**INDEX 96 CONGRESS**

**CONSTRUCTION**
**Session**

# TECHNICAL RECOMMENDATIONS FOR THE USE OF NONWOVEN GEOTEXTILES TO PREVENT REFLECTIVE CRACKING

**by**

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Due to the increase of traffic, wheel loading or unadapted structures use, the road network in Europe and in the U.S.A. needs to be hardly repaired, not only for economic reasons but also for safety.
The nonwoven geotextile industry can contribute to the rehabilitation of the roads and permit to extend the service life of civil engineering infrastructures.

## 1. INTRODUCTION

The rehabilitation of cracked roads by simple overlaying is rarely a durable solution. The cracks rapidly propagate through the new overlay because the new overlay - bituminous layer - does not have enough deformability to bridge living cracks without damage. This phenomenon is called *"reflective cracking"* and is widespread over many countries.

The appearance of cracks on the top layer of a road is a phenomenon that can be avoided by a good performance and design of the road structure. In any case, it can cause numerous problems :

- discomfort for the users;
- reduction of the safety;
- intrusion of water and subsequent reduction of the soil bearing capacity;
- pumping of soil particles through the cracks;
- progressive degradation of the road structure in the neighbourhood of the crack, due to local overstresses.

Two categories of methods are currently used to reduce the development of cracks in the road structure :

- interventions on the crack itself to eliminate cracks or to limit their activity (pre-cracking, injections, materials,...);
- use of an accurate overlay system.

In addition to this second solution, an appropriate interlayer system may be used between the old structure and the new one : it is realised by means of an interface product combined with a fixing system to guarantee the adherence with the interlayer.

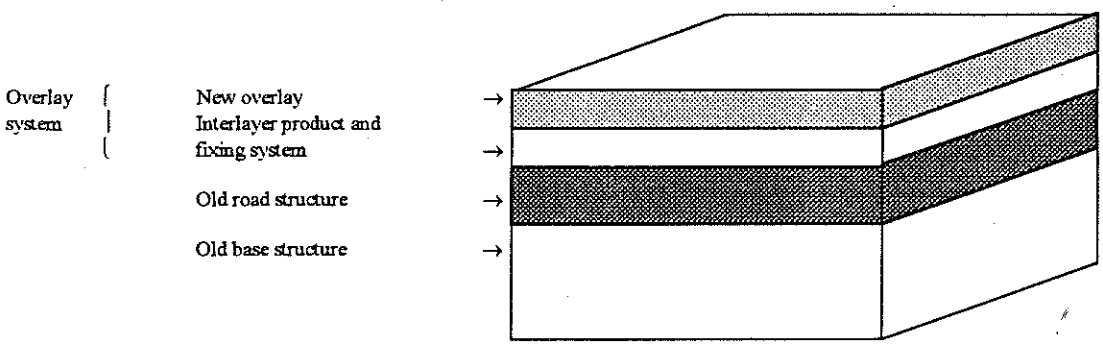



Figure 1 : road structure

## 2. CRACKS ORIGIN AND PROPAGATION

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 doesn'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 figure 2 presents the different mechanisms of reflective cracking.

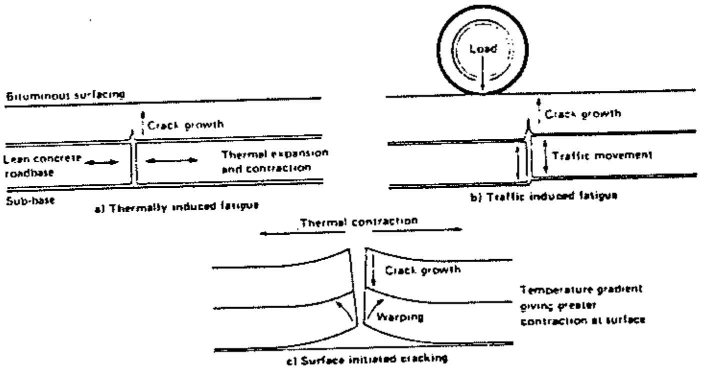



Figure 2 : mechanisms of reflective cracking [Nunn, 1989]

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

## 3. NONWOVEN GEOTEXTILE AND BITUMEN AS INTERLAYER SYSTEM

The role of an interlayer system works on two levels :

- stress release : basement and/or overlay differential movements of thermal origin may be absorbed by the interlayer, having an important stress release effect on the structure. On the other hand, traffic stresses must be transmitted correctly between the pavement layers. All the interlayers actually developed are based on bitumen or modified bitumen. The visco-elasto-plastic behaviour of this material fits very well to the above mentioned requirements;
- waterproofing : in case of cracks, we must avoid any intrusion of water in the soil underneath the pavement. Otherwise, soil bearing capacity will decrease and some pumping effect is to be expected under traffic loads, inducing extra stresses into the pavement and additional distress.

It is absolutely necessary to have a sufficient adherence of the interlayer system with the underlayer and with the new bituminous overlay in order to guarantee a good distribution of the stresses induced by traffic and thermal effects. In the case of nonwoven geotextile impregnated bitumen interlayer, bitumen can insure the adhesion, stress release and waterproofing properties while the nonwoven will act as a container to avoid creep and compression.

For nonwovens it is necessary to determine the quantity of bitumen they can absorb in order to have an appropriate impregnation of the nonwoven with binder. An insufficient quantity of binder indeed leads to improper functioning of the interlayer. An excess of binder can lead to problems during placement due to sticking to the vehicle tyres with possible detachment of the interlayer product from the underlayer.

## *4. CHARACTERISATION OF AN INTERLAYER SYSTEM AND ITS COMPONENTS*

In order to choose what type of overlay system is suited in a given situation, the characteristics which are relevant for the role they have to play in the road structure have to be determined. Tests are therefore necessary on the interlayer system itself and on the behaviour of the interlayer as part of the overlay system. Characterisation of the interlayer system implies tests to be carried out on the interlayer product and on the system itself.

For nonwoven, the following properties seem to be relevant :

- base material : polyester, polypropylene, polyamid;
- mass per unit area ($g/m^2$);
- thickness (mm);
- ultimate strength (kN/m);
- strain at ultimate strength (%);
- perforation (kN);
- stiffness (kN/m) : since thin interlayer products are less then a few mm in thickness, they can be considered as two-dimensional foils. The stiffness S is given by : $S = F / (\varepsilon\ b)$, in which F is the applied force, $\varepsilon$ the corresponding deformation and b the width of the specimen. Interlayer products in general do not behave linearly. Therefore, their stiffness depends on the level of force or strain : e.g. one can determine the stiffness at failure, at x % of ultimate strength or at y % of failure strain;
- temperature susceptibility;
- chemical resistance;
- quantity of bitumen that can be absorbed by the interlayer product.

Tableau I

| Characteristics | PET | PP | Bitumen |
|---|---|---|---|
| Softening point (°C) | 250 | 160 | 30 → 100 |
| Glass transition T (°C) | 80 | - 15 | - |
| Degradation T (°C) | 300 | 280 | - |
| Tensile (N/mm²) | 1000 | 600 | 0.5 → 10 |
| Elongation (%) | 15 | 15 | - |
| E modulus (N/mm²) | 12500 | 12000 | 10000 → 30000 (traff.)<br>100 → 1000 (therm.) |
| Density | 1.38 | 0.91 | - |
| Chemical resistance :<br>- solvents<br>- fuels<br>- de-icing | <br>+<br>+<br>+ | <br>+<br>+<br>+ | <br>-<br>-<br>+ |
| Biological resistance | + | + | ± |
| Water resistance | + | + | + |

At the level of the interlayer, index tests must be also realised on combined materials (bitumen and nonwoven geotextile) :

- shear modulus;
- compressibility;
- stiffness modulus (vertical);
- thermal resistance.

Finally, performance tests will be chosen in order to point out the real effect of the interlayer on the prevention effect of reflective cracking. It concerns :

- combined materials :
  - stiffness modulus as a function of frequency and temperature;
  - shear modulus as a function of frequency and temperature;
  - waterproofing;
- structure : crack propagation simulation test
  - under traffic loading;
  - under thermal loading;
  - under combined effects.

## *5. DESIGN MODELS AND LABORATORY SIMULATION*

Laboratory testing technics are generally developed to examine different aspects of a system for the situations where reflective cracking may normally develop. Although many different facilities are described in the literature, it is possible to classify them in a limited number of types according to the particular situation they are supposed to address.
In all tests, the onset of the crack and its growth in function of the time or the number of loading cycles is monitored. The tests are generally carried out for comparative purposes. In some cases however, they are used to calibrate and verify analytical models.

Tableau II : testing procedures

| Loading | Testing procedure |
|---|---|
| Traffic loads | Beam testing<br>Wheel tracking |
| Thermal shrinkage of base layer | Controlled crack opening repeated loading |
| Thermal shrinkage of upper layer | Restricted beam under constant rate of temperature change |
| Traffic + thermal shrinkage of base layer | Combination of horizontal opening of a crack with vertical repeated loads |

For example, with the test device presented hereafter, we obtained some interesting results on the crack propagation in the overlay, without and with some types of bitumens and nonwoven textiles.

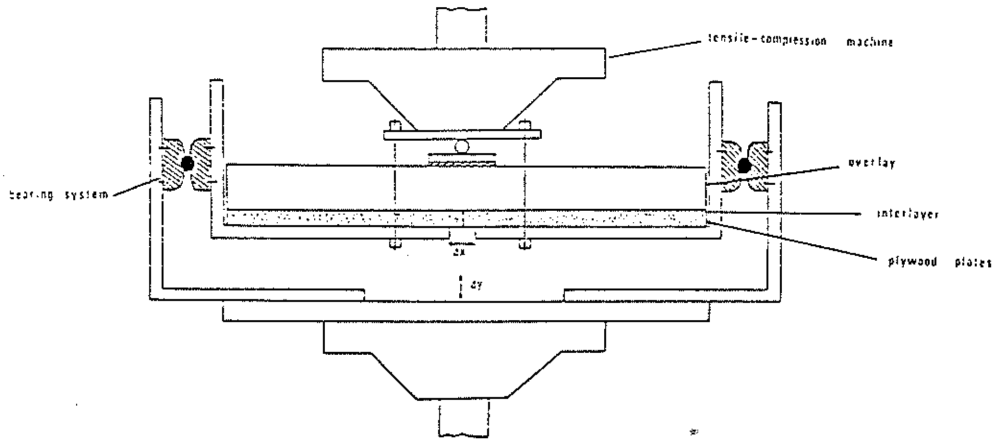
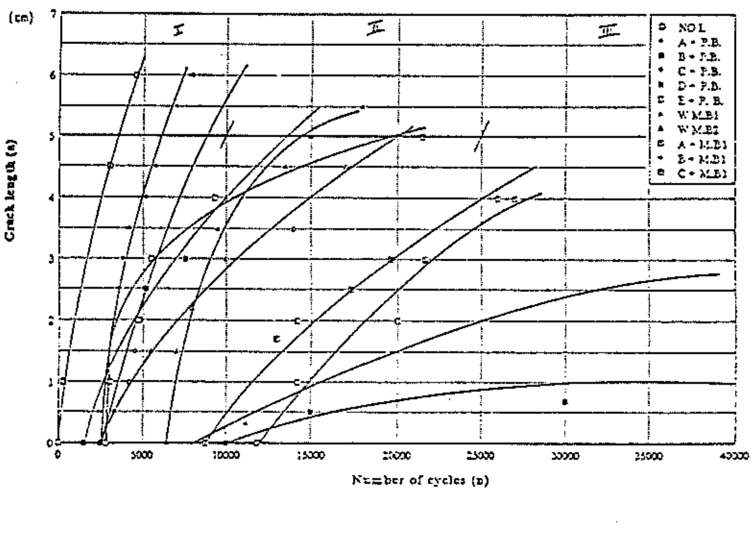



Figure 3 : test device developed at the University of Liege




Zone I : without interlayer

Zone II : interlayer : nonwoven + pure bitumen

Zone III : interlayer : nonwoven + modified bitumen

Figure 4 : crack propagation vs time

## 6. *NUMERICAL AND ANALYTICAL APPROACHES*

A lot of numerical programs have been developed in several universities and research centres; most of them are based on finite elements developments, like we did at the University of Liege. Our program 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 constituted as given in figure 5 [Rigo et al, 1993].

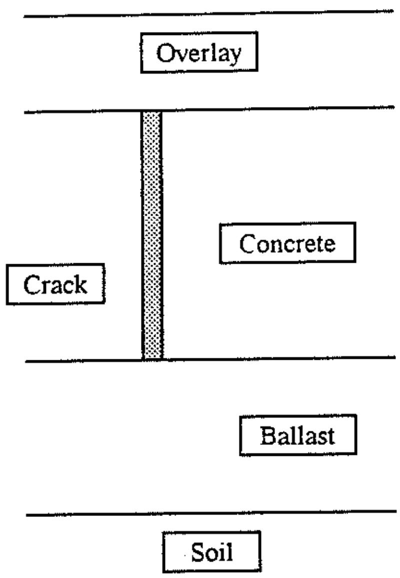



Figure 5 : road structure modelisation

### 6.1. *Basic principle*

The investigated structure has been divided into small elements by means of a 2D-finite element mesh (figure 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 realised step by step until the simulated crack reaches the top surface of the overlay.

### 6.2. *Technical datas*

The technical characteristics of the different materials are :
- overlay : E goes from 3100 to 210 MPa (frequency O,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 load 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 chosen 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 $\Delta T = 10°C$.

### 6.3. *Traffic and thermal loadings*

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

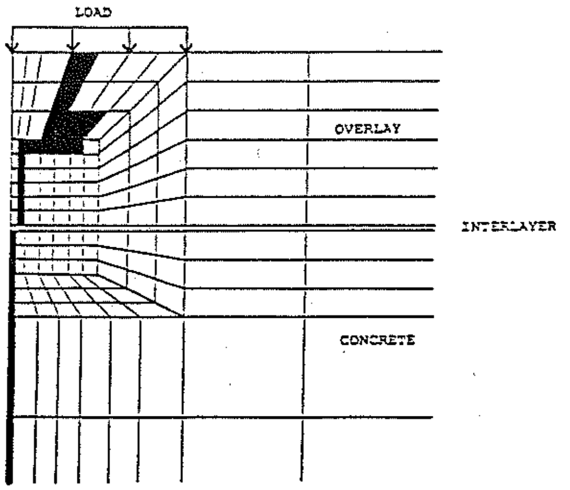



Figure 6 : crack propagation under combined effects

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

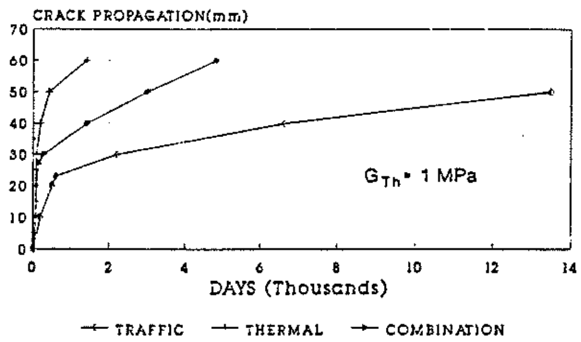



Figure 7 : crack propagation versus time, under traffic, thermal and combined effects

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.

Figure 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.

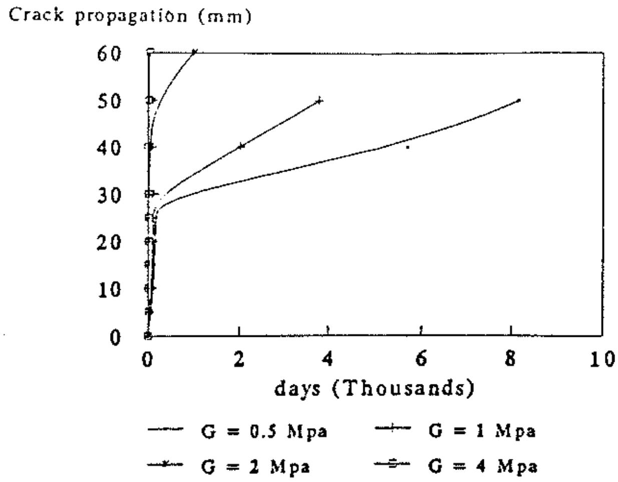



Figure 8 : overlay crack propagation during its service-life (traffic and thermal effects) versus the thermal shear modulus of the interlayer

## *7. HARMONISATION AND RECOMMENDATIONS*

An important work is realised at the RILEM level (Réunion Internationale des Laboratoires d'Essais sur les Matériaux) in order to give to designers and constructors some recommendations for the use of remediations techniques in reflective cracking.
This group reassembles a lot of experts who will write the state of the art and recommendations in five steps :

1. assessment and evaluation;
2. definition and characterisation of the components of a system (interlayer products, overlay);
3. choice of the appropriate solution;
4. preparation of the site;
5. laying procedure (binder tackcoat, interlayer, overlay).

A presentation of the conclusions will be done at the Reflective Cracking Congress in Maastricht, October '96.
The CEN TC 189 has also a working group on the subject.

## *8. CONCLUSIONS*

Correct installation is a key to the performance of the reflective cracking control system. For systems using nonwoven geotextiles, some recommendations can already be given :

a) the supporting surface has to be cleaned;
b) the potholes and irregularities have to be filled;
c) the cracks have to be sealed;
d) the binder must be applied on a dry surface and in a good quantity;
e) the fabric has to be unrolled under tension in order to avoid wrinkles or folds;
f) the overlap is to be cared;
g) the maneuvring on the surface fabric has to be avoided.

This can reach to a good result but it will be of the prime importance to analyse correctly the situation, to make measurements in order to have a diagnosis of the old structure. Laboratory tests for index, performance and evaluation will give the best solution and the best technic to be applied on site.

## 9. BIBLIOGRAPHY

Rigo J.M. *General Introduction, main conclusions of the 1989 Conference on Reflective Cracking in Pavements, and future prospects.*
Proceedings of the 2d International RILEM Conference "Reflective Cracking in Pavements. State of the Art and Design Recommendations", Liege, Belgium March 10-12, 1993.
E & FN SPON, London.

Francken L. *Laboratory simulation and modelling of overlay systems.*
Proceedings of the 2d International RILEM Conference "Reflective Cracking in Pavements. State of the Art and Design Recommendations", Liege, Belgium March 10-12, 1993.
E & FN SPON, London.

Rigo J.M., Hendrick L., Courard L., Costa C., Cescotto S., Kuck P.J.
*Evaluation of crack propagation in an overlay subjected to traffic and thermal effects.*
Proceedings of the 2d International RILEM Conference "Reflective Cracking in Pavements. State of the Art and Design Recommendations", Liege, Belgium March 10-12, 1993.
E & FN SPON, London.

Rigo J.M., Mergeai-Mathy B., Marchandise-Piron J., Eckmann B., Muller J.M., Touzard B.
*Laboratory testing and design metho for Reflective Cracking interlayers.*
Conference C.E.P. - L.M.C. "Reflective Cracking in Pavements. Assessment and Control". Liege, Belgium, March 8, 9 and 10, 1989.
University of Liege, Belgium.

Courard L, Rigo J.M. *Effect of geotextiles on crack propagation in the pavement overlays.*
Fifth International Conference on Geotextiles, Geomembranes and Related Products. Singapore, 1994.

Vanelstraete A.. Draft *"Choice and design overlays"*.
RILEM TC-PRC (edition 1.10.95).