STUDY TOUR 2012

5th EURASPHALT & EUROBITUME CONGRESS ISTANBUL

Long Life Pavements

2012 Study Tour Key Topics

1. Long life pavements
   - Experience, design systems, use, durability & performance
2. High performance asphalt & binders
   - High modulus asphalt (EME, HiMA), modifiers
3. Sustainability
   - RAP/WMA, bitumen substitutes, carbon calculators & energy analysis climate change impacts, societal concerns
4. Health & Safety
   - Construction of road works, health considerations for bitumen and asphalt products
5. Procurement Systems
   - Proprietary products (Avis Technique, HAPAS, etc.), "green" procurement, REACH, responsible sourcing, PPP and contract models

Topic 1: 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)*

➢ **Need for revision of design to include LLP and FEL concepts**

- 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.

➢ **What can we learn from them?**

Topic 1: Long life pavements

Questions

- **Usage and performance records** (evidence of successful implementation)
  - Examples and case studies
  - Composition, traffic, deflection history
  - Typical maintenance
- **Design aspects** (proven structural design procedures)
  - Design procedures
  - Most appropriate approach - mechanistic or catalogue
  - Prioritisation of focus – design models or construction
- **Material properties** (proven material design procedures)
  - 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

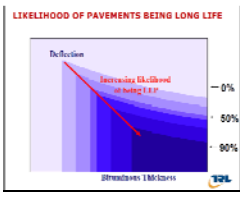
Topic 1: Long life pavements

Questions

- **Fatigue & healing** (appropriate laboratory testing and criteria)
  - 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
- **Contract and construction** (specification, construction and quality control requirements)
  - Initial construction cost – flexible vs. rigid
  - Specification requirements in D&C contract

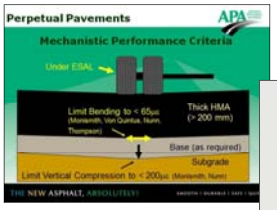
Definition

- Long-life (fully flexible) pavements, LLP or Perpetual pavements, PP
- *"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"*
- No structural cracking, only surface cracks (top-down) - surfacing materials and designs excluded
- Fatigue endurance limit (FEL)



Background

- AAPA 2010 study tour to the USA
- European Studies, European long-life pavement group, ELLPAG
- Austroads publications

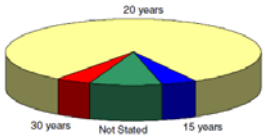


AAPA 2010 study tour

- 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
  - FEL is not a single value, e.g. the distribution of the strains (percentage below and above) affects the performance
  - Laboratory FEL may not directly translate to the FEL in the field
- Australian flexible pavement design practice should investigate the opportunities
- Use existing laboratory tools in Australia to compare with proven USA materials
- Quantify the performance Australian pavement materials
- Modification of the Australian design procedure (CIRCLY)

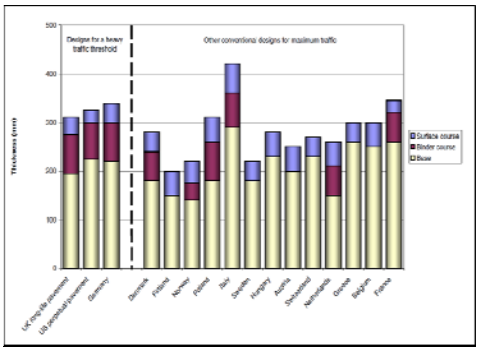
European experience – ELLPAG

- 2004 report with summary of situation in member countries and recommendations
- LLP and FEL accepted, but not explicitly used in design
- Recommendations for further research not yet implemented
- The 100msa80 designs - average asphalt layer thickness of 295mm (195mm to 350mm).



Stated Nominal Design Periods in European Countries

European experience – ELLPAG



Austroads publications

- The latest Austroads, GUIDE TO PAVEMENT TECHNOLOGY PART 2: PAVEMENT STRUCTURAL DESIGN (2012) "*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…. future research will enable this concept to be incorporated in the mechanistic design process.*"
- Austroads AP T199-12, Development of a Nonlinear Finite Element Pavement Response to Load, 2012. Finite element vs. elastic layer calculation of stresses and strains.
- Austroads AP-T131/09, Asphalt Fatigue Endurance Limit, 2009. "*sound structural condition and meeting functional requirements despite many having, at the time, already exceeded the design life predicted* "

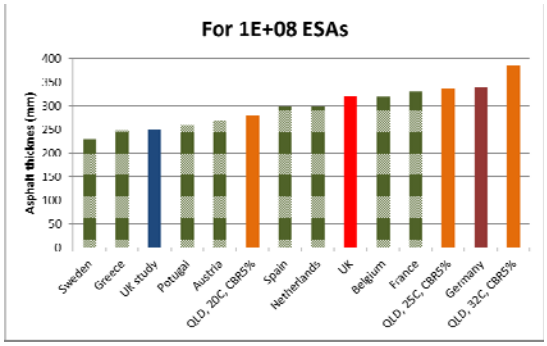
Q1: Usage and performance records

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

Usage and performance records

- Initiated in the UK: study by Nunn (1990s) – no structural defects > 250 mm bound layer
- Very little further specific information
- Concept widely accepted, but implemented differently by the road authorities
  - UK (chart) and Germany (catalogue) – traffic limits, i.e. 80 mesa and 3.2 E+07 ESA
  - France – high modulus layers
  - Netherlands – standard design
- Importance of structured maintenance - replacement of the surfacing layer

Usage and performance records

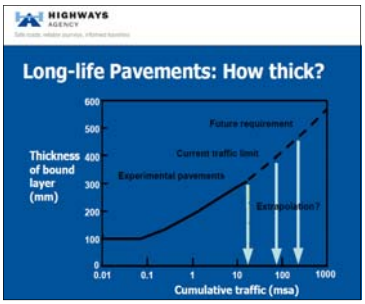


Q2: Design aspects

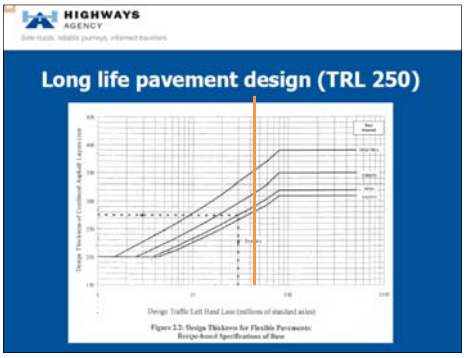
- To evaluate the design procedures
- To determine the most appropriate approach - either mechanistic or catalogue-based
- Prioritisation of focus – either design models or construction

Design aspects

- No formal mechanistic – empirical designs
- Graphs and catalogues
- Use BISAR for special cases

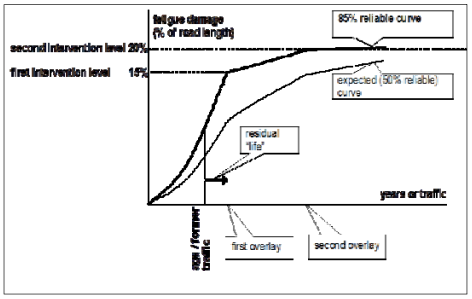


Design aspects



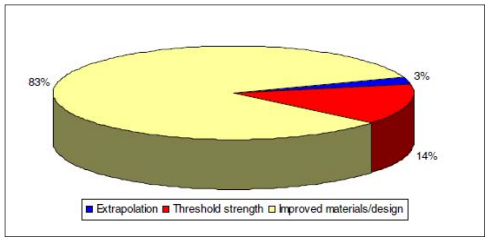
Design aspects

Dutch approach



Design aspects

European design development preference



Design aspects

- General acceptance of the concept of a threshold value, but it has not been defined.
- Horizontal tensile strains below the HMA may not be the governing strains - failure of thick layers may not be caused by bending.
- Conversion of laboratory test results to field performance is problematic.
- Use of existing pavement performance to calibrate the models
- The preference for catalogue design rather than M-E designs for routine LLP designs.

Q3: Material properties

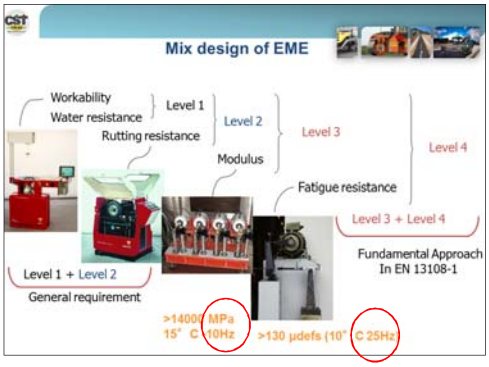
- Types of materials typically used
- Relevant material properties
- Measurement of material properties
- Laboratory curing and testing
- Incorporation of "non-standard" materials, e.g. PMB, EME, RAP

Material properties

- France – high modulus bases, EME
- UK – EME and conventional
- Germany – conventional and modified
- Netherland – conventional

Type of mix	Category (Voids %) GB (D 11mm) C100 (D 14mm) C120 (D 20 mm)	Water sensitivity ITSR ratio	Rut depth (60°C, 10 Hz) * 10,000 cycles (%) ** 30,000 cycles (%)	Stiffness modulus (15°C-10 Hz) in MPa	Fatigue – subscribe cycles (@ 1 million de cycles)
GB Class 2	≤ 11	≥ 0.65	≤ 10*	≥ 9,000	≥ 80.10⁶
GB Class 3	≤ 10	≥ 0.7	≤ 10*	≥ 9,000	≥ 90.10⁶
GB Class 4	≤ 9	≥ 0.7	≤ 10**	≥ 11,000	≥ 100.10⁶
EME Class 1	≤ 10	≥ 0.7	≤ 7.5**	≥ 14,000	≥ 100.10⁶
EME class 2	≤ 6	≥ 0.75	≤ 7.5**	≥ 14,000	≥ 130.10⁶

Material Properties



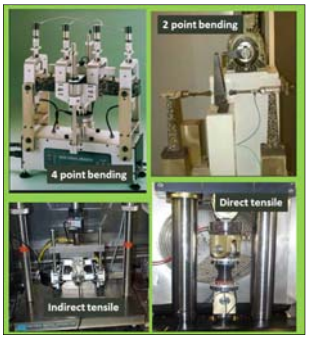
Material properties

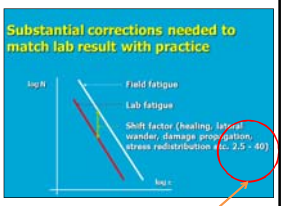
- The benefits of higher quality (in terms of higher modulus, better deformation resistance, longer fatigue life and / or durability) - recognized.
- Large amount of work is done both in Europe and the UK
- No uniform European / UK design procedure exists for the non-standard materials
- Similar structural properties, e.g. stiffness, fatigue and deformation resistance.
- Laboratory fatigue properties specified in France and in the Netherlands –
  - 90 and 100 µm for conventional asphalt mixes
  - 130 µm for EME2 mixes (for the specified test method and temperatures).

Q4: Fatigue and healing

- 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

Fatigue and healing

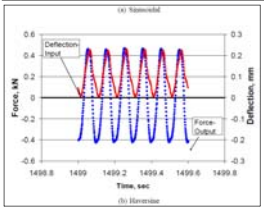




Fatigue and healing

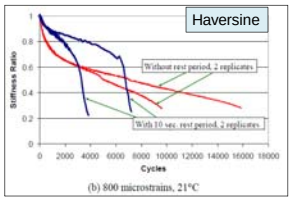
- Fatigue resistance is a specimen and test, not a material property.
- No standard test procedure in Europe and the UK
- Substantial adjustments are needed to convert laboratory tests to field performance - a factor of 10 used in the Netherlands (4 * 2.5)

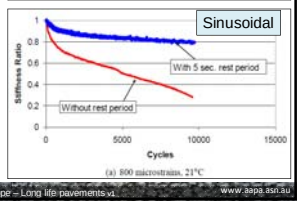
- Loading type
- Sample size
- Temperature
- Loading cycle
- Controlled stress or strain
- Definition of failure – 40 or 50% of stiffness (strain control)



Fatigue and healing

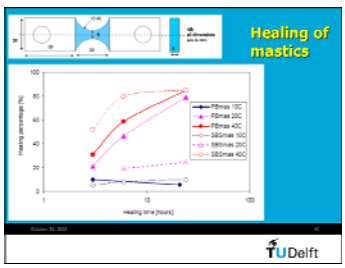
- Effect load application
- Type
  - Strain controlled (>150 mm)
  - Stress controlled (<150 mm)
- Duration/frequency
  - 10 Hz, 0.1 sec/cycle
  - Wheel at 80 km/h, 0.045 sec/cycle
- Shape
  - Sinusoidal
  - Haversine





Fatigue and healing

- Healing entails the recovery in strength (fatigue) and not stiffness
- Healing (strength recovery) of asphalt mixtures is limited
- Long rest periods are beneficial but only at elevated temperatures
- Essentially a flow process



Fatigue and healing

- Difference test devices and protocols are used - difficult to compare results
- Conversion from laboratory tests to field performance is problematic and no standard value or uniform conversion protocol exist
- Fatigue tests have not been used to determine FEL values for use in the structural design.
- Minimum laboratory strain values for HMA bases are specified in France and the Netherlands.
- The healing of asphalts is complex and difficult to measure - temperature, healing time and type of binder
- Indications are that temperature is more important than time and healing only takes place at high temperature.

Q5: Contract and construction

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

Contract and construction

- There were limited discussions on contracts and contracting as it pertains to LLPs
- Approach seems to be similar to that in Australia
- The D&C contracts (Netherlands) have a warranty period of 7 to 10 years.

Summary

- The concept of Long-life pavements (LLPs) is widely accepted in Europe and the UK
  - UK and Germany - maximum traffic loading (80 and 32 million ESA)
  - The Netherlands – standard design
  - France - high modulus layers
- A group, ELLPAG was established to investigate LLP in Europe and the UK and produced a report in 2004
  - Research identified, but not yet conducted
  - Preferred design option - The use of improved materials and/or designs

Summary

- The LLP designs are based 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.
- Maintenance
  - Involves the replacement of the surfacing layer only
  - Important for the performance of LLPs and
  - Should be based on a sound selection, asset management and design methodologies.

Summary

- Fatigue testing
  - Results dependent on test device, loading applications, test temperatures and definition of failure
  - Conversion from laboratory tests to field performance is problematic – use the performance of existing pavements to calibrate
  - Horizontal tensile strains below the HMA may not be the governing strains for thick layers
- Healing
  - Accepted as occurring
  - Definition and testing are complex
  - Indications are that temperature is more important than time and healing only takes place at high temperature.

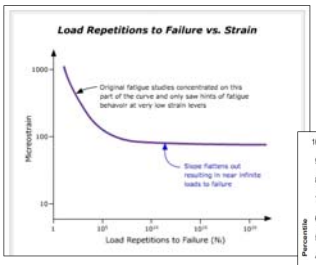
Summary

- Austroads,
  - *"increasing recognition of … endurance strain limits for asphalt fatigue*
  - *future research will enable this concept to be incorporated in the mechanistic design process*."
- Higher quality materials
  - The benefits of higher quality (in terms of higher modulus, better deformation resistance, longer fatigue life and / or durability) material is recognized.
  - Typical laboratory maximum strain values are
    - 90 and 100 µm for conventional asphalt mixes
    - 130 µm for EME2 mixes

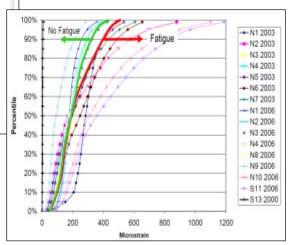
Summary

- 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.
- In essence
  - Very informative study tour – people, discussions, 'real situation'
  - General acceptance that LLP and FEL should be implemented
  - More accurately quantify fatigue testing
  - Conversion to field performance

Summary



Single governing strain
Vs.
Distribution of strains



Recommendations

- Australia would benefit from consideration of endurance strain levels in the design of flexible pavements and should be further investigated
- Progress in the Europe and the UK should be monitored, with a specific focus on work being done at the TRL and Delft University.
- However, any local development should not rely on a significant amount of information from Europe and the UK
- The best source of information to calibrate local models would be the performance of existing pavements, especially ones which had been rehabilitated