The framework allows the Tier One Contractors to directly contract with the framework suppliers.

5. When contract arrangements are used to procure network management services, how is a culture of ownership or stewardship of the network encouraged?

Answer received from the UK Highways Agency (U10)

The Agency's maintenance contracts are based on a quality management approach which ensures that the Service Provider must have a Quality Plan in place to deliver key Agency objectives through processes and procedures. There are a number of provisions in the contract which ensures both ownership and stewardship such as:

Provider's organisation is accountable for ensuring that all processes are implemented as designed in the Service Providers Quality Plan.

Watchman Role– The Service Provider has to carry out a Watchman Role function which is specifically designed at encouraging ownership and stewardship by overseeing activities to monitor, collect data, analyse and provide performance intelligence across all Maintenance and Operational Requirements relevant to the performance of the Area Network. This requirement encourages Service Providers to organise their management resource on a 'route' basis which fosters local ownership and stewardship.

Joint ownership between the Agency and Service Providers is encouraged through the Network Board (joint representation) and there are shared savings from process improvements and innovation. The Network Board can set improvement targets in respect of network performance.

Extensions of time are available to the Service Provider based in part on performance of the network.

6. Under contracted network management, how do road agencies retain expertise to remain an informed client?

Answer received from the UK Highways Agency (U10)

This is achieved through the day to day involvement with the Service Provider, regular progress and performance meetings and through the Watchman role. The Agency owns the Asset Management systems that the Service Provider populates, and so retains the data and information necessary to remain an informed client.

The Agency scrutinizes and formally accepts the Service Provider's Quality Plan and monitors compliance – the Quality Plans are presented in a consistent format nationally by means of an Agency developed Business Process Model (BPM) which allows the Agency to retain expertise on a national basis rather than via disparate approaches across Areas.

Performance Data is reported to and retained by the Agency including the raw data that drives performance rather than simply the out-turn metric.

Extensive reports on all matters relating to network management are provided to the Agency as part of the contracts. Continual Improvement and Innovation is managed through the Agency with shared benefit.

7. From the procurement aspect I would be interested if there is an experience or case studies that demonstrate a definitive cost impact from a change in procurement type or contractor.

Answer received from the UK Highways Agency (U10)

The Agency's procurement strategy has evolved since its formation in the early 1990s. It has always used a model of "outsourcing" the vast majority (>90%) of its expenditure.

Maintenance has evolved from Managing Agent/Term Maintenance Contract (MA/TMC) to Managing Agent Contractor (MAC) through to the current model being used in the Asset Support Contract (ASC). MA/TMC contracts were based on the ICE 5th edition and were used by the Agency up until the late 1990s when the Agency moved from two separate contracts to a single MAC contract combining the roles of the MA/TMC. The benefits of moving to a MAC, included early creation of the delivery team, clear points of responsibility, with no unnecessary layers of supervision, selecting suppliers on the basis of best value and performance measurement with continual improvement. The Agency has recently developed the new ASC which is expected to deliver substantial savings over the current arrangements. This will be achieved through new asset maintenance and operational requirements which are 'outcomebased' and less prescriptive about how and when work is delivered, without compromising safety. Other changes include a higher threshold for directly delivered works, to allow more procurement through the asset support contract rather than by separate tender and clearer incentives for innovation and efficiency, including the opportunity for contract extensions based on good performance. The move to the new ASC starts from July 2012 as part of a rolling programme that will be complete in July 2015.

Major Projects have moved from ICE design and build through Early Contractor Involvement and "standard" NEC works design and build contracts. The current Managed Motorways programme is being delivered through a National Framework utilising NEC target cost construction contracts. The strategy is to have a number of contractual options available.

Specific contract strategy can then be adopted for the particular project in question. It is believed that this strategy can deliver best value rather than adopting a "one size fits all" contracting strategy.

Reference Material

List of the presentations or other material gathered during the tour.

1. Innovation implementation in road contracts, EAPA, 2003 (B03)
2. The asphalt pavement embodied carbon tool (asPECT): Developing a carbon footprinting methodology for asphalt products, Matt Wayman, TRL UK, 5th E&E June 2012 Turkey (05EE-160)
3. SEVE, the new tool for road builders companies: a tool to promote WMA and Cold Asphalt Mixes, Christine Leroy, USIRF, 5th E&E, June 2012 Turkey (A5EE-529)
4. DuboCalc and the CO2 performance ladder, Jan van der Zwan, presentation RWS, June 2012 (N007).
5. Validation of new materials – Innovation test Centre, RWS, Jan van der Zwan, presentation June 2012 (N014)
6. System based contract control – How to control contracts, RWS, Jan van der Zwan, presentation, June 2012 (N011)
7. Contract systems – the Market approach, RWS, Jan van der Zwan, presentation, June 2012 (N012)
8. Specifications – functional specifications, RWS, Jan van der Zwan, presentation, June 2012 (N013)
9. Highways Agency, PFI Briefing, (U11)
10. Report answering Study Tour Questions, Iain Rillie, May 2012, TRL (U10)

9. 5th EUROBITUME & EURASPHALT CONGRESS

Observations

The four yearly Eurobitume & Eurasphalt Congress is the lead conference for flexible pavements and binders in Europe. It sets a high standard for papers which are peer reviewed and many papers are not accepted. Participation is international, attracting authors and researchers from a range of countries outside Europe, with its multi-lingual nature encouraging wider participation. No papers were sourced from Australia for this congress.

Binders and mixtures generate the most papers. This reflects the keen technical interest in Europe on the development and understanding of binders and asphalt mixes. As in previous events, the 5th Eurobitume & Eurasphalt Congress (5thE&E), contains much on new developments and reporting of performance results on binders, modified binders, additives to binders and their role in improving the performance of asphalt mixtures. Under the theme "asphalt the sustainable road to success", many papers scoped and attempted to address the options and benefits of flexible pavements in sustainability. The drive to reduce the generation of greenhouse gasses is a politically supported initiative which has changed the way infrastructure delivery is evaluated. Tools have been developed to include sustainability factors when undertaking life cycle cost analysis; and new processes and materials are being developed to lower emissions in road building and maintenance. A number of papers and speakers noted the small role the provision of the road plays in CO2 generations versus that if its use by vehicles.

The structure of the congress and the setting in Istanbul, Turkey, helped frame the needs that roads fulfil in society and the variable conditions under which the road system works. With over 260 papers, moderators played a key role in capturing the dominant or new issues arising from each of the themes and then nominating two or three papers for presentation at the plenary. A large area at the venue and a substantial time slot was provided, which allowed over 16o authors to be available to discuss and review their papers with the delegates. Interaction and social networking worked well.

The 5thE&E was well attended and, once again, confirmed its position as the lead European congress for our sector's research and technological developments.

5th E & E Congress

Asphalt, the sustainable road to success' was the theme for the 5th E&E congress held in Istanbul. The congress was a great success with 267 accepted papers. Key features of the congress are listed as below:

- 2 key note + 6 technical sessions (267 papers) –
  - Sessions 1&2 - Introduction to congress theme by keynote speakers
  - Health safety and social issues (24 papers)
  - Sustainability, energy use and climate change (27 papers)
  - Resource use and recycling (45 papers)
  - WMA and low temperature techniques (35 papers)
  - Durability and Performance: binders (54 papers)
  - Durability and performance: mixtures (78 papers)
- 11 moderator reports (186 papers)
- ' Meet the author' poster session (163 posters)
- over 1,000 delegates (including ~ 100 suppliers): 13 Australians only (9 from the AAPA study tour)
- 111 exhibition booths (67 companies + 1 press corner)

Use of moderators and the availability of translation into six languages (English, French, German, Spanish, Russian and Turkish) were some of the key factors leading to the success of the Congress.

Eight specific headings were selected to address the theme and formed the basis of the Congress sessions and were grouped as follows:

1. Societal impact
2. Financing of road maintenance and maintenance
3. Responsible sourcing and green procurement
4. Improving Health and Safety
5. Energy and carbon

6. Adapting to climate change
7. Resource use and recycling
8. Durability and performance – mixtures, binders and pavements

Feedback is captured from the sessions at the 5th E&E Congress under similar headings and is drawn from moderators' reports and noteworthy papers and presentations. Where relevant to the Study Tour's five key topics, the information is also contained in the detailed feedback in this report.

1. Social Impact, Financing Road Maintenance

Delivered in the key note session was a stirring speech by the Transport Minister for Turkey who expounded on the value of roads for development and social advantage explaining the large investments being made by Turkey. A presentation of note, was that by Prof Dr Mustafa Karasahin, "Roads and their Social Impacts", which postulated that road transport is necessary, but not sustainable, and its safety outcomes are out of step with the changed norms of society. That said, the growth path to date for developing countries was to move up the private vehicle chain from mopeds to cars which pushed the need for the provision of roads. Examples of positive outcomes for Turkey was the use of busways to concentrate the passenger traffic whilst improving the road space for freight and passenger cars.

2. Energy and carbon

Jan van der Zwan of the Netherland RWS explained the tiny part in the carbon generation cycle played in providing the road infrastructure versus the massive CO2 generated in its use when conveying people and goods. In global terms asphalt production represents 92 million tonnes of CO2, which is roughly 2% of the transport generated approximately 4 700 million tonnes of CO2. Other fascinating fact was our ignorance at the carbon footprint of items we use on a daily basis. A cheese burger has a carbon footprint 100 times greater than a kilogram of hot mix asphalt!

- Carbon footprint asphalt
  60 g CO2e /kg
- Carbon footprint orange jus
  1600 g CO2 e/kg
- Carbon footprint cheese burger
  6000 g CO2 e

High gain solutions were seen to influence the energy usage by the traffic through reducing rolling resistance, reducing aerodynamic resistance and speed, and improving traffic management.

3. Sustainability, energy use and climate change

Challenges for the future In the keynote address by Bull-Wasser (2012), some future challenges for the road and transport industries included:
- ageing infrastructure
- rising amount of traffic (hgv)
- availability of affordable bitumen
- globalisation / demographic change / sustainability
- climate change and its potential impacts on road pavements, especially in terms of the operating cost of road network

Some suggestions to prepare for these challenges are:
- quantify risk profile – this will aid in identifying preventive, adaptive and/or mitigated actions required (Figure 2).
- make use of climate analogues to import technical solutions from elsewhere
- greater information exchange on dealing with effects of climate changes is strongly encouraged

- focus on adhesion and durability (water sensitivity)

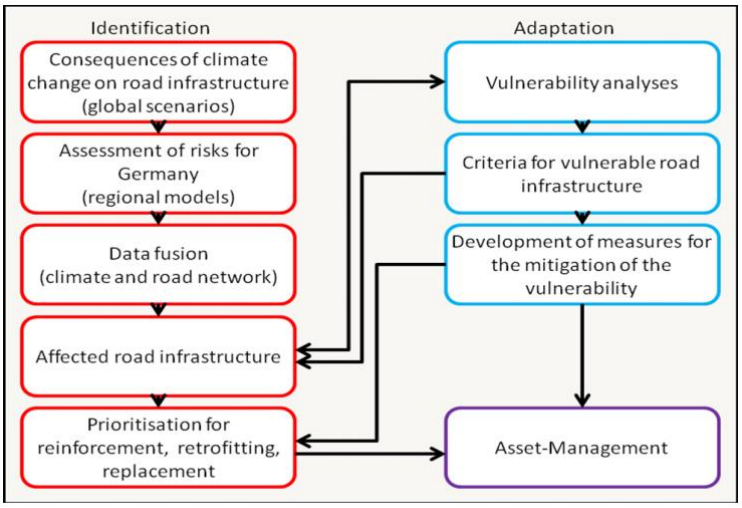


Figure 2: Strategy approach to climate change: risk identification and adaption (Bull-Wasser, 2012)

4. Durability and Performance- pavements

Durability is regarded as a prerequisite for sustainable pavement (Molenaar 2012). Use of less asphalt concrete was suggested to be the quickest way to reduce CO2 emission. The CO2 reduction can be attained by application of:

- thinner structures and longer lifetime – utilise construction demolition waste, which consists of mixtures of crushed concrete and masonry. The properties of these waste materials can be further enhanced by stabilisation with foamed bitumen or cement and the use of polymer modification.
- better quality – Molenaar (2012) showed that reduced variability of porous AC can reduce maintenance cost and delays to traffic. The reduction of variability can be achieved by optimising logistics and improvement in production control
- high RAP % in new mixtures (Table 1)

Table 1. Characteristics of recycled base course mixtures (Molenaar 2012)

	E^* max [MPa] At 20 °C and 8 Hz	$\varepsilon_{fatigue}$ at N = 10^6 at 20 °C and 30 Hz [μm/m]
Base course mixture requirements EN	11000 - 14000	80 - 100
Mixture with 100% RAP + resin	15647	101
Mixture with 70% RAP + resin + roofing	10219	139
Mixture with 45% RAP + resin + roofing	10164	139

Source: Courtesy of Rasenberg Contractors (extracted from Molenaar 2012)

o Perpetual asphalt base courses can be built easily using a high % of RAP and other bituminous “waste”: fractionize the RAP and/or use of “green” WMA (foam) especially in combination with recycling Note that in the Australian situation, the continued use of sprayed seals would meet Molenaar’s criterion for reducing carbon dioxide emissions. To further optimise sustainability, high durability bitumens should be used.
Not only that, where asphaltic concrete is used in Australia, a reduced air void content (5% or less) would reduce oxidation and thus extend surface life and also reduce the chance of water ingress, which can result in early stone loss or structural failure.

5. Durability and performance – binders (Airey 2012)

It is important to establish robust and stringent testing operating conditions for modified binders, such as PMBs, before they can be considered suitable for use as DSR binder performance indicators.
A wide range of modifiers and additives has been studied in an attempt to improve the rheological properties and performance of binders.

- Modifiers studied include shale-oil residue (as extender oil), polyphosphoric acid (PPA), synthetic wax, oxidised ("sol-gel") and distilled ("sol") bitumens, SBS and natural bitumen. Good field performance was observed for trial sections constructed using cross-linked SBS bitumen – enhanced resistance to low temperature cracking and long-term ageing.
- Additives studied: organoclays, prepolymers or supramolecular
- Clay modified bitumen emulsions

There is increased interest in multiple stress creep recovery test (MSCRT) as a means to quantify permanent deformation performance. Development of new tests and techniques to evaluate binder characteristics such as fatigue, low temperature fracture and thixotropy. Some tests and techniques are:

1. The use of Annular Shear Rheometer (ASR) to measure fatigue seems interesting Figure 3.

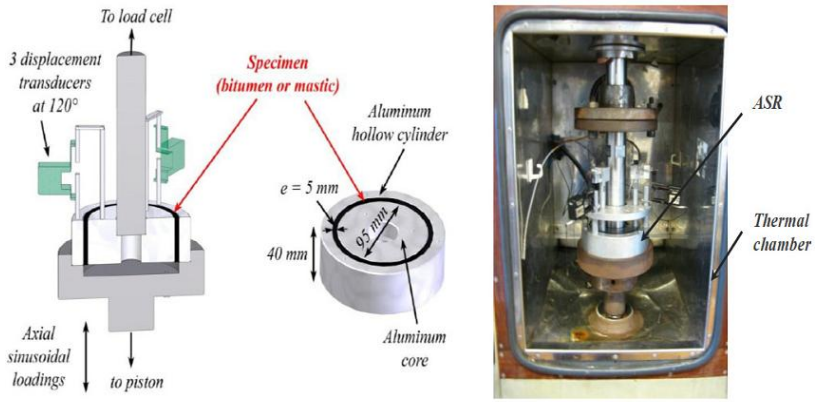


Figure 3: Annular Shear Rheometer (ASR) (Buannic et al . 2012)

2. Measurement of binder fatigue failure using Essential Work of Fracture (EWF) method – a Double Edge Notched Tensile (DENT) geometry is used to test samples at a monotonic rate to failure (Figure 4).

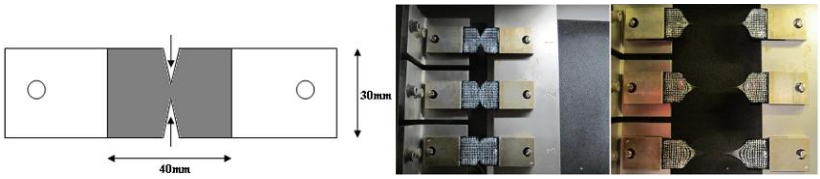


Figure 4: geometry and testing arrangement using Double Edge Notched Tensile (DENT) (Andriescu et al. 2012)

3. Bitumen Bond Strength (BBS) test to evaluate adhesive strength between bitumen and aggregate before and after conditioning in water.

4. Atomic Force Microscopy (AFM) to investigate the effect of different additives (e.g. Polyethylene wax, SBS and crumb rubber) on bitumen by at looking the morphology of the bitumen and modified bitumen (Antunes et al (paper 0496) and Munera et al (paper 505)). Three characteristic regions in the neat bitumen (asphaltenes, resins and maltenes) were identified by AFM (Munera et al 2012 (paper 505)).

Field validation - need of future research on long-term laboratory ageing tests for binders is highlighted in order to improve correlation with actual field ageing.

6. Durability and performance – mixtures (Ann Vanelstraete 2012)

In view of the importance of adhesion in (HiMA/EME) mix design, the papers on binder aggregate adhesion reviewed in the Congress were of interest. They were summarised in a moderator report presented by A.Vanelstraete (Belgian Road Research Centre).

Adhesion

Several test methods to rank bitumen-aggregate interaction were analysed in paper 197 (M.Wistuba et al.):

- Contact angle measurements on bitumen (in various ways)
- On the bitumen-aggregate level : the rolling bottle test and the static water storage test according to EN 12697-11 part B; the direct tensile strength test on rods drilled out from aggregate rock and stuck together with bitumen film
- On the asphalt mix level: the indirect tensile strength test and the direct tensile strength test, both after conditioning in water.

It was concluded that strength test did not distinguish between adhesion and cohesion properties. Contact angle measurements of water droplets on bitumen did not sufficiently distinguish between binders but bitumen drops on glass slides did, though producing results that need further study. The rolling bottle test was regarded as suitable for indicating adhesion if digital imaging was used. The static water storage test did not result in bitumen detachment and the standard conditions are regarded as inappropriate.

Paper 132 (J.Besamusca et al.) described the work done by the Industry Group Adhesion as part of the CEN Ad-Hoc Group Adhesion – Durability to search for a simple, quick and easy-to-use bitumen stickiness indicator. In view of that scope, several simple tests were evaluated and a set of tests was selected for further testing with several binders. This work revealed some interesting and important issues. The main aim, however, to find an easy test, was unsuccessful; there is no such easy test.

In paper 325 (A. Akilli et al.) a pull-out test on embedded aggregate samples with bitumen on the steel plate is developed as an alternative test for the Vialit-test (which is often under discussion).

Several binder-aggregate combinations were compared.

Several papers deal with the search for adequate tests for adhesion, either by a simple test to assess the stickiness of a binder to a given aggregate, or by evaluation of the adhesion between binder and aggregate, or by testing the mixture itself. In general, it is clear that tests on the binder level alone are not sufficient. Even binder-aggregate tests may give an incomplete picture.

Additives & polymers

The role of bitumen performance improving additives was again demonstrated with the use of highly modified binders used in thin wearing courses with high demands for durability. (papers 185 & 336). Work was also described which covered the use of polymer powder of mix improvement in small works or asphalt batches. (paper 152)

Crumb rubber modification property improvements were quantified in fatigue and rutting resistance linking the material properties to the techniques used for blending. (paper 463)

Lastly the increase in stiffness modulus and resistance to permanent deformation achieved through the inclusion of polypropylene fibres was detailed. (paper 179).

Products to improve performance were also reported, covering the advantages of applying hydrated lime.

Papers included details on reduced stripping potential on winter damage and ageing (papers 272, 355, 437) and a precise method to determine the required quantity of hydrated lime (paper 230). The ability of polyphosphoric acid to improve stiffness ad ageing properties was presented in paper 140.

7. Closing session

Concluding remarks (selected from the summary presented by Elgert Beuving)

- Sustainability is a challenge, not a threat
  - three pillars in balance: environment, society and economy
- Durability, a prerequisite for sustainable pavements
- WMA is the way of sustainability
- Adapting to climate change: focus on adhesion and durability (water sensitivity) due to the changes in rainfall
- A good road network is essential for the development of regions
- Asphalt is 100% recyclable
- Asphalt is not ‘trashfalt’. Look at all the consequences, for now and the future
- Optimal RAP management is needed to fully use the recycling potential
- Road authorities: If you want a higher quality, ask for it
- We need to change attitude to move forward

Summary and recommendations

The conference provided a vast range of detailed papers and positions on technology, social issues and sustainability options and challenges to the bituminous surfacing and pavements sector. The material has relevance to Australia and should be provided as an information source when considering those topics in Australia.
The concluding remarks also have relevance for Australia and should be considered when taking future actions on sustainability.

Recommendations:

1. Treat the requirement for more sustainable practices and products as an opportunity and not a threat.
2. Improve sustainability through more durable pavements.
3. Improve sustainability by using cost effective products with lower CO2 and energy footprints.
4. Preserve non-renewable natural materials by maximising their reuse and recycling.
5. Do not use asphalt or binders as a “dump” for undesirable materials.

Reference Material

The reference material, conference papers, presentations and moderators reports of the 5th Eurobitume & Eurasphalt conference are available via the electronic version of this report.