8th RILEM International Conference on Mechanisms of Cracking and Debonding in Pavements

June 7 - 9, 2016 – Nantes, FRANCE

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

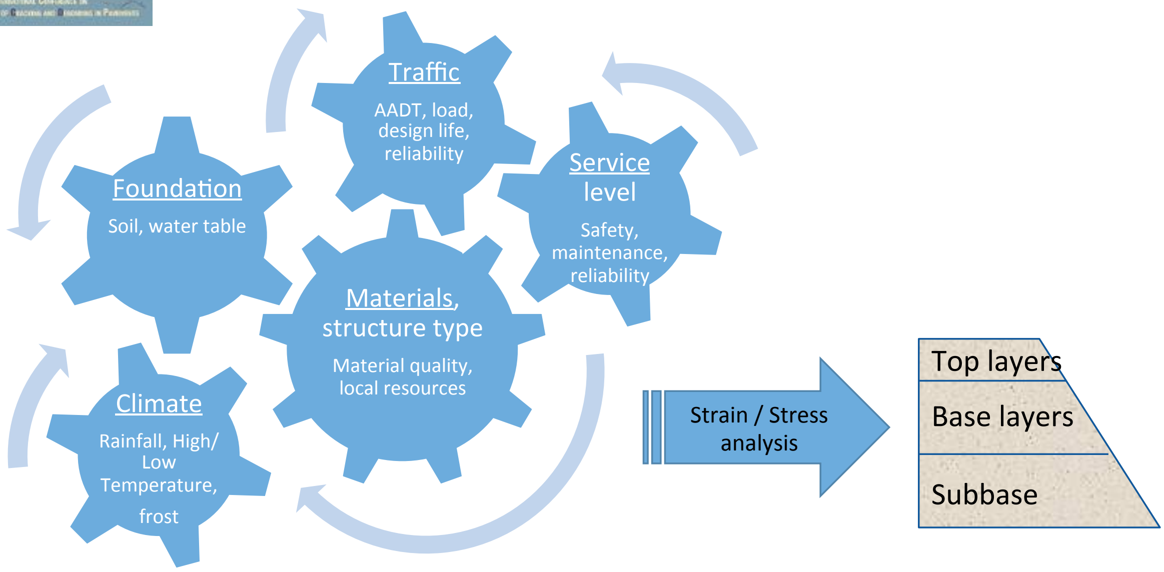
Aim of pavement, why to design?

- 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

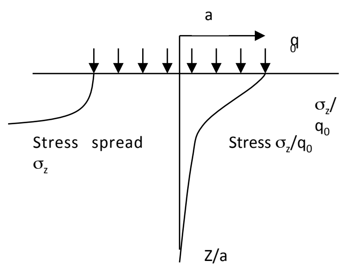


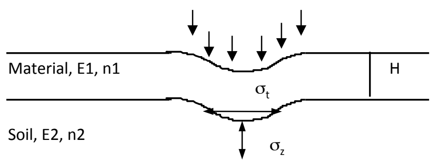
- Optimise technically and economically with various constraints!!!!!

Pavement design mechanism

Where are the cracks?

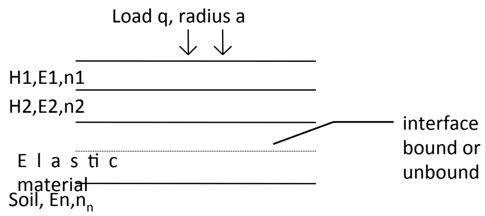
- Boussinescq (1866)
  - Infinite layer
  - Independent of material characteristics





- Hogg (1938) & Westegaard (1926)
  - 2 layers
  - Material dependent (Stiffness)

- Burmister (1943)
  - Multi layers
  - Linear Elastic Theory
  - Isotropic & horizontally infinite layers



Analytical approach

Modelling

Where are the cracks?

Structure

- Type of structure
- Type of materials

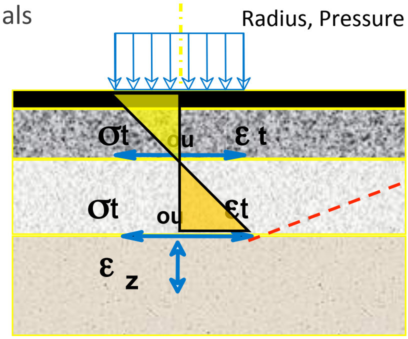
E_1, H_1, ν_1
E_2, H_2, ν_2
E_3, H_3, ν_3
E_4, H_4, ν_4

And interface bounding conditions

Load model

- Equivalent Standard Axle Load

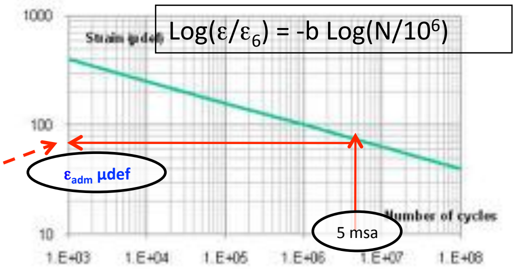
Radius, Pressure



Material

Fatigue curve

$\mathrm{Log}(\varepsilon/\varepsilon_6) = -b\ \mathrm{Log}(N/10^6)$



$\varepsilon_t < \varepsilon_{adm}$

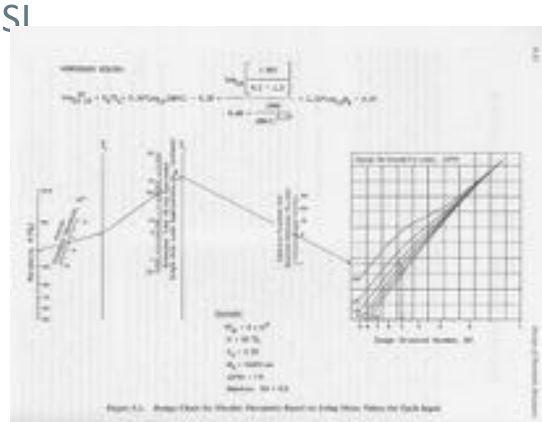
AASHTO Method (1993)

- 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

Where are the cracks?

$$\mathrm{Log}(W_{18}) = Z_R \times S_0 + 9.36 \times \log(SN+1) - 0.20 + \frac{\log\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40+\frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log(MR) - 8.07$$

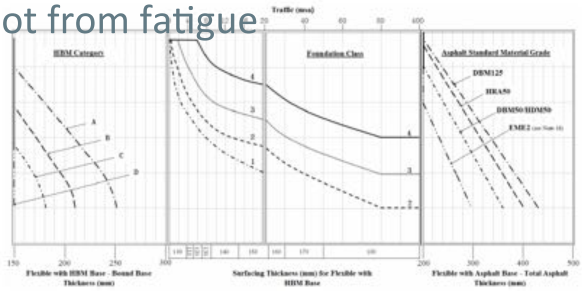
- Using general regression equation or nomograph



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

Where are the cracks?



MEPDG philosophy

- To replace AASHTO 1993 focus more on performances
- Progressive approach with accuracy of data

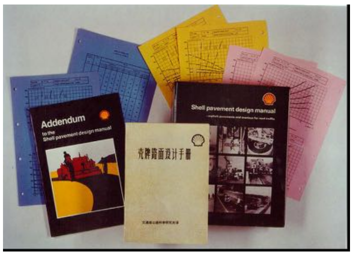
Where are the cracks?

Level 3
By default design,
User-selected values

Level 2
Close to AASHTO 1993,
User-selected values from database,
Modulus assessed through binder

Level 1
Dynamic modulus master curve,
Site specific traffic spectrum,
Field deflexion

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

Where are the cracks?

French Pavement Design

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

$$\varepsilon_{allow} = (NE/10^6)^b \text{ x} (E_{\theta 1}/E_{\theta 2})^{1/2} \text{ x } 10^{-b\delta t} \text{ x } k4 \text{ x } k5 \text{ x } \varepsilon_{6\ \theta 1}$$

- Use of Alize-LCPC software*
  - User friendly fully customised (climate, road/airport)
  - Design and overlay design

ALIZE-LCPC

* http://www.itech-soft.com/alize/index.php?lang=en

Design criteria

Where are the cracks?

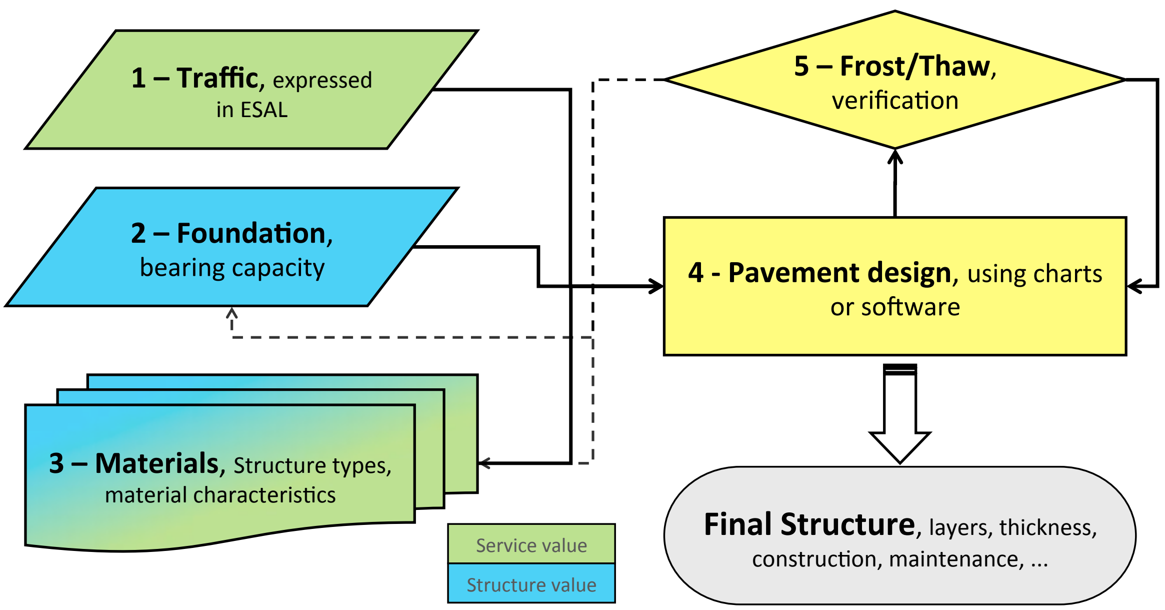
- For soil and unbound material
  → vertical strain on top
  - $\varepsilon_{vadm} = A\ N^{-0.222}$ A = 12000 low traffic 16000 high traffic
- For bituminous material
  → horizontal strain at the bottom
  - $\varepsilon_{hadm} = \varepsilon_6\ (N/10^6)^{-1/b}$ -1/b around 5
- For hydraulic material
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

Mostly fatigue criteria

Pavement design process

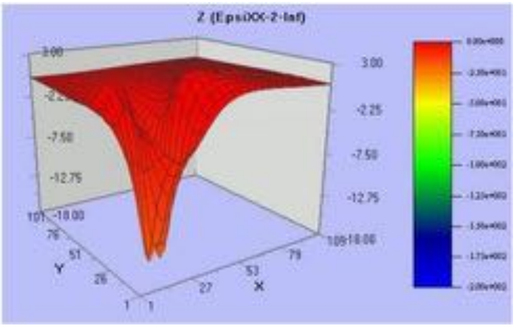
Climate

- Pavement design in 5 steps

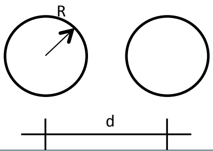


Various loading configuration

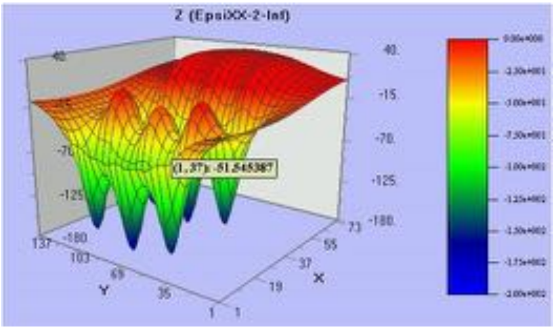
- Standard road axle loading
  - Axle load 8.16 t (18klb)
  - Single twin wheel axle



Standard axle modelling (8.16t)



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



Sensitive analysis

Reference case:

11 GB 2
12 GB 2
PF2

300 truck/day
20 years

Debonding

Unbound layers:

11 GB 2
12 GB 2
PF2

300 truck/day
1 year 2 months

Weak foundation

11 GB 2
12 GB 2
PF1

300 truck/day
10 years

Thickness variation

11 GB 2
10 GB 2
PF2

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

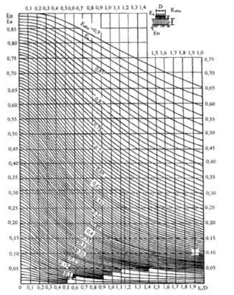
- Analytical approach in ODN 218.046.01 (ГОСУДАРСТВЕННАЯ СЛУЖБА ДОРОЖНОГО ХОЗЯЙСТВА МИНИСТЕРСТВА ТРАНСПОРТА РОССИЙСКОЙ ФЕДЕРАЦИИ)
  - Mechanical design and
  - Freeze/thaw resistance
- Material characteristics assess via laboratory test
  - Specific job mix formula, strength at 0°C, 20°C, 60°C
  - Assumption 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

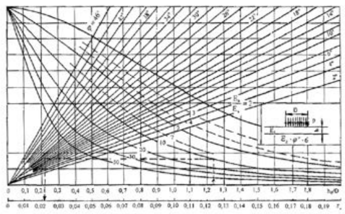
Design process

- 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 $\sum N_p = 0{,}7 N_p \frac{K_c}{q^{(T_{ca}-1)}} T_{pôz} K_n$
- 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 $E_s = \left(\sum_{i=1}^{n} E_i h_i\right) : \left(\sum_{i=1}^{n} h_i\right)$
  - Use of nomograph
- Fatigue resistance $\sigma_r < \frac{R_N}{K_{np}^{mp}}$
  - Use of total pavement strength
- Freeze resistance
  - Freeze depth, use of deep sand layer





Where are the cracks?

Conclusion

Cut & Fold Erik Johannson http://www.erikjohanssonphoto.com/

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, …

Where are the cracks?