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[CI-05]

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"The reflective cracking in thin surfacings"

1st World Conference on Highway Surfacings, Budapest, 1998

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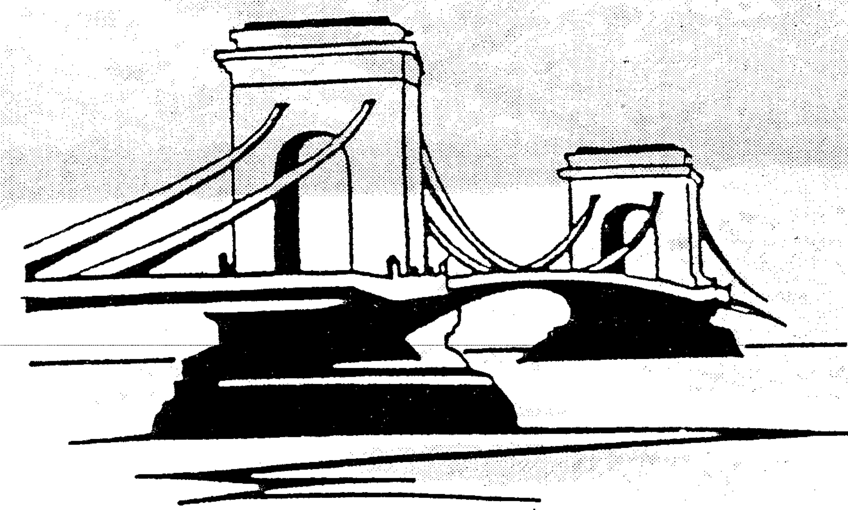

May 11–13, 1998
Hotel Atrium Hyatt – Budapest
Hungary

PROCEEDINGS

The Reflective Cracking in Thin Surfacings

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ABSTRACT: This paper shows a laboratory study on reflection cracking in thin surfacings, where the reflective cracking take an important point in pavement life, undertaken with the Reflective Cracking Device and the Crack Activity Meter. The Crack Activity Meter was used to measure load associated differential vertical and horizontal movement between the two sides of a crack in cracked pavements before overlay. The crack movements after overlay were calculated with a finite element model. The Reflective Cracking Device used with the shear machine, introduced by SHRP program, was employed to simulate in laboratory the crack activity patterns measured in the field.

1. INTRODUCTION

Overlays are the most commonly used method for pavement maintenance. However, they often do not perform as desired due to the existing cracks that propagate through the new pavement layers. This type of cracking is known as reflective cracking and it is a result of vertical and horizontal movements at the crack tip. Those movements caused by thermal stresses, traffic loads or by a combination of these two mechanisms induce stress concentrations in the overlay and the existing acks of the old pavement propagate through the new pavement layer and it is usual to see the overlays cracked after few years of service.

The rehabilitation of cracked pavements is made, usually, by placing bituminous layers over the cracked pavement. Between the old and the new layers, a stress reliant layer is placed to reduce the propagation of the reflective cracking. This bituminous material interlayer, produced with a 5mm maximum aggregate size and with a high bitumen content, placed with no more than few centimeters and it is subjected to high reflective cracking level. Majidzadeh et al (1977) and Monismith et al (1980) used fracture mechanics to develop a procedure for pavement overlay design where they have concluded that the increase of thickness decrease the reflective cracking level. In this case, the thickness responsible for the reflective cracking is the thickness of the structure above the old pavement. This thickness, sometimes, is sufficient to retard the reflective cracking during the overlay life.

If this type of bituminous mixture is used only to resurface the pavement, the thickness above the old pavement is very low and the thin layer is subjected to high reflective cracking level.

This paper presents an approach to evaluate the reflective cracking in thin surfacings based on laboratory tests with the Reflective Cracking Device (RCD) designed by Sousa et al (1996). Old pavement crack differential movements were measured in road with the Crack Activity Meter (CAM) designed by Rust (1987). The mixture studied was a 5 mm maximum aggregate size and a conventional and a polymer modified bitumen were used.

2. CRACK ACTIVITY

Load associated reflective cracking is governed simultaneously by an horizontal opening and/or closing and a vertical shearing at the crack zone. The simulation of this process must consider the simultaneity of the two modes of opening in the analysis of this problem.

The differential vertical and horizontal movements between the two sides of the crack, usually named crack activity, were measured with the CAM produced by CSIR in South Africa.

The CAM is composed of two LVDT (Linear Variable Differential Transformers), one placed vertically and the other placed horizontally. Thus, both differential movements can be simultaneously measured. Figure 1 shows a schematic representation of the CAM placed over the crack. At the two sides of the crack, two brass plates are glued at the pavement with epoxy. The CAM is glued over one brass plate while the stopper is glued at the other brass plate.

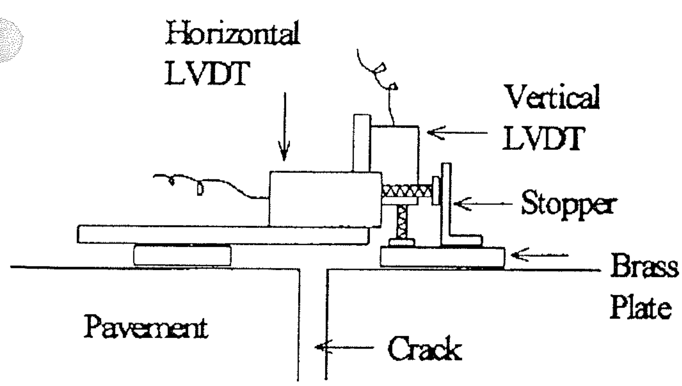

Figure 1. Crack Activity Meter.

The CAM system is composed by the CAM device, a signal conditioning box, a wheel clock and the software to control the CAM system. The wheel clock is fixed at the load track and move jointly with the load wheel. At each 30 mm of load track movement, the wheel clock sends a signal to the conditioning box.

At this instant the conditioning box reads the CAM measurements and sends them to the computer. Positive values represent opening of the crack while negative values represent crack closing.

The evaluation of the crack activity before overlay was made in 12 cracked cross sections in the Portuguese road network and only flexible pavements were studied.

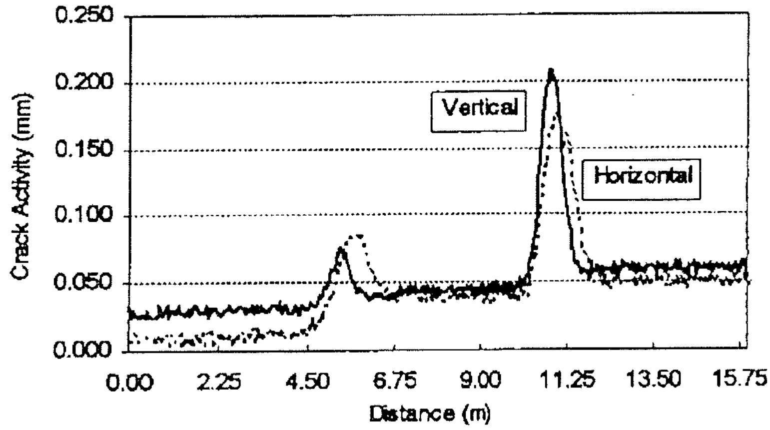

Figure 2. Crack movements of the longitudinal crack before pavement overlay.

The crack activity for a longitudinal crack is shown in Figure 2, and represents typical crack activity of the cracked pavement used for this study. The crack activity measured in the pavement before the overlay is different from the crack activity after overlay since it depends on the overlay thickness and material stiffness.

The crack activity after overlay can be evaluated using a finite element analysis, knowing the old pavement properties. The influence of the overlay thickness in the crack activity after overlay, for a 5000 MPa overlay stiffness, is presented in Figure 3.

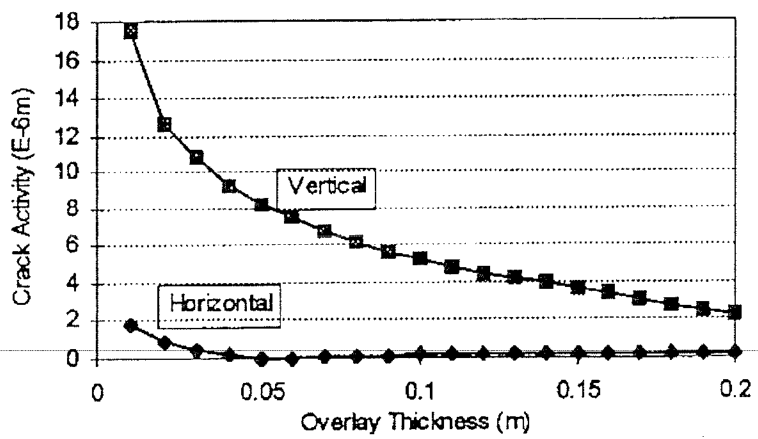

Figure 3. Crack activity after pavement overlay as function of overlay thickness.

Two important conclusions can be taken from the finite element analysis: after overlay the horizontal crack activity is almost null and the vertical activity is highly reduced and follows a logarithmic law.

3. REFLECTIVE CRACKING

Laboratory simulation of reflective cracking phenomena was made using the Reflective Cracking Device to fit in CS 7200 Shear Testing Machine, applying the displacement pattern measured in the road with the CAM. This device can use specimens with thickness up to 70 mm and initial crack opening up to 12.5 mm with rectangular or cylindrical specimens. The maximum specimen length and width is 175 mm. Figure 4 shows a schematic representation of the crack zone that is simulated by the RCD. The specimen is glued to the RCD, simulating the bounding of the overlay to the old pavement.

Two LVDTs are mounted in the RCD to measure the crack opening (Mode I) and the crack shearing (Mode II). Those LVDTs are used as feedback control for the two machine actuators of the shear machine.

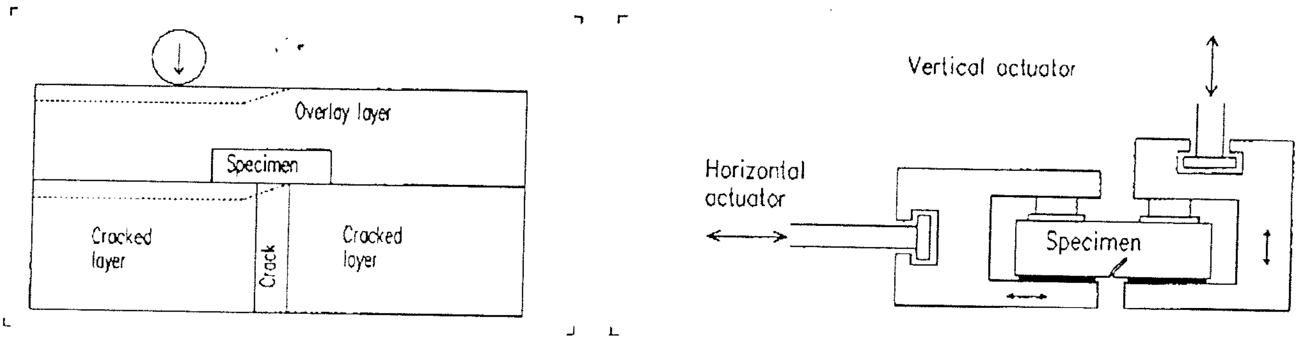

Figure 4. Crack zone representation, on the left, and the Reflective Cracking Device, on the right.

4. LABORATORY TEST PROGRAM

The bituminous mixture of this study is a dense well-graded sand mixture with a maximum aggregate size of 5 mm, manufactured according to the Portuguese standards. The aggregate used was a 100% crushed granit. Two bitumen types were used; a conventional 60/70 penetration grade bitumen and a SBS modified bitumen named "Caribit", both provided by Shell Portugal. The mixtures were produced in laboratory and compacted with a steel rolling wheel compactor. Cylindrical test specimens with 15 cm diameter were cored from slabs compacted in laboratory. Three specimen thicknesses were produced to simulate an overlay thickness, 4, 5 and 6 cm. Those three thicknesses are used to extrapolate the reflective cracking fatigue life for any overlay thickness.

For these tests the crack width of the reflective cracking was set to 6 mm, corresponding to three times the crack width measured in pavement. The test frequency was 10 Hz and the test temperature was 20 °C.

To simulate the reflective cracking through overlays, the crack activity after overlay, calculated by using a finite element model, was applied to the specimen by the shear machine through the RCD. Once this crack activity is very low and thus the test take several days, the test program was undertaken at high crack activity involving the use of a fatigue law to extrapolate the results to the desired crack activity. The applied vertical crack activity is showed in Table 1 and the applied horizontal crack activity was 10% of the vertical.

Table 1. Applied crack activity

Specimen thickness (cm)	Crack Activity (mm)	Specimen thickness (cm)	Crack Activity (mm)	Specimen thickness (cm)	Crack Activity (mm)
4	0.1551	4	0.3102		
5	0.1383	5	0.2766	5	0.5532
6	0.1246	6	0.2492	6	0.4984

Once the applied crack activity is very high, corresponding to 16, 32 and 64 times the expected crack activity after overlay, only 80 000 cycles were applied.

5. REFLECTIVE CRACKING ANALYSIS

To evaluate reflection cracking through overlays, Sousa et al (1996) suggested that a equivalent stiffness in the crack zone could be used to define the fatigue life for this problem. This equivalent stiffness is defined as the average stiffness in specimen volume above the crack and is defined as follows:

$$S = \frac{\frac{F}{LH}}{\frac{\delta}{w}}$$

where S = equivalent stiffness in crack zone; F = measured force; δ = applied displacement; L = crack length (i.e. specimen length); H = specimen height and w = crack width.

Using the equivalent stiffness in the crack zone to analyze the reflective cracking, two types of stiffness evolution were found during the test. Such as in flexural beam tests, stiffness exponential evolution was found with high R^2 values close to 0.95 (Figure 5). The most usual stiffness evolution found in these tests was the logarithmic law with high R^2 values close to 0.98 (Figure 6).

In Figure 7 the initial equivalent stiffness as function of crack activity after overlay is showed for conventional and modified bitumen. The mixtures with conventional bitumen have a lower stiffness than the mixtures with modified bitumen. The equivalent stiffness increase with the decrease linearly of the crack activity.

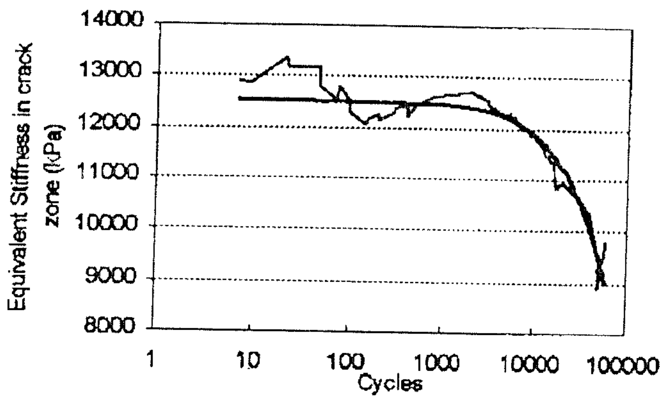

Figure 5. Exponential evolution of equivalent stiffness in crack zone.

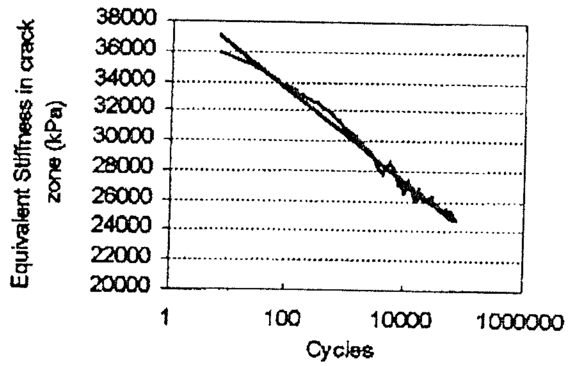

Figure 6. Logarithmic evolution of equivalent stiffness in crack zone.

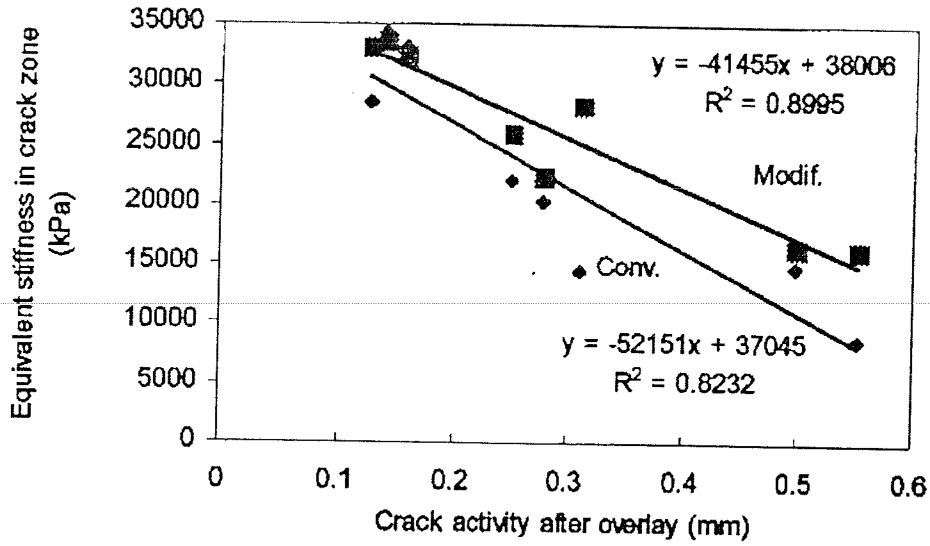

Figure 8. Initial equivalent stiffness as function of crack activity after overlay.

8. CONCLUSIONS

The reflective cracking can be controlled by the pavement crack activity before and after overlay. Before overlay, this crack activity shows high values in both horizontal and vertical directions. After overlay, the horizontal crack activity in the bottom of new layers is almost null and the vertical activity is highly reduced and follows a logarithmic law. These crack activities are influenced by the overlay properties, namely the overlay thickness and material stiffness.

The laboratory study with the reflective cracking device showed that the stiffness behavior during test follows either an exponential law or a logarithmic law. Mixtures with conventional bitumen exhibit lower stiffness than mixtures with modified bitumen.

9. REFERENCES

1. Majidzadeh, K., C. Buranarom & M. Karakouzian, 1976. Application of fracture mechanics for improved design of bituminous concrete, Report FHWA-RD-76-91.
2. Monismith, C. L. & N. F. Coetzee, 1990. Reflection cracking Analyses, laboratory studies and design considerations.
3. Sousa, J.B., S. Shatnawi & J. Cox, 1996. An approach for investigating reflective fatigue cracking in asphalt-aggregate overlays, Proceeding of the Third International RILEM Conference.
4. Rust, F. C., 1987. Load associated crack movement and aspects of the rehabilitation of reflection cracking in cemented pavements, Faculty of Engineering, University of Pretoria, South Africa.