



**HAL**  
open science

## Simplified modelling of a cracked composite pavement

Armelle Chabot, Quang Dat Tran, Bertrand Pouteau

► **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-01677029>**

Submitted on 7 Jan 2018

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Simplified modelling of a cracked composite pavement

A. Chabot\*, Q. D. Tran\*\*, B. Pouteau\*\*\*

\*Division Matériaux et Structures de Chaussées /LCPC ([www.lcpc.fr](http://www.lcpc.fr))

\*\* Laboratoire Analyse et Identification des Matériaux/ENPC ([www.enpc.fr](http://www.enpc.fr)); \*\*\*Eurovia

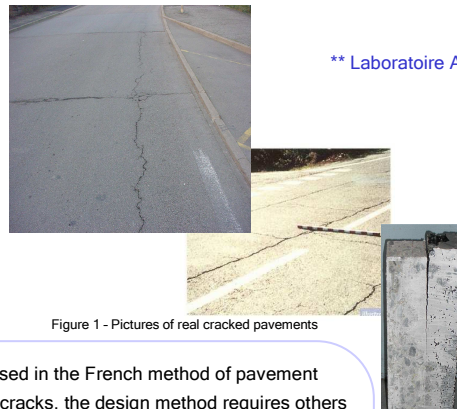


Figure 1 - Pictures of real cracked pavements

## 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.

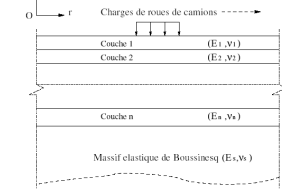


Figure 2 - The burmister model

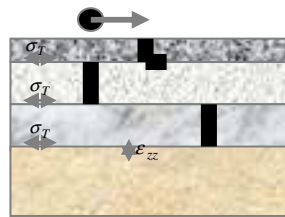


Figure 3 - cracked pavement structure

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

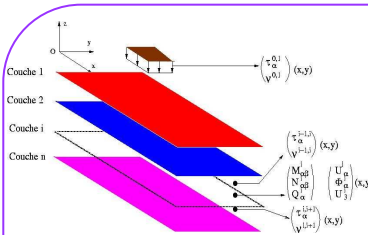


Figure 4 - The M4-5n model

### 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  $\sigma_{ij}$
- > Hellinger-Reissner formulation (Reissner, 1950)

### The Soil -> Boussinesq model

[Boussinesq, 1890]

- > Analytical equations between external forces and surface displacement

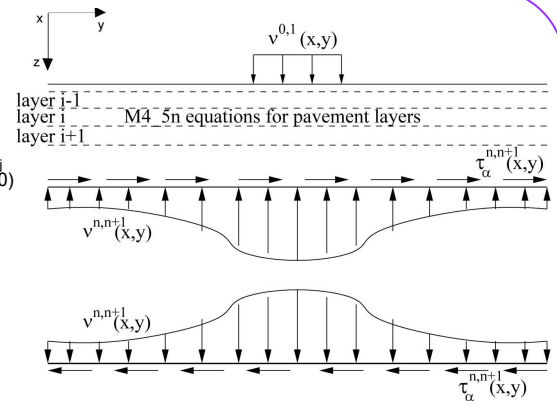


Figure 6 - Simplify modelling

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.)

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

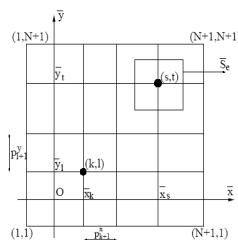


Figure 7 - The M4-B mesh

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

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

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

For the Boussinesq equations ->  
Half Analytic method

Linear system - use of Matlab software

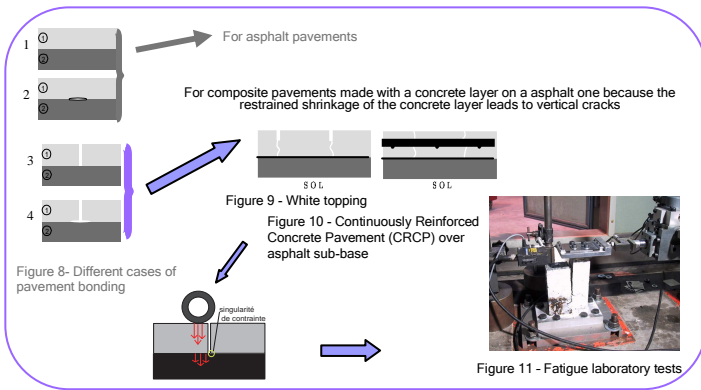
$$K_1 X = K_2 \Sigma + K_3$$

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

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

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

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



ATILH



Figure 12 - The in situ experiment



Figure 13 - The FABAC machine

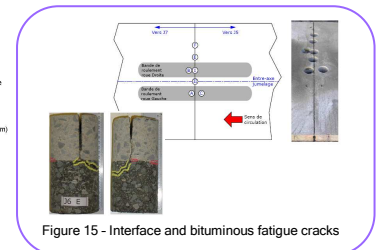
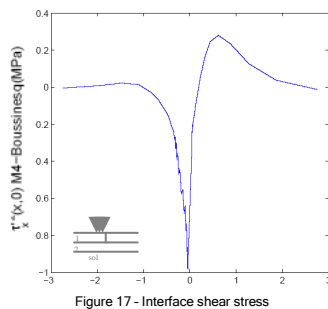
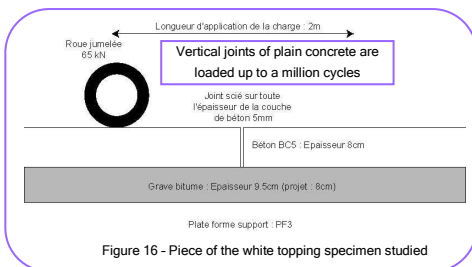
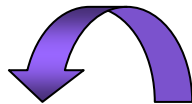
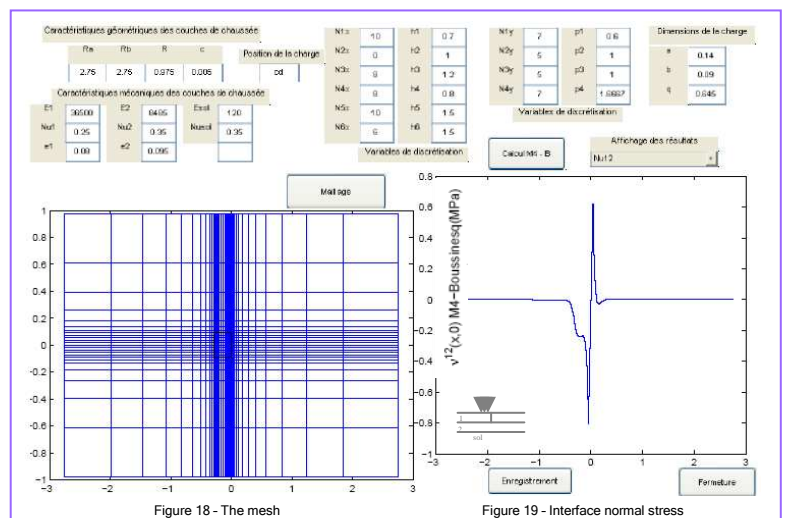


Figure 14 - The white topping specimen



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:

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