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Accelerated pavement testing and modeling of reflective cracking in pavements

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Abstract

In the field of reflective cracking initiation and propagation in pavement structures, an Accelerated Pavement Testing (APT) has been developed. The numerical method is also supported. Numerical results obtained by calculations made with the finite element CESAR-LCPC software are then compared with the experimental data. The reflective cracking APT experience is the first step in the development of a new laboratory equipment to evaluate the design of bituminous layers to repair pavements. The experiment was performed on a 30 m track where eight discontinuities were established by cutting-off the sub-bases in order to ensure a crack development in the bituminous layer. The conditions that promote crack propagation were reproduced by the application of heavy periodic loads using the Fabac ALT-APT test rig. The width of the bituminous layer was decreased to facilitate the observation of the crack propagation, while avoiding creep of the material. The structure has a large number of sensors that measure longitudinal and transverse deformations at the bottom and at the surface of the bituminous layer. The deflections and the displacements are measured at several levels of the structure, as well as the temperature and the lateral edge cracking which is monitored by cracking sensors on both sides of the track. Preliminary results on two joints were used to determine the mechanisms of rupture of the structure. Four more tests with improved sensors have completed the information. Experimental and numerical results are compared in order to validate the analysis of the fatigue process (debonding, damage and cracking) in full scale pavement.

Keywords: Mechanics; Pavement; Reflective cracking; ALT-APT

1. Introduction

1.1. Context

The bottom–top propagation cracking into the surface bituminous layers is the main mechanism of deterioration in semi-rigid roadways, which include base layers treated with hydraulic binders covered with an

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asphalt concrete surface layer. The reflective cracking damage mechanism also affects the bituminous overlays used as reinforcement of cracked pavements, in order to extend their service life. In spite of the great number of existing roadways concerned, there is no reliable method that can predict the development of reflective cracking as a function of the traffic, or that can be used to determine the minimal thickness of the bituminous overlay necessary to reinforce a given damaged pavement. In the French guide for the design of pavements structures [10] some scenarios of preventive maintenances are envisaged for the semi-rigid roadways only when they correspond to a very precise constructive criterion. In any case, no method has been defined to repair cracked roadways which would be a function of the damages caused by the reflective cracking. Furthermore, there is few records of an operational test that can quantify the effectiveness of bituminous surface layer complex in reflective crack cases.

Two main approaches to predict reflective cracking can theoretically be used. The first one is to improve mathematical models of the cracking initiation and propagation phenomenon. The second one is to develop a laboratory method associated to a particular innovative reflective cracking test. In both cases pertinent precise data will be required to validate and/or calibrate the calculations or the procedures. In the ''Laboratoire Central des Ponts et Chaussées'' (LCPC), which is the main laboratory in pavement research of the Ministry for Transportation in France, the second approach is being developed over the last years.

Different investigations were undertaken on this subject and today the objective is to set a new laboratory test – MEFISTO2 – to predict reflective cracking on the base of the MEFISTO equipment [7]. Most precisely, this test equipment is to be created to quantify life time service of bituminous layer complex used on top of semi-rigid pavements or in reinforced cracked pavements supporting heavy load traffic. The dimensions of the tested samples are 560 mm × 110 mm × 95 mm. The definition and the reproduction, on the sample laboratory test, of a realistic strain field of cracked pavements under real loading conditions, needs validated numerical tools. To respond to this necessity the LCPC has worked on two main aspects.

On the one hand, the simulation of reflective cracking in a multilayered structure caused by heavy loads requires numerical models related to the phenomenon of multi-layer material cracking [5]. The standard available calculation method is the Finite Element software created in the LCPC (CESAR-LCPC). Since 3D calculations are high time cost, researches on improved simplified methods, to increase speed calculation, are also in progress, particularly for parameter analysis requirement in iterative computations needed for cracking propagation. This is the case of the research carried out in the PhD thesis of Tran [11], and the research work of Chabot and Erlacher [2], where a simplified method of calculation for double-layered cracked pavement has been developed.

On the other hand it also requires accurate experimental data on the behaviour and the damage of materials subjected to this phenomenon in a heavy loaded roadway. In this approach, experiments of cracking in laboratory and an experiment with heavy load simulators FABAC were performed [3].

1.2. Objectives of the accelerated pavement testing

The experience made with this APT facility (FABAC) is the next step in the development of a new laboratory equipment to evaluate the behaviour of bituminous layers confronted to reflective cracking mechanism.

The data of cracking, strains and displacements obtained on the test track with the APT facility are used to identify the good assumptions and the choice of numerical values leading to a satisfactory simulation of the reflective cracking in pavement, using the finite element analysis (FEA). The FEA numerical simulations are made with the software CESAR-LCPC [1]. The module used in this study is TACT – TACT stands for conTACT – which introduces different boundary conditions at the interface between the two top layers of the pavement. In the present work, after describing the APT experience, focus is made only on the results concerning reflective cracking initiation and its relevance for the model validation.

A successful validation of the model will allow its use into further numerical calculations concerning reflective cracking. The next modeling steps are the evaluation of reflective cracking into a real pavement geometry and then into a sample laboratory test geometry. This final modeling will define the loading protocols to reproduce reflective cracking conditions when testing the sample with the new laboratory equipment MEFISTO2.