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► **To cite this version:**

Armelle Chabot, Quang Dat Tran, Bertrand Pouteau. Simplified modelling of a cracked composite pavement. First International Elsevier Conference on Failure Analysis (ICEFA-I), Jul 2004, Lisbonne, Portugal. ⟨hal-01677029⟩

HAL Id: hal-01677029

<https://hal.science/hal-01677029v1>

Submitted on 7 Jan 2018

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Simplified modelling of a cracked composite pavement

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Figure 1 - Pictures of real cracked pavements

Objectives:

Mechanical study of bond between layers of composite pavements with a new model which has been built for:

- the evaluation of cracked asphalt and/or concrete pavements
- design solutions for rehabilitation
- reflective cracking study

The Bismister model [Burmister, 1943] is used in the French method of pavement design (Alizé-Lcpc software). If there are cracks, the design method requires others models.

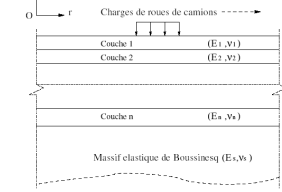


Figure 2 - The burmister model

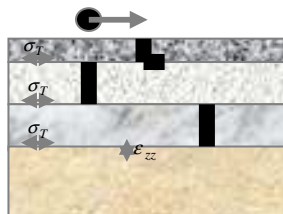


Figure 3 - cracked pavement structure

The M4-Boussinesq model [Tran et al., 2004]

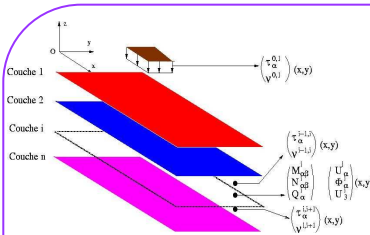


Figure 4 - The M4-5n model

Pavement multi-layers -> M4-5n model

Multi-particle model of multi-layer materials with 5n equilibrium equations (n: total number of layers)

[Chabot A. 1997] [Chabot, Ehrlicher, 1998]

- > Polynomial approximation per layer i in z for σ_{ij}
- > Hellinger-Reissner formulation (Reissner, 1950)

The Soil -> Boussinesq model

[Boussinesq, 1890]

- > Analytical equations between external forces and surface displacement

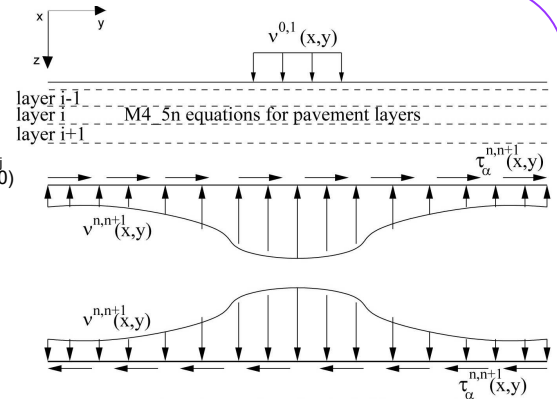


Figure 6 - Simplify modelling

Figure 5 - Boussinesq model

The numerical method used

Main Unknowns

→ 5 displacements per layer

$$X^i = T [U_1^i, U_2^i, \Phi_1^i, \Phi_2^i, U_3^i] \quad \forall i \in [1, n]$$

+ 3 interface stresses

$$\Sigma = T [\bar{\tau}_1^{n,n+1}, \bar{\tau}_2^{n,n+1}, \bar{\nu}^{n,n+1}]$$

$$AAx_{11} + BBx_{22} + CCx_{12} + DDx_{11} + EEx_{12} + FFx = GG\Sigma_1 + HH\Sigma_2 + IIS + JJ$$

(5n equ.)

$$\int_S f(\bar{x}, \bar{y}, \bar{\xi}, \bar{\eta}) \Sigma(\bar{\xi}, \bar{\eta}) d\bar{\xi} d\bar{\eta} = \sum_1^{(N+1)^2} \int_{S_s} f(\bar{x}, \bar{y}, \bar{\xi}, \bar{\eta}) \Sigma(\bar{\xi}, \bar{\eta}) d\bar{\xi} d\bar{\eta}$$

(3 equ.)

$$X = T [X^1 X^2 \dots X^n]$$

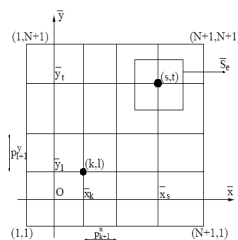


Figure 7 - The M4-B mesh

$$\frac{X_{(i,j)/1} + X_{(i+1,j)/1}}{2} = \frac{X_{(i+1,j)} - X_{(i,j)}}{k_{j+1}}$$

$$\frac{X_{(i,j)/2} + X_{(i,j+1)/2}}{2} = \frac{X_{(i,j+1)} - X_{(i,j)}}{k_{j+1}}$$

For the M4-5n equations -> Newmark
Difference finite method

For the Boussinesq equations ->
Half Analytic method

Linear system - use of Matlab software

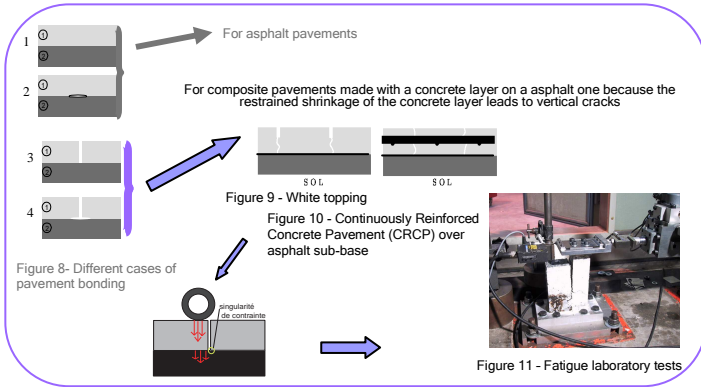
$$K_1 X = K_2 \Sigma + K_3$$

$$K_4 X = K_5 \Sigma + K_6$$

$$X = T [X_{1,1}, X_{1,2}, \dots, X_{N+1,N+1}] \quad 5n(N+1)^2$$

$$\Sigma = T [\Sigma_{1,1}, \Sigma_{1,2}, \dots, \Sigma_{N+1,N+1}] \quad 3(N+1)^2$$

Study of adhesion between concrete and asphalt [Pouteau et al., 2004]



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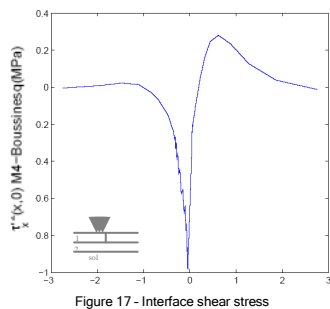
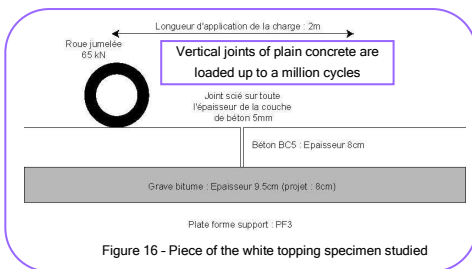
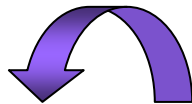
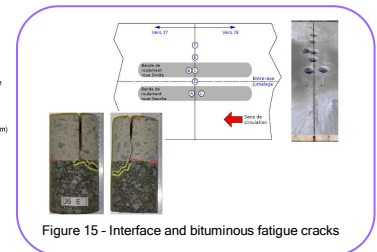
Figure 12 - The in situ experiment



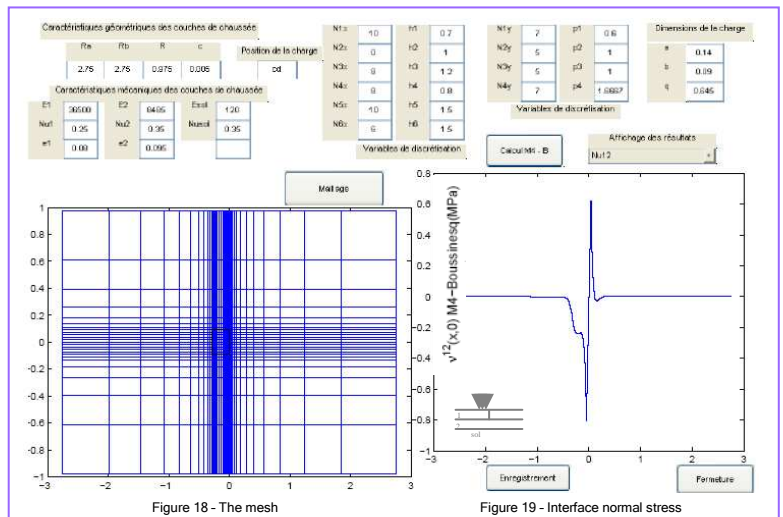
Figure 13 - The FABAC machine



Figure 14 - The white topping specimen



The Matlab interface developed [Guillo, 2004]



Conclusions:

To make a proper analysis of crack initiation and propagation in cracked pavement structures, a simplified model (named the multi-particle model of multi-layer materials, M4) linked to the Boussinesq model for the soil has been developed [Tran et al., 2004]. To study the bond of composite pavement structures, an in-situ experiment has been performed using an accelerating pavement loading facility [pouteau et al., 2004]. It shows different kinds of crack propagations: cracks at the interface between the layers and cracks through the materials. With that so-called M4-Boussinesq model, the initial mechanical fields of that in-situ experiment has been calculated.

Modelling prospects:

- ✓ ϵ_{xx} and ϵ_{yy} strain comparisons with the model and the FABAC sensors
- ✓ Fortran or C++ Programming of the M4-Boussinesq model
- ✓ Introduce delamination cracks