Effect of Geotextiles on Crack Propagation in the Pavement Overlays

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ABSTRACT: The rehabilitation of cracked roads by using a bitumen impregnated geotextile as interlayer between the sub-base and the new overlay has been largely developed from the eighties. The evaluation of the efficiency of this anti-reflective cracking system has been studied by means of experimental and numerical methods. The results are pointing out the influence of the geotextile and the bitumen.

1 INTRODUCTION

When pavements have been in service for a certain number of years, defects will appear at the pavement surface. These defects can be related to ageing of the surface layer (e.g. surface cracking), to lack of deformation resistance of the structure (e.g. rutting), environmental effects or a lack of structural bearing capacity of the structure (fatigue cracking).
When these effects have developed to a certain severity and extent, maintenance is needed in order to provide sufficient service to the road user for a substantial period of time. The evaluation of the condition of the road structure is necessary and a correlation must be developed with the causes of the observed effects (Molenaar, 1993).

The cracking occuring in rigid or semi-rigid structures, resulting from cements treated layer shrinkage, thermal movements or the movement of the joints between concrete slabs, is in relation with three different fundamental mechanisms :

- thermal stresses : temperature variations induce openings and closures of the cracks induced by the shrinkage in the cement treated base layers of the structure. If the bituminous concrete overlay perfectly adheres, the thermal movements induce stress concentration in the overlay and then crack propagation from the bottom to the top if it don't resist;
- traffic loads : the cyclic application of traffic loadings induces an additional distress of the overlay and the propagation of the cracks originated by thermal effects;
- thermal stresses : a rapid cooling down of the top layer can also induce important tensile stresses and cracks.

The Fig. 1 presents the different mechanisms of reflective cracking.

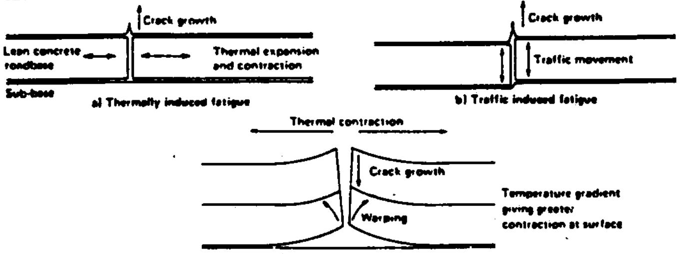


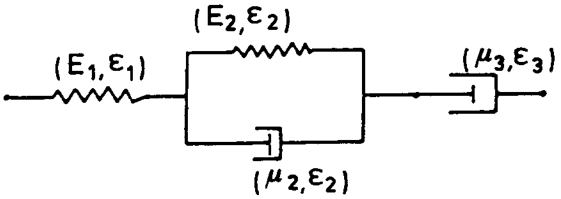
Fig. 1

It is generally agreed that the thermal stresses induce the cracks and take part to their initial propagation while traffics stresses take part to the following step.

2 GEOTEXTILE AND BITUMEN AS A REMEDIATION TECHNIC

The interlayer between the old pavement and the new overlay is constitued with a bitumen impregnated geotextile. This interlayer acts as stress release and waterproofing membrane : indeed, it permits a slide or a slippage between the overlay and the rigid structure in case of a thermal gradient and insures a sufficient bonding between the two ones.

This behaviour is directly related to the visco-elastoplastic behavior of the bitumen.



where E is the elasticity modulus, μ the viscosity and ε the deformation

Fig. 2 Boltzmann model

When a load is applied on the bitumen material, the general deformation is given by

$$\varepsilon = \varepsilon_1 + \varepsilon_2 + \varepsilon_3$$

$$\varepsilon = \frac{\sigma}{E_1} + \frac{\sigma}{E_2}(1 - e^{-t/\theta_2}) + \frac{\sigma}{\mu_3} t$$

$$\text{where } \theta_2 = \frac{\mu_2}{E_2}$$

Temperature changes will act on the dash-pot parameter μ_3 and permits viscous deformation while traffic loading will stress the elastic component (E_1) because the viscous effect will have no time to react (μ_2, μ_3). They are the reasons why the bitumen used for interlayer systems is generally modified with plastomers in order to reduce their thermal susceptibility (increasing of μ_2 and μ_3).

3 EXPERIMENTAL APPROACH

The different conditions-traffic, temperature variations,... - may appear independently or jointly as the main causes of the distress. This will result in complex situations which may be treated separately in a first approach and superposed to get a final picture of the reality.

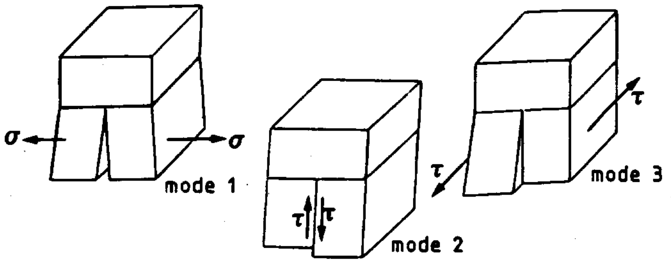


Fig. 3 Irwin failure modes

Different simulation devices have been developed : the first one to simulate traffic loading (modes 1, 2 and 3) by flexural devices for example and the second to simulate thermal stresses, by opening and closing of a crack (mode 1).

The difficulty is coming when we try to simulate the two phenomenous together : combination of horizontal opening of a crack with vertical repeated load has been described by Vecoven J.H. during R.C. 89.

Laboratory simulations procedures are so existing. They are very useful in revealing and proving the effectiveness of overlay systems under different conditions of loading and environment. But we must bear in mind that the scale factor is their most important limitation.

Observations have been also made directly on site. They permit to conclude that the nature of the geotextile doesn't seem to be important if it is incompressible, but the binder and its proportioning are of the primary importance and it is preferable to use modified bitumen.

So it is necessary to continue the study of experimental approaches, in correlation with evaluation by modelling and validation on full scale monitored projects.

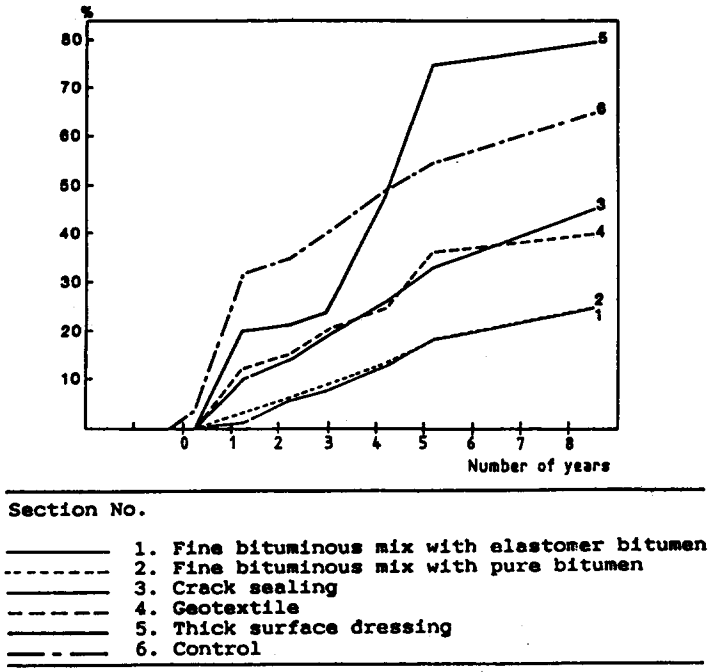


Fig. 4 Percentage of reflective cracking

4 NUMERICAL AND ANALYTICAL APPROACHES

The numerical program has been developed to permit the study of the combined thermal and traffic effects. It considers various positions of lorry axles and determines the total effect on the crack tip, in combination with a temperature variation; it is based on a division of the hole structure in finite elements, working mainly in linear elastic mode.
The structure analysed with this method was constitued as given in Fig. 5 (Rigo et al., 1993)

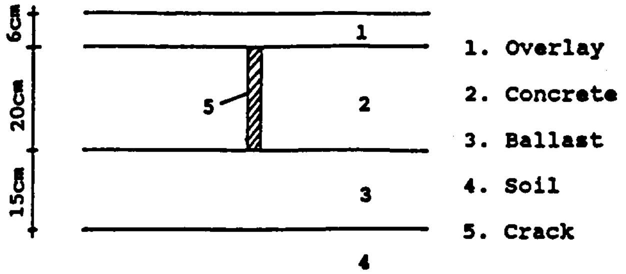


Fig. 5 Road structure

4.1 Basic principle

The investigated structure has been divided into small elements by means of a 2D-finite element mesh (Fig. 6) (Rigo et al., 1993). The principal stresses and the resulting damages are evaluated for each element under traffic and/or thermal effects taking the stress history of each element into account. Once the damage is equal to unity for a given element, this one is removed from the mesh and the next calculation step is based on a mesh with an empty element as a simulation of the crack. This is realized step by step until the simulated crack reaches the top surface of the overlay.

4.2 Technical datas

The technical characteristics of the different materials are :
- overlay : E goes from 3100 to 210 MPa (frequency 0,1 Hz) when temperatures goes from 10 to 30°C; for traffic loading (frequency 10 Hz) E = 5400 MPa;
- interlayer

		Traffic	Thermal
G	(MPa)	2	1
E_V	(MPa)	1300	1000
E_H	(MPa)	4	2

V = perpendicular to interface
H = parallel to interface
- concrete : E = 15000 MPa
  $\alpha = 12.10^{-6}$
- granular sub-grade : E = 200 MPa
  $\alpha = 12.10^{-6}$

The traffic loads corresponds to a 13 T/axle, with a pressure of 6,62 bars on a 9 cm width band. The most critical position has been choosen for the applied loading : just near the crack.
The overlay temperature is 30°C at the surface and 10°C at the interface. The concrete slab has been subjected to a ΔT = 10°C.

4.3 Traffic and thermal loadings

When traffic and thermal effects are combined, the crack propagates more verticaly than in the case of traffic loads alone, due to the thermal stresses.

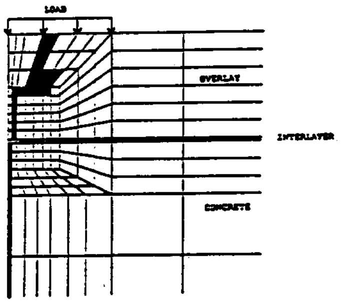


Fig 6 Crack propagation under combined effects

The evolution of the crack can be presented as a function of the time.

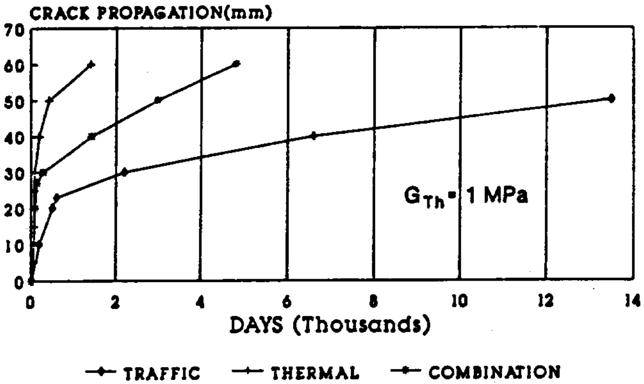


Fig. 7 Crack propagation versus time, under traffic, thermal and combined effects

It appeared to be interesting to follow the crack propagation as a function of the G value of the interlayer.
For this purpose the elastic shear modulus was adapted and the next results were obtained.

Fig. 8 gives the evolution of the overlay service-life versus the thermal shear modulus of the interlayer. For this exercise, the traffic shear modulus was kept constant and equal to 2 MPa. All the other data remained constant.
It can be observed that the crack propagation seems to be rapid for the early age of the structure due to an important thermal contribution and then, depending on the $G_{thermal}$ value the crack propagation is more or less slowed down.

The overlay service-life is dramatically decreased when the $G_{thermal}$ value goes up to 1 MPa.

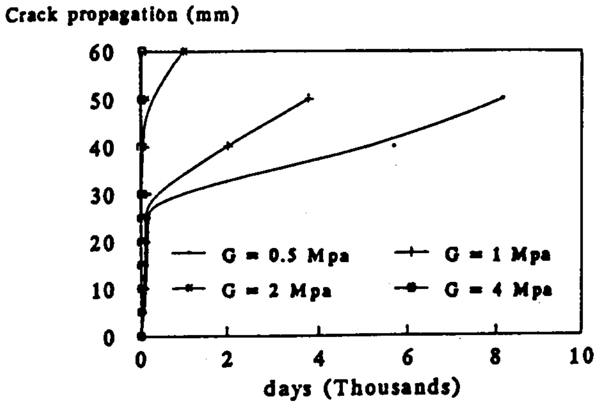


Fig. 8 Overlay crack propagation during its service-life (traffic and thermal effects) versus the thermal shear modulus of the interlayer

5 CONCLUSIONS

The selection of the interlayer bitumen and the textile are thus of the prime importance for the success of the whole process. The results of the experimental study showed that about 2/3 of the interlayer stress release function is due to the impregnating bitumen. The remaining 1/3 was due to the textile, that works as a container. The vertical shear movements are very detrimental for the interlayer and must be reduced before the use of such as interlayer.
More and more informations about the real behaviour are needed to realize a modelization as near as possible of the reality.
It was one of the most important conclusions of the Reflective Cracking Congress in Liege, 1993.

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