RILEM State-of-the-Art Reports

William G. Buttlar · Armelle Chabot
Eshan V. Dave · Christophe Petit
Gabriele Tebaldi *Editors*

Mechanisms of Cracking and Debonding in Asphalt and Composite Pavements

State-of-the-Art of the RILEM TC 241-MCD

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RILEM State-of-the-Art Reports

RILEM STATE-OF-THE-ART REPORTS

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Preface

History of the Previous RILEM Technical Committees on Pavement Cracking

Crack reflection through a road structure has been addressed since 1989 by the RILEM TC97-GCR *Application of Geotextiles to the prevention of Cracks in Roads* led by Louis Francken. It started a series of four international RILEM conferences on *Reflective Cracking* with the first two international RILEM RC conferences held in Liege (RC1989, RC1993) [1] and [2]. The RILEM TC 157-PRC *Prevention of Reflective Cracking in Pavements* (1993–1997) was established to further explore the potential for improving pavement crack resistance with a broader range of products and technical solutions. This led to the organization of the third and fourth RILEM RC conferences in Maastricht (RC1996) [3] and Ottawa (RC2000) [4]. Many of the innovative systems recommended at RC conferences have been implemented, and the four proceedings of these conferences remain unparalleled sources of information on the problem of Pavement Reflective Cracking. The information gathered by the RILEM Technical Committee 157-PRC was used to finalize a state-of-the-art report that was published in 1997 and presented in the RILEM 18 report with updated results [5].

To approach cracking problems in pavements in a more general sense, the scope of the state-of-the-art activities and the conferences was extended, after 2000, to other modes of cracking modes such as fatigue, ageing or top-down cracking. A successful series of three conferences on ‘Cracking in Pavement’ have presented these updates first in Limoges (CP2004) [6] and then in Chicago (CP2008) [7] and Delft (CP2012) [8]. Between 2004 and 2011, the RILEM Technical Committee 210-CAP Cracking in Asphalt Pavement led by Prof. Andre A. A. Molenaar has organized the last two conferences.

Main Objectives of TC241-MCD (2011–2017)

The RILEM Technical Committee 241-MCD on *Mechanisms of Cracking and Debonding in Asphalt and Composite Pavements* has been conducting scholarly activities geared towards developing a deeper fundamental understanding of the mechanisms behind cracking and debonding in asphalt concrete and composite (e.g. asphalt overlays placed on PCC) pavement systems. Although most modern pavement design methods do not directly account for the presence of cracking and debonding in asphalt and composite pavements, many of the critical modes of pavement deterioration involve one or both of these mechanisms.

In order to achieve its goals, the TC 241-MCD (Chair: Bill Buttlar, University of Missouri, USA; Secretary: Armelle Chabot, IFSTTAR/MAST, France) has been performing its work within three interrelated technical groups (TGs) (see Fig. 1). Each TG has involved an integration of testing, modelling and connection to related field studies:

- *TG1 Cracking in Asphalt Material* (Convener: Eshan Dave, University of New Hampshire, USA)
- *TG2 Interface Debonding Behaviour* (Convener: Christophe Petit, Université de Limoges, France)
- *TG3 Advanced Measurement Systems for Crack Characterization* (Convener: Gabriele Tebaldi, Université of Parma, Italy—University of Florida, USA)

The main advances have been presented during the 8th RILEM International Conference on Mechanisms of cracking and Debonding in Pavements in Nantes (MCD2016) [9].

> Cracking in asphalt and concrete pavements has been a research topic for decades and many conferences like the RILEM conferences on Cracking in Asphalt Pavements have been dedicated to it. In time we have acquired a vast amount of knowledge about the factors affecting cracking in pavements as well as about the factors that control the cracking resistance of pavement materials like asphalt and cement concrete and stabilized materials. However the factors influencing de-bonding between layers only received limited attention. It almost looks like we are ignoring the importance of a good bond between successive layers. This is perhaps best reflected by the following example When designing the

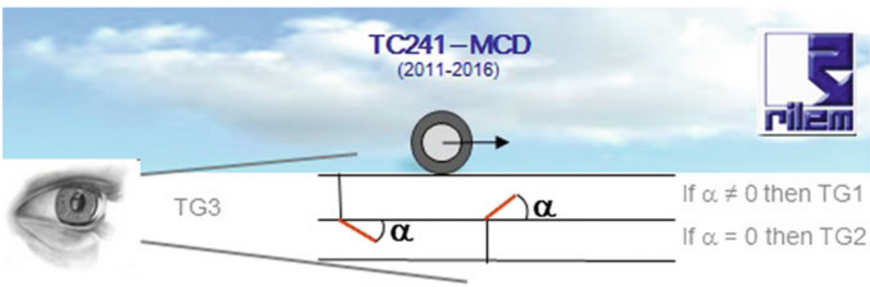

Fig. 1 Logo of the RILEM TC241-MCD

thickness of an asphalt pavement we mostly assume that the total asphalt thickness acts as one layer. The fact that the total thickness is made up of multiple single layers is simply ignored although it is known for decades that the shear strength of the interface between two asphalt layers as determined by means of e.g. the Leutner test is approximately 50% of the shear strength of the asphalt mixtures above and below the interface. This indicates that the layer interfaces are the weakest part of the asphalt layer! Therefore it is no surprise that many of the cracks we observe in our pavements are affected by the poor bond between layers. Poor bonding between the wearing course and layer below it is one of the reasons of pothole formation.

This first conference, MCD2016, on "de-bonding" is a very important one because it is the first time that the weakest part in pavement structures being the interface between layers gets the full attention it deserves. I am convinced that the outcomes of this conference, MCD2016, will contribute to a better understanding of how interfaces perform, to improved design methodologies that do take into account the initiation and propagation of de-bonding and its effect on the overall performance of pavements.

Prof. A. A. A. Molenaar (January 29th, 2014)

This book is authored and edited under the auspices of RILEM Technical Committee TC 241-MCD. Contributions were collected during the first half of the committee's planned five-year scope, followed by compilation, discussion and final editing. It presents technical contributions from RILEM members and international partners that provide an outline of the state of the art in field investigations, laboratory testing and modelling devoted to the understanding of pavement cracking mechanisms, organized according to the theme areas of the TGs (i.e. fracture in the asphalt bulk material, interface debonding behaviour and advanced measurement systems). This book also draws from the contributions of the TC241-MCD members emanating from their work conducted in the latter stages of the TC 210-CAP (Cracking in Asphalt Pavements). The TC 241-MCD membership list is given below.

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Contents

Chapter 1
Introduction

William G. Buttlar and Armelle Chabot

1.1 Field and Accelerated Pavement Testing Studies

This section provides selected results from field observations and full-scale accelerated pavement tests involving cracking studies that have been conducted worldwide. The pictures, observations, and measurements from these studies help in 'qualifying' the engineering problem of asphalt and composite pavement cracking. Qualification is a crucial first step in understanding the pavement cracking problem, and provides motivation and guidance in the subsequent activities of lab testing and crack modeling.

1.1.1 French Motorways

In the 2010s, IFSTTAR has been involved in a detailed survey of 16 old French toll motorway sections (from 2 to about 20 km long), in order to identify their failure mechanisms and compare their real behaviour with French design hypotheses [1, 2]. The study concerned thick bituminous and composite pavements, built more than 20 years ago, from different parts of France (except from the south). This section summarizes the main outcomes found for two types of French pavement roads.

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1.1.1.1 Thick Bituminous Pavements

The survey included 11 thick bituminous pavements, with thicknesses of bituminous layers varying between 25 and 40 cm. The study showed that only two of the 11 bituminous pavement presented typical fatigue cracking, starting at the base of the bound layers. These two pavements had both received a level of traffic exceeding largely their design life. Two sections were affected by thermal cracking, associated with high aging of the upper pavement layers. These pavements were both located in mountainous regions, with more severe climatic conditions (cold winters). The main deterioration mode (5 sections) was debonding, which could affect surface layers (binder course), or deeper layers, which were in fact old wearing courses, which had been overlayed by several new layers. This debonding was mainly identified by coring, but could also be detected by analysis of deflection measurements. Sections with debonding presented consistently higher deflections, and especially higher values of radius of curvature than sections with well-bonded layers. These sections were analysed using the French pavement design method, to try to estimate their remaining life, and these calculations confirmed that debonding can reduce very significantly the pavement life, and in some cases lead to very high tensile stresses at the bottom of the debonded layers, leading to rapid deterioration of these upper layers (Fig. 1.1).

Fig. 1.1 Examples of cores from thick bituminous pavements, showing debonding of surface or internal layers

1.1.1.2 Semi Rigid Pavements

The 5 remaining sections of the study were semi rigid sections, including cement bound base or subbase, and covered by a variable thickness of bituminous materials. These sections were all more than 25 years old. The study showed that on these sections, the main mode of deterioration is reflective cracking, propagating upward form the cement treated layers. When a significant level of deterioration was attained, a debonding between the cement treated and bituminous layers was also observed on most sections (Fig. 1.2). Four of the 5 semi rigid sections evaluated in the study required an important rehabilitation, after 20–25 years, consisting in removing totally the old bituminous layers placed on top of the hydraulic treated base, and replacing them by new layers. However, the investigations made during these rehabilitation works indicated that, on all 4 sections, the cement treated base was still in very good condition, and presented no fatigue deterioration.

One of the conclusions that this study was the important role played by layer debonding in the deterioration of heavy traffic pavements (both bituminous and

Fig. 1.2 Example of core from semi-rigid pavement, showing typical debonding between bituminous and cement-treated layers

semi-rigid), and the need for improved non-destructive testing (NDT) methods to evaluate the extent and severity of such debonding. Some studies have been initiated at IFSTTAR along this direction, which have shown that ground penetrating radar (GPR) and mechanical wave propagation methods [3] as well as the use of new sensors [4] can provide accurate information on the bond conditions between layers. More realistic models, taking into account variable interface conditions, influence of climatic conditions and real distribution of traffic also need to be developed.

1.1.2 United States Roadways

The predominant form of cracking on US roadways varies by geographic and climatic region. Cracks in asphalt pavements are expensive and difficult to properly treat, which motivates studies to understand, prevent and treat crack-related distress forms. In southern states where temperatures are warmer, fatigue cracking, as shown in Fig. 1.3 (including top-down cracking) and debonding are of primary concern. Block cracking is also sometimes noted in mid-continental and/or desert locations, where aged surfaces and large temperature swings from day to night are present. Reflective cracking is also prevalent in composite pavement structures (such as jointed Portland cement concrete pavements with asphalt overlays). Reflective, block, and slippage cracking also occur in northern, colder climates, as shown in , 1.4, 1.5, 1.6.

Fig. 1.3 Fatigue cracking in asphalt pavement in Savoy, Illinois. *Photo* W. Buttlar