CONTRIBUTION OF VISCOELASTICITY IN THE DYNAMIC SIMULATION OF HWD TESTS FOR FLEXIBLE PAVEMENT ASSESSMENT

BROUTIN Michael, PhD (presenting)*, STAC, France
KTARI Rahma, Limoges University, France
PICOUX Benoît, PhD, Limoges University, France
NEJI Jamel, PhD ENIT, Tunisia
PETIT Christophe, PhD, Limoges University, France

* michael.broutin@aviation-civile.gouv.fr
Outline of the presentation

➢ Background
  • Principle of pavement testing using HWD
  • STAC’s advanced dynamic analysis method

➢ Refinements of the method: introduction of viscoelasticity in bituminous materials
  • Modelling and resolution
  • Operational implementation
Outline of the presentation

➢ Background
   • Principle of pavement testing using HWD
   • STAC’s advanced dynamic analysis method

➢ Refinements of the method: introduction of viscoelasticity in bituminous materials
   • Modelling and resolution
   • Operational implementation
Measuring principle

Buffers

Drop height $H$

Mass $M$

Load plate

Load plate; Force sensor and geophone $G$

Pavement

Data analysis principle

Geophones positions

G1

Moving direction

Towing vehicle

G4b

G8b

G6b

Main beam

Extension beam

Numerical basin

Experimental basin

Sensor and

Effort [kN]

Déflections

Typical rawdata

Principle of HWD


BROUTIN Michael, PhD
HWD principle

- A three step process
  - 1 - Backcalculation of the parameters of the chosen mechanical pavement modeling
  - 2 - Critical stresses/strains calculation under real traffic linked to the rational design method
  - 3 - Pavement residual life and/or pavement bearing capacity (Single wheel load or PCN) determination development of rational PCN; cannot be disconnected to thoughts about rational ACN (ICAO/PSG matter)
Outline of the presentation

➢ Background
  • Principle of pavement testing using HWD
  • STAC’s advanced dynamic analysis method

➢ Refinements of the method: introduction of viscoelasticity in bituminous materials
  • Modelling and resolution
  • Operational implementation
STAC’s dynamical method

Multilayered elastic modelling
FEM modelling
External action: force history (measured by HWD force sensor)

Surface AC Base AC UGA
Subgrade
Load plate

Structure under study

\[ G_9 \]
\[ G_8 \]
\[ G_7 \]
\[ G_6 \]
\[ G_5 \]
\[ G_4 \]
\[ G_3 \]
\[ G_1 \]

\[ u_r = 0 \]
\[ u_z = 0 \]

Mesh has been optimized (width (L) and fineness)

STAC’s dynamical method
Modelling improved (vs pseudo-static methods)
Complex shape of force signal (double peak)
Modelling closer to real phenomenon
- Inertia effects
- Damping

Nevertheless bituminous material modelling can be refined
Viscoelastic behavior

AUSCULTATION DES CHAUSSÉES SOUPLES AÉRONAUTIQUES AU HWD
Guide technique

Background
• Principle of pavement testing using HWD
• STAC’s advanced dynamic analysis method

Refinements of the method: introduction of viscoelasticity in bituminous materials
• Modelling and resolution
• Operational implementation
Viscoelasticity consideration

- Huet & Sayegh rheological model [Sayegh, 1965]

\[ E^*(\omega) = E_0 + \frac{E_\infty - E_0}{1 + \delta(i\omega a(T))^{-k}(i\omega a(T))^{-h}} \]

7 parameters → Backcalculation too complex

- Simplified Huet model

\[ E^*(\omega) = \frac{E_\infty}{1 + A(i\omega)^{-\alpha}} \]

3 parameters
Viscoelasticity consideration

- Adjustment of the viscoelastic parameters
  - Using complex moduli results from laboratory tests performed on the STAC’s instrumented test facility bituminous materials (BBA+GB)
  - Fitting on the HWD signal frequency range (1-80Hz)
Viscoelasticity consideration

- Fitting on the GB:

- Results:

<table>
<thead>
<tr>
<th>Material</th>
<th>$E_\infty$</th>
<th>$A$</th>
<th>$\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBA 0/10</td>
<td>30378</td>
<td>8,623</td>
<td>0,343</td>
</tr>
<tr>
<td>GB 0/14</td>
<td>31859</td>
<td>4,733</td>
<td>0,339</td>
</tr>
</tbody>
</table>
Numerical resolution

- In the frequency domain
  
  1- FFT on the force signal
  \[ F(t) = F_0 e^{i\omega t} \Rightarrow \tilde{F}(\omega) = \tilde{F}_r(\omega) + i \tilde{F}_i(\omega) \]

  2- Resolution of the complex problem
  \[
  \begin{bmatrix}
  K - \omega^2 M & \omega C \\
  -\omega C & K - \omega^2 M
  \end{bmatrix}
  \begin{bmatrix}
  \tilde{U}_r \\
  \tilde{U}_i
  \end{bmatrix}
  =
  \begin{bmatrix}
  \tilde{F}_r \\
  \tilde{F}_i
  \end{bmatrix}
  \]

  3- Inverse FFT to find time domain solution
Deflections attenuation is linear with the distance to load center.

\[ y = -12.543x + 25 \]
\[ R^2 = 0.9982 \]
Outline of the presentation

- Background
  - Principle of pavement testing using HWD
  - STAC’s advanced dynamic analysis method

- Refinements of the method: introduction of viscoelasticity in bituminous materials
  - Modelling and resolution
  - Operational implementation
Implementation

- Viscoelastic direct calculation time-consuming
- Approximate method is advocated: define on the base of a sensibility study (as a function of material, temperature, layer thicknesses), corrections to be applied to deflections for the dynamical method to be used
Thank you for attention