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THERMAL NONDESTRUCTIVE CHARACTERISATION OF LAYERS DETACHMENT IN THE ROADWAYS

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***Abstract** - in this work, we present numerical simulations, in 3 D, which aim at studying the aptitude of the thermal nondestructive testing to detect the detachment of layers of two roadways structures : semi-rigid and thick. We will study the influence of the defect geometry of the separation type between the layers on the simulated thermographical image on the surface. For that, we will consider two parallelepipedic roadways structures, of the same dimensions; the first one is of semi-rigid type and the second one is thick. These structures are excited by a heat flux on the surface, the opposite face being maintained at a constant temperature and other surfaces are thermically isolated. Separation between two layers of the roadway is materialized by the insertion of a air blade. Once steady operation is established, we will take and study the thermographical image on the surface. This study is made using numerical commercial computation software, based on the finite element method.*

***Keywords:** roadway, semi rigid, thick, detachment, Thermal nondestructive characterization, Finite elements, Heat transfer*

1 Introduction

Separation between the roadways layers is of a harmful influence over the lifespan of such structures. These defects come either from defects to the implementation, or of the difficulty of obtaining a good joining between materials, in particular between bituminous and hydraulic layers. The detection of these defects is thus of primary importance in order to identify the problematic zones and to develop thereafter remedies to attenuate the negative impacts and to lengthen the lifespan of the roadways. The ideal scenario in the detection of the defects is based on nondestructive approaches to prevent to obstruct the vehicular traffic [1]. In this article, we will draw up a numerical study of the roadway response, containing defects of detachment type, with a thermal wave and the influence of such defect on the simulated thermographical image on the road surface. The adopted approach is a numerical approach based on the finite element method and concretized by commercial numerical computation software.

2 Description of the model

In this study we considered two structures: semi rigid and thick. The two structures have the same length (L=8000 mm) and the same width (l=4000 mm) (fig. 4). The thickness depends on the type of the structure.

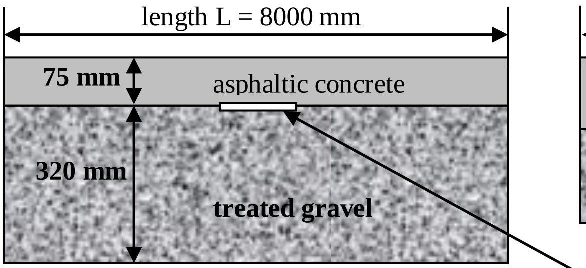

Fig. 1 : semirigid structure

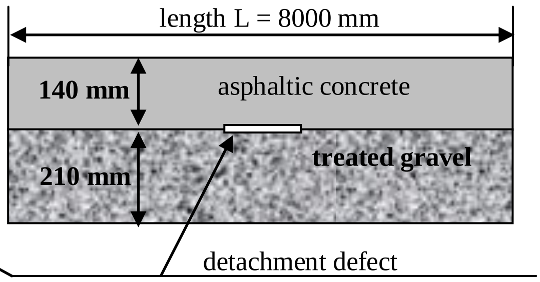

Fig. 2 : thick structure

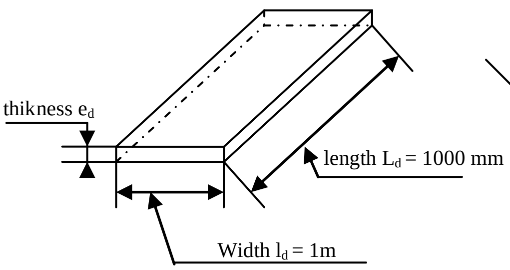

Fig. 3 : defect structure

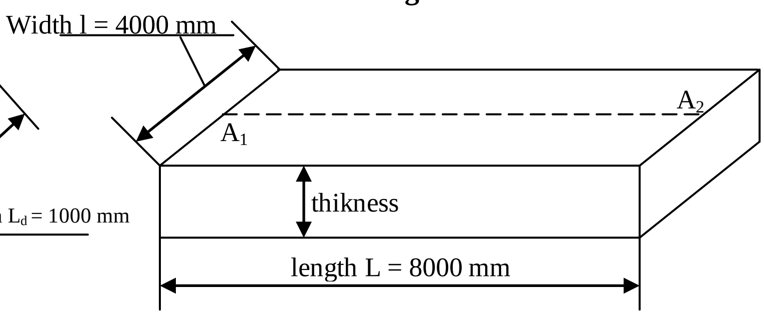

Fig. 4 : roadway structure in prospect

The simulated structures are identical, with the thicknesses close to the various layers (fig. 1; Fig. 2) [2], indeed, the semi rigid structure contains a surfacing out of asphaltic concrete a 75 mm thickness, as for the thick structure, it contains a surfacing 140 mm thickness. For the base course, it is a layer out of low register treated with the hydraulic binders, it is a 320 mm thickness of for the rigid semi structure and of 210 mm for the thick structure.

3 Mathematical model

To solve the following thermal equation:

$$a\nabla^2 T = \frac{dT}{dt} \qquad (1)$$

The report $a = \frac{\lambda}{\rho c}$ is called thermal diffusivity.

We call upon the numerical method of the finite elements [3, 4]. The analytical resolution is indeed impossible being given the geometry of the problem. The method consists in using an approximation by finite elements of the unknown functions T to discretize the variational form of the equation (1) and to transform it into system of algebraic equations of the form:

$$\mathrm{A}\ T = F \qquad (2)$$

With :
A square matrix of dimension [N_h, N_h]
F a vector of N_h components
T the vector of the temperatures to be calculated
We start by building the variation form of the equation (1). We carry out a spatial discretization which consists in calculating the elementary integrals by using the finite element and a temporal discretization.
There are many specialized software which make it possible to implement the method of resolution of problems by finite elements in a more or less simple and convivial way. They take care in particular of the grid of the studied object, of the automatic numbering of the elements and the nodes, of the calculation of a solution then of the chart of the results.
In this study, we used commercial software based on the finite element method and which makes it possible to calculate the evolution of temperature at any moment and in any point of material. The material is considered isotropic.

The calculation of the thermal response is made in the case of a portion of roadway subjected to a step of flow on the surface, on the front face, continuous and extended of density Q=100 W/m^2. The back face being maintained at a constant temperature T_a = 25°C and the others faces are insulated (Q=0). It is supposed that the thermal excitation is applied in a uniform way to considered surface. The initial temperature is T_0=25 °C.

4 Results of simulations

The computation results thermal are presented in the case of a portion of roadway [2] container :

- asphaltic concrete wearing layer characterized by λ = 1.5 W/m.K (thermal conductivity), ρ = 2400 Kg/m3 (density) and C = 907 J/Kg.K (specific heat).
- a base layer in treaty gravel characterized by λ =0.95 W/m.K (thermal conductivity), ρ=2350 Kg/m^3 (density) and C = 886 J/Kg.K (specific heat).

By exploiting the equation of heat, knowing the thermophysical characteristics of the roadway, and by using a commercial numerical computation software based on the finite element method, we can determine the distribution of temperature in any point of the structure, the assumptions calculation are as follows:

- the temperature in bottom of structure (base of the platform) is constant;
- there is not discontinuity between the various layers of materials;
- the defects of the detachment types are represented as blades (fig 3)of air characterized by [5]: λ=0.0272 W/m.K (thermal conductivity), ρ=1.057 Kg/m^3 (density) and C=1005 J/Kg.K (specific heat)
- in this work, we will study the influence thickness (ed) and the width (ld) of such a defect (fig. 3) on the distribution of the temperature on the road surface.

The results of simulation are given thereafter in the form of thermal images representing the distribution of the apparent temperature, in degree Celsius (°C), on the upper surface of the roadway. The scale of temperature chosen to describe the variation in the temperature on the surface is a scale of color which associates the highest temperatures of surface (potentially problematic zones) the red color and the lowest temperatures (zones a priori healthy) the blue color.

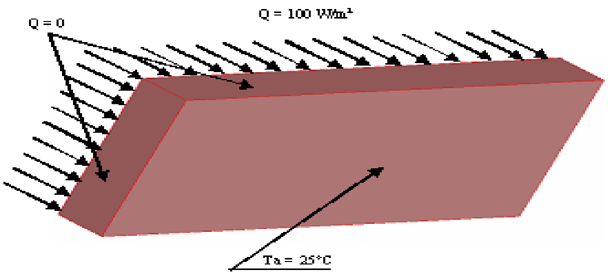

Fig. 5 : Boundary conditions

4.1 Effect of the width defect

In this part, we considered two portions of roadway, a semi rigid and the other thick one, in which we inserted three defects having respectively a width l_d of 100, 150 and 300 mm., the length L_d = 1000 mm and the thickness e_d = 10 mm.

Figures 6 and 7 represent profiles of temperature distribution on the road surface, respectively for a portion of semi rigid roadway and thick one. They show hotter thermal tasks on the level of the problematic zones than those of the healthy zones.

Figure 8 and 9 represent the temperature evolution according to A_1A_2 line passing by the points [(0,2,0.395); (8,2,0.395)] in the case of a portion of semi rigid roadway and by the points [(0,2,0.350); (8,2,0.350)] in the case of a potion of thick roadway. They highlight the influence of the defect width on the surface temperature distribution; thus, more the width is small, more the intensity of the peak reflecting the presence of defect is low. Of such intensity allows to determine the necessary sensitivity of the material of non destructive testing to use.

We can note also that temperature peaks associated to defects are weaker in the case of a thick roadway as in the case of a rigid semi roadway, that is due to the position compared to surface; indeed, in the case of a semi rigid roadway, the defects are at 75mm from the surface, and in the case of the thick roadway, they are located at 140mm from the surface.

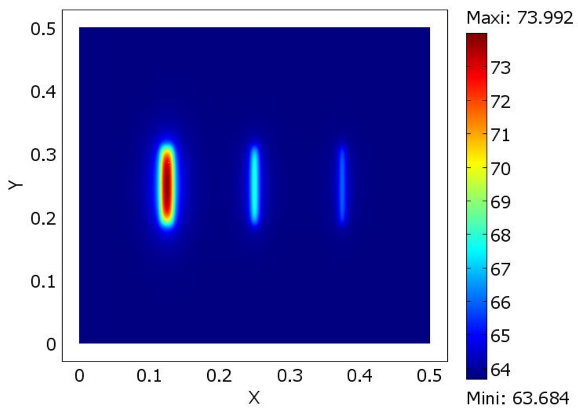

Fig. 6 : Effect of the width defect on the thermographical image of the entry face (semi rigid structure)

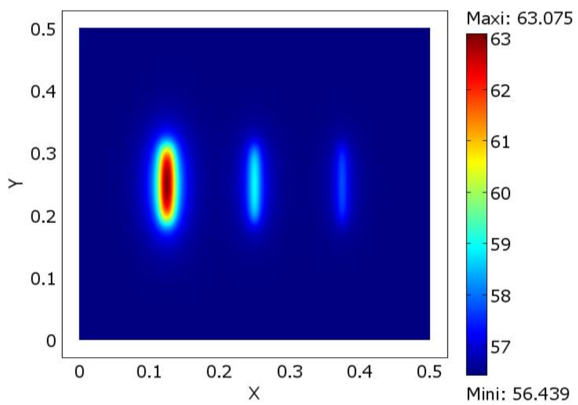

Fig. 7 : Effect of the width defect on the thermographical image of the entry face (thick structure)

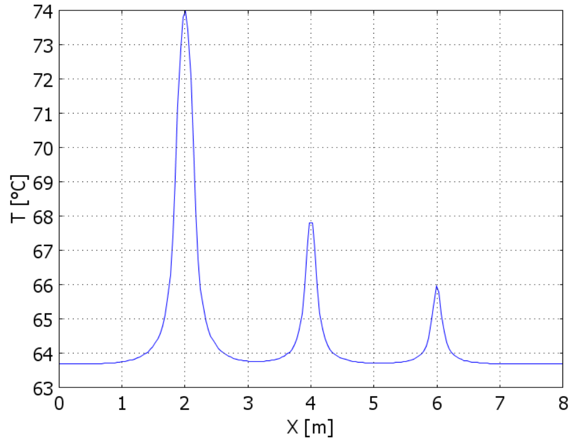

Fig. 8 : Distribution of the temperature along axis A_1A_2
A_1A_2 : [(0,2,0.395) ; (8,2,0.395)] (semi rigid structure)

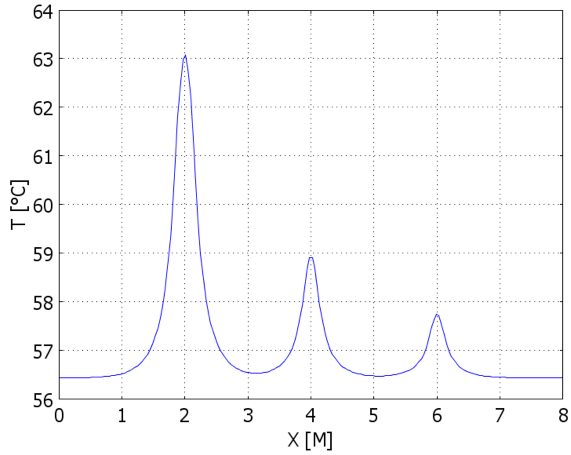

Fig. 9 : Distribution of the temperature along axis A_1A_2
A_1A_2 : [(0,2,0.395) ; (8,2,0.395)] (thick structure)

4.2 Effect of the thickness defect

In this part, we considered the same structures of roadway, but in this time, we inserted 3 defects of the same width l_d = 100 mm, and length L_d = 1000 mm and the respectively thickness e_d of 10mm, 20mm and 30mm.

Figures 10 and 11 respectively show the simulated thermographical image on the road surface in the case of a semi rigid roadway and a thick one.

Figures 12 and 13 show the temperature evolution according to A_1A_2 line passing, in the case of a portion of semi rigid roadway, by the points:
[(0,2,0.395) ; (8,2,0.395)] and, in the case of a portion of thick roadway, by the points: [(0,2,0.350) ; (8,2,0.350)]. These images illustrate the thickness influence of the defect on the simulated thermographical image on the road surface. The defects, being resistive, are opposed to the heat flow, which generates on the surface hotter zones at the defects location. In the same way, we can note that the intensity of such tasks is higher in the case of a semi rigid roadway than in the case of a thick one; and that is due to the thickness of the wearing course.

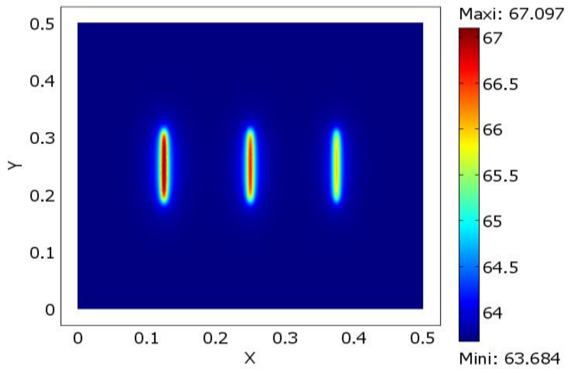

Fig. 10 : Effect of the thickness defect on the thermographical image of the entry face (semi rigid structure)

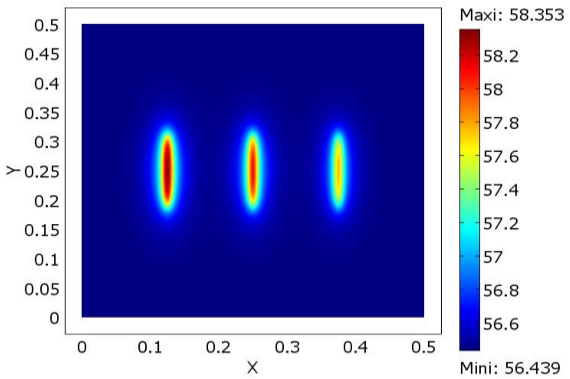

Fig. 11: Effect of the thickness defect on the thermographical image of the entry face (thick structure)

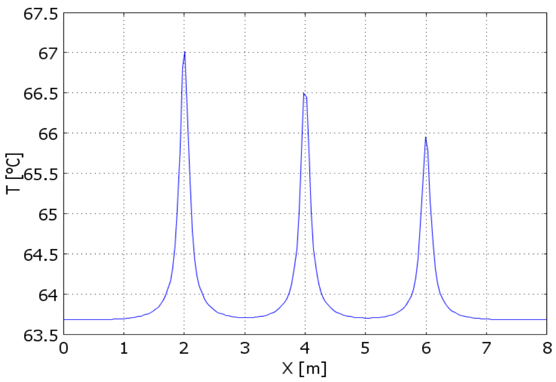

Fig. 12 : Distribution of the temperature along axis A_1A_2
A_1A_2 : [(0,2,0.395) ; (8,2,0.395)] (semi rigid structure)

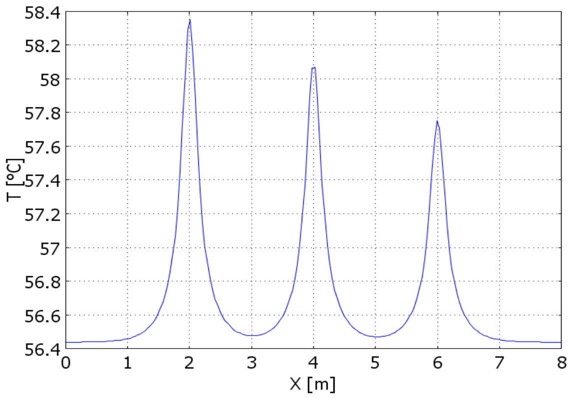

Fig. 13 : Distribution of the temperature along axis A_1A_2
A_1A_2 : [(0,2,0.395) ; (8,2,0.395)] (thick structure)

5 Conclusion

In this work, we studied the influence of the geometrical parameters of interface defects between the basic wearing course and that of two roadway portions: one being semi rigid and the other thick one. One can conclude that theoretically, as in other work already completed [5, 6, 7] and who approached other types of defects, separation between the layers of roadway can be detected by thermography, in the condition that the temperature variation between the healthy zones and the problematic one is sufficient so that it is detectable by the used thermal material of nondestructive testing.

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