Workshop: New approaches to address pavement failure more realistically in asphaltic pavement design methods

Pavement design: Past, present, future, where is the crack?

_Laurent Porot_

- About pavement engineering
- Pavement design approaches
- Conclusions

DC to Richmond Road in 1919 – from the Asphalt Institute
Pavement engineering

Aim of pavement, why to design?

- The aim of pavement is to ensure a safe reliable journey for goods and people whatever the conditions

A need to connect

Road Serviceability

? 

Pavement Structure
Pavement design principle

- Optimise technically and economically with various constraints!!!!!
Analytical approach

Where are the cracks?

Modelling

Structure
- Type of structure
- Type of materials

Load model
- Equivalent Standard Axle Load
- Radius, Pressure

Material
- Fatigue curve

And interface bounding conditions

ε_t < ε_{adm}

AASHTO Method (1993)

- Empirical approach based on the AASHO road test (end of 50’s)
- Standard axle load 8t
- Introduction of
  - Present Serviceability Index PSI
  - Structural Number SN
  - Reliability factor

\[
\log(W_0) = 9.36 \log(SN+1) + 0.20 + \frac{\log(\text{PSI} - 8.07)}{0.40} + 2.32 \log(MR) - 5.58
\]

- Using general regression equation or nomograph
British method

• **Empirical approach**
  - TRL 1132 from 1982 & TRL 850 from 1997
  - DMRB Volume 7 Section 2

• **Standard axle load 8t**

• **Based on**
  - Concept of long life pavement for « indeterminate life »
  - Failure from top cracking not from fatigue

• **Material properties**
  - Modulus @ 20°C, 5Hz

• **Using specific chart**

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MEPDG philosophy

• **To replace AASHTO 1993 focus more on performances**

• **Progressive approach with accuracy of data**

Where are the cracks?
Shell Pavement Design Method

• Long history
  • From 1963 with design charts
  • 1973 with BISAR and 1978 with SPDM

• Based on Burmister model
  • Material model (BANDS)
  • Structure model (BISAR)
  • Climate conditions and traffic spectrum (SPDM)
  • Thickness, rutting, overlay design (SPDM)

• Key features
  • Healing factor, layer bonding
  • No reliability factor
French context

- Heavy standard axle load
  - 13t/ axle
- Severe winter in 60s
  - Important pavement degradations
- LCPC and the technical network
  - Research and development from both private and public
  - Full scale pavement facilities in Nantes
- Toll highway framework
  - Driven by whole life cycle cost optimisation


Early development of holistic pavement design approach

French method

- Empirical - analytical approach based on analysis of strain and stress in a multilayer model and fatigue law with field calibration
- Material characteristics assess via laboratory test
  - Modulus @ 15°C 10Hz,
  - Fatigue @ 10°C 25Hz
- Heavy standard axle load 13t
- User defined method with correlation factors
  \[ \varepsilon_{\text{allow}} = \left( \frac{NE}{10^6} \right)^b \times \left( \frac{E_{\theta_1}}{E_{\theta_2}} \right)^{1/2} \times 10^{-b\delta t} \times k4 \times k5 \times \varepsilon_{\theta_1} \]
- Use of Alize-LCPC software*
  - User friendly fully customised (climate, road/airport)
  - Design and overlay design

Design criteria

- For soil and unbound material → vertical strain on top
  - $\varepsilon_{vadm} = A \cdot N^{-0.222}$, $A = 12000$ low traffic, $16000$ high traffic
- For bituminous material → horizontal strain at the bottom
  - $\varepsilon_{hadm} = \varepsilon_6 \cdot (N/10^6)^{-1/b}$, $-1/b$ around 5
- For hydraulic material → horizontal strain at the bottom
  - $\sigma_{hadm} = \sigma_6 \cdot (N/10^6)^{-1/b}$, $-1/b$ around 12-13

Mostly fatigue criteria

Pavement design process

- Pavement design in 5 steps

1 – Traffic, expressed in ESAL

2 – Foundation, bearing capacity

3 – Materials, Structure types, material characteristics

4 – Pavement design, using charts or software

5 – Frost/Thaw, verification

Final Structure, layers, thickness, construction, maintenance, ...

Climate

Service value
Structure value
Various loading configuration

- **Standard road axle loading**
  - Axle load 8.16 t (18kib)
  - Single twin wheel axle

- **B777 aircraft gear**
  - Total weight 240-300t, 13 bars
  - 6 wheels gear

Sensitivity analysis

**Reference case:**
- PF2
  - 11 GB 2
  - 12 GB 2
  - 300 truck/day
  - 20 years

**Unbound layers:**
- PF2
  - 11 GB 2
  - 12 GB 2
  - 300 truck/day
  - 1 year 2 months

**Weak foundation**
- PF1
  - 11 GB 2
  - 12 GB 2
  - 300 truck/day
  - 10 years

**Thickness variation**
- PF2
  - 11 GB 2
  - 10 GB 2
  - 300 truck/day
  - 11 years
Russian Pavement Design

Russian context

- One of the world largest country
  - Various climate zones from cold to sub tropical
  - Wide road network
- Long historical scientific background
  - MADI (Московский автомобильно дорожный государственный) research facilities
  - Over last decades many innovations introduced
  - Partnerships with LCPC back in 70s
Russian method

- **Analytical approach in ODN 218.046.01** (ГОСУДАРСТВЕННАЯ СЛУЖБА ДОРОЖНОГО ХОЗЯЙСТВА МИНИСТЕРСТВА ТРАНСПОРТА РОССИЙСКОЙ ФЕДЕРАЦИИ)
  - Mechanical design and freeze/thaw resistance
- **Material characteristics assess via laboratory test**
  - Specific job mix formula, strength at 0°C, 20°C, 60°C
  - Assumption for other characteristics
- **Different climate zones**
- **Traffic with**
  - different standard axle load up to 115 kN
  - Number of days per year depending on climate zone
- **Use of nomographs or software**

**Design process**

- **Road category and traffic class**
  - 5 road categories with reliability from 0.7 to 0.98
  - Standard axle load depends on road category and project
  - Total traffic for 70 to 205 days depending climate zones
- **Mechanical calculation**
  - Total pavement strength, allowed total deflexion layer by layer
  - Maximal strength on subgrade layer (at 20°C)
  - Fatigue resistance of bound materials (stress)
- **Freeze / thaw calculation**
  - Total freeze depth depending on climate zone
Design criteria

- Total equivalent traffic loading \( \sum N_f = 0.7N_f \frac{K}{q^{1/3-D}}T_{ph}N_p \)
- Total pavement strength
  - Use of nomograph \( K = E_i/E_{i-1} \)
  - Asphalt concrete 2000 to 3200 MPa
- Maximal strength on the subgrade
  - 2-layer model with \( E_z = \left( \frac{\sum E_i h_i}{\sum h_i} \right) \)
  - Use of nomograph
- Fatigue resistance \( \sigma_f < \frac{R_N}{K_{ff}} \)
  - Use of total pavement strength
- Freeze resistance
  - Freeze depth, use of deep sand layer

Where are the cracks?

Conclusion
Conclusion

• Trend towards more analytical pavement design vs. empirical
• Common features using Burmister multi-layer model
  • Elastic linear model and fatigue law
• Where are the cracks?
  • Fatigue resistance addressed in pavement design
  • Debonding can be assessed
  • Thermal cracking (low temperature) addressed with asphalt mix design
• More model in Pavement Management System
  • HDM4, ...