Maintenance and Rehabilitation of Pavements and Technological Control

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Edited by
Hosin “David” Lee
M. Asghar Bhatti
Preface

The sustainable maintenance and rehabilitation of pavements is becoming a key challenge in many countries in 21st century. It is well known that road and airfield pavement is the backbone of the economic prosperity and public welfare. But, the sustainability challenges pavement builders and managers to respond creatively to new and dynamic problems of rehabilitating and maintaining pavements in the most environmentally friendly manner by lowering energy cost, reducing traffic noise, and minimizing air and water pollution.

With sustainability as the main theme the MAIREPAV5 (MAIintenance and REhabilitation of PAVements and Technological Control) conference was organized at the Canyons Resort in Park City, Utah, USA by the University of Iowa, from August 8-10, 2007. This is the 5th International Conference in the series of conferences organized to allow researchers, government agencies, consultants and contractors to exchange technological advancements and innovations of building and maintaining longer-lasting road and airfield pavement. The first conference was held in São Paulo, Brazil by Mackenzie University in 1999, the second in Auburn, USA by the University of Mississippi in 2001, the third in Guimarães, Portugal by University of Minho in 2003, and the fourth in Belfast, Northern Ireland by the University of Ulster in 2005.

This book consists of papers presented at the MAIREPAV5 conference. The book includes two keynote papers on FHWA pavement and materials program and importance of good construction on reducing maintenance costs and eighty-eight peer-reviewed papers. Each paper was reviewed by at least two experts from the International Organizing and Scientific Committee. The final revised manuscripts were then reviewed by the editors to ensure compliance with the recommendations and suggestion made by the reviewers. The book is organized into fifteen sections based on the order of the technical sessions presented at the conference: asphalt pavement materials, concrete pavement materials, pavement construction, asphalt pavement performance modeling, concrete pavement performance modeling, pavement economic analysis, asphalt pavement rehabilitation, concrete pavement rehabilitation and recycling, pavement evaluation, asphalt pavement recycling I, pavement noise and safety, pavement management, asphalt pavement recycling II, sustainable pavement materials, and pavement preservation.

We would like to recognize the co-sponsors of MAIREPAV5: International Society for Maintenance and Rehabilitation of Transportation Infrastructure (iSMARTi), Federal Highway Administration (FHWA), Transportation and Development Institute (T&DI) of American Society of Civil Engineers (ASCE), Transportation Research Board (TRB), Korean Society of Road Engineers (KSRE), and Public Policy Center (PPC) and Civil & Environmental Engineering Department of the University of Iowa. We would like to record our indebtedness to distinguished members of International Organizing and Scientific Committee who have peer-reviewed papers and guided us to the success of this conference. Finally, we would like to thank authors who convened in Park City, Utah from all over the world to share their knowledge and experiences in building and maintaining pavements and their invaluable contributions to this book.

It was our honor and privilege to host MAIREPAV5 and edit this book.

Hosin “David” Lee / M. Asghar Bhatti
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# Contents

**Preface**  
MAIREPAV5 Committees  
Contents

## Keynote Lectures

1. **The FHWA Pavement and Materials Program**  
   Peter J. Stephanos (Federal Highway Administration)  
   Page 1

2. **Importance of Good Construction on Reducing Maintenance Costs**  
   Ray Brown (National Center for Asphalt Technology)  
   Page 7

## A.1 Asphalt Pavement Materials

1. **A Hamburg Wheel Track Study on HMA Mixes Using Acid and Non Acid Modified PMAs and Local Aggregates With and Without Lime**  
   Howard J. Anderson, Kevin VanFrank (Utah Department of Transportation)  
   Page 13

2. **Development of “Hybrid Asphalt Mixture” for Expressway Maintenance**  
   Shigeru Shimeno, Kazumasa Kawamura, Daijiro Matsumoto (Nippon Expressway Research Institute Company — Japan)  
   Page 19

   Manuel J. C. Minhoto (Polytechnic Institute of Bragança — Portugal), Paulo A. A. Pereira, Jorge C. Pais (University of Minho — Portugal)  
   Page 25

   G. Mohammed Memon, Terry L. Atha (Hudson Asphalt)  
   Page 31

5. **Evaluation of the Mechanical Performance of Asphalt Pavement Structures Matching Design Methodologies and Laboratory Fatigue Test Data**  
   Leto Momm, Breno Salgado Barra (Federal University of Santa Catarina (UFSC) — Brazil)  
   Page 37

   Osman Nuri Çelik (Selcuk University — Turkey), Seyfullah Ceylan, Mevlüt Kaya (Konya City Municipality — Turkey)  
   Page 43

## B.1 Concrete Pavement Materials

1. **Ohio’s Use of Fractured Slab Techniques – A Historical Review**  
   Arudi Rajagopal, Jack Croteau (Infrastructure Management and Engineering), Roger Green, Aric Morse (Ohio Department of Transportation)  
   Page 49

2. **Measurement of PCC Coefficient of Thermal Expansion for Various Aggregate Types**  
   Neeraj Buch, Shervin Jahangir-nejad, Joel Brown (Michigan State University)  
   Page 55

3. **Prediction of Reflective Cracking With Stress Intensity Factors**  
   Chen-Ming Kuo, Yo-Chuan Yo, Hsiao-Han Wang (National Cheng Kung University — Taiwan)  
   Page 61

4. **Evaluation of Pavements With Thin-Bonded Concrete Overlays Through 3D Finite Element Modeling**  
   Taizo Nishiyama (Japan Institute of Construction Engineering — Japan), M. Asghar Bhatti, Hosin “David” Lee (The University of Iowa)  
   Page 67

5. **Quantifying the Effects of Truck Weights on Axle Load Spectra of Single and Tandem Axle Configurations**  
   Syed Waqar Haider, Ronald S. Harichandran (Michigan State University)  
   Page 73

6. **Significant M-E PDG Design Inputs for Jointed Plain Concrete Pavements in Michigan**  
   Syed Waqar Haider (Michigan State University), Hassan K. Salama (Al-Azhar University — Egypt), Neeraj Buch, Karim Chatti (Michigan State University)  
   Page 79
7 Influence of Traffic Inputs on Rigid Pavement Performance Using M-E PDG in the State of Michigan  
Syed Waqar Haider (Michigan State University), Hassan K. Salama  
(Al-Azhar University — Egypt), Neeraj Buch, Karim Chatti (Michigan State University)  

C.1 Pavement Construction

1 Evaluation of Selected Reinforcing Materials for Retarding Reflection Cracking of Asphalt Overlay on Concrete Pavement  
Byung J. Cho, Young S. Doh, Seung-Zoon Kwon, Kwang W. Kim (Kangwon National University — Korea)  

2 A Methodology for Selecting Treated Bases and Sub-Bases Mixtures for Pavement Design and Construction  
José Vidal Nardi (Federal Centre of Technological Education of Santa Catarina (CEFET-SC) — Brazil)  

3 Effect of High Groundwater Level on Roadway Pavements: A Full-Scale Experimental Study  
W. Virgil Ping, Ching-Chin Ling (Florida State University), Bruce Dietrich, David Horhota (Florida Department of Transportation)  

4 New Technologies in the Paving Process Need to Be Based on "Common Practice" and Operators' Heuristics  
Henny ter Huerne, Seirgei Miller, André Dorée (Twente University — The Netherlands)  

5 The Deflectometric Control During the Constructive Process and the Consideration of the Non-Linearity of the Materials Used on Pavement Construction  
Glicério Trichês (Federal University of Santa Catarina — Brazil), Guido Paulo Simm Júnior (PROSUL Ltda, Federal University of Santa Catarina — Brazil)  

A.2 Asphalt Pavement Performance Modeling

1 Evaluation of Asphalt Interlayer Mixes to Mitigate Reflective Cracking in Composite Pavements  
Thomas Bennert (Rutgers University), Todd Lynn (SemMaterials, L.P.)  

2 Basic Study on Rut Shape Characteristics in Consideration of Vehicle Dynamics  
Kazuya Tomiyama, Akira Kawamura, Alimujiang Yiming (Kitami Institute of Technology — Japan), Tateki Ishida (Civil Engineering Research Institute — Japan), Shigenori Nakajima (WAcom Hokkaido CO., LTD — Japan)  

3 Change of Deformation Strength Due to Mixture Aging  
Jae H. Jung, Jong S. Lee, Jun S. Kweon, Kwang W. Kim (Kangwon National University — Korea)  

4 A Study on Temperature Dependent Modulus for Asphalt Concrete  
Kunihioto Matsui, Kiyoshi Fujinami, (Tokyo Denki University — Japan), Shigeo Higashi (Kajimaroad Co., Ltd. — Japan), Tasuku Nagae (Sacata Denki Co., Ltd. — Japan)  

5 Effects of Layer Interface Slip on the Response and Performance of Elastic Multi-Layered Flexible Airport Pavement Systems  
James W Maina, Morris De Beer (CSIR Built Environment — South Africa), Kunihioto Matsui (Tokyo Denki University — Japan)  

B.2 Concrete Pavement Performance Modeling

1 Full-Scale Field Testing of Rapid-Setting Materials for Slab Replacement  
L.A. Barna, J.S. Tingle, P.S. McCaffrey (U.S. Army Engineer Research and Development Center)  

2 Finite Element Model to Study Structural Pavements Design: Investigation in Terms of Stresses and Strains Considering Elasto-Plastic Frictional Contact Mechanics Technologies  
Alex Alves Bandeira, João Virgilio Merighi, Rita Moura Fortes (Mackenzie Presbyterian University — Brazil)  

3 Study of the Bond Strength in the Interface of Porous Concrete and Portland Cement Concrete  
Rita Moura Fortes, João Virgilio Merighi, Alex Alves Bandeira (Mackenzie Presbyterian University — Brazil)
4 A Wavelet-Based Interpretation of Vehicle-Pavement Interaction  
H.M. Zelelew, (Washington State University), A.T. Papagiannakis (University of Texas at San Antonio), B. Muhunthan (Washington State University) 169

5 Dynamic Time Domain Backcalculation of FWD Data  
Ming-Lou Liu (I-Shou University — Taiwan), Yi-Fang Chuang (National Central University — Taiwan), Jui-Chang Chuang (I-Shou University — Taiwan) 175

C.2 Pavement Economic Analysis

1 A Cost-Comparison Methodology for Selecting Asphalt Concrete Mixtures  
Kevin K. McGhee (Virginia Transportation Research Council), Trenton M. Clark (Virginia Department of Transportation) 181

2 Life-Cycle Cost Analysis and Use Policies for Modified Asphalt Pavement  
Kimio Maruyama, Jun Tako, Masayuki Kaneko (Civil Engineering Research Institute for Cold Region, Public Works Research Institute — Japan) 187

3 Economics Analysis Between Rigid and Flexible Pavement  
Silvio Rodrigues Filho (ESA Engenharia e Sistemas Ltda — Brazil), Câssio Eduardo Lima de Paiva (UNICAMP — Universidade Estadual de Campinas — Brazil) 193

4 Pay Factor Development for Hot Mix Asphalt Pavements Using Fatigue Testing Data  
Michael Zelenock (Cadillac Asphalt), Andrea Kvasnak (Auburn University), Jason Bausano (SemMaterials, L. P.), R. Christopher Williams (Iowa State University) 199

5 Vehicle Operating, Accident and User Time Costs in Pavement Management Systems: Approach for Portuguese Conditions  
Bertha Santos (University of Beira Interior — Portugal), Luis Picado-Santos (University of Coimbra — Portugal), Victor Cavaleiro (University of Beira Interior — Portugal) 205

6 Models for the Analysis of Maintenance Strategies Effects on Road Pavements Life Cycle Costs  
José Manuel Coelho das Neves, João Gomes Morgado (CESUR, IST, Technical University of Lisbon — Portugal) 211

A.3 Asphalt Pavement Rehabilitation

1 Maintenance and Rehabilitation of Low Cost Surface Dressing for Low Volume Roads – Experimental Road Sites  
Pétur Pétursson (Icelandic Building Research Institute — Iceland) 217

2 Rehabilitation Study of a Heavily Trafficked Urban Road  
Joel R. M. Oliveira, Paulo A. A. Pereira (University of Minho — Portugal), Luis G. Picado-Santos (University of Coimbra — Portugal) 223

3 Evaluation of the Rutting Susceptibility of Louisiana Superpave Mixtures  
Louay Mohammad (Louisiana State University), Shadi Saadeh (Louisiana Transportation Research Institute) 229

4 Crack Initiation Assessment of Wearing Course Mixtures Using Aggregate Skeleton Property  
Iman Haryanto, Osamu Takahashi (Nagaoka University of Technology — Japan) 235

5 Quantify Pavement Segregation  
Chieh-Min Chang (Naval Academy, Department of Marine and Mechanical Engineering — Taiwan), Jian-Shiuh Chen, Chien-Cheng Fang (National Cheng Kung University — Taiwan) 241

6 Evaluation of North Dakota’s Local Superpave Mixes’ Performance Using the Asphalt Pavement Analyzer  
Nabil Suleiman (University of North Dakota) 247

7 Study of Aggregate-Mastic Bond Properties in Bituminous Mixtures  
Hugo M.R.D. Silva, Jorge C. Pais, Paulo A.A. Pereira (University of Minho — Portugal) 253

8 Correlation Between Monotonic and Repetitive Test Results in Bituminous Mixtures  
Hugo M.R.D. Silva, Jorge C. Pais, Paulo A.A. Pereira (University of Minho — Portugal) 259
9 Rehabilitation Alternatives Using New Asphalt Rubber Mixtures With Brazilian Materials
Paulo A. A. Pereira, Jorge C. Pais (University of Minho — Portugal),
Glicério Trichês, Liseane P. T. L. Fontes (University Federal of Santa Catarina — Brazil) 265

B.3 Concrete Pavement Rehabilitation and Recycling

1 Full Scale Traffic Tests of Rapid-Setting Materials for Full-Depth Patching of Concrete Pavements
Lucy P. Priddy, Jeb S. Tingle (U.S. Army Engineer Research and Development Center) 271

2 Rehabilitation of Continuously Reinforced Concrete Pavement with Bonded Overlay
Yoon-Ho Cho (Chung-Ang University — Korea), Dong-Ho Kim, Seong Cheol Choi, Moon C. Won
(The University of Texas at Austin) 277

3 The Effectiveness of Shot-Peening and Water-Blasting Techniques on Micro and Macrotexture Characteristics of Airport Pavements
Maurizio Crispino, Riccardo Rampini (Politecnico di Milano, DIAR — Italy) 283

4 Use of Crushed Concrete as Aggregates in Continuously Reinforced Concrete Pavement
Moon C. Won (The University of Texas at Austin) 289

5 The Use of Crushed Concrete Slabs in Base Layers of Airport Pavements
Maurizio Crispino, Emanuele Toraldo, Mauro Pozzi (Politecnico di Milano, DIAR — Italy) 295

6 Evaluation of Spall Repair Materials for Airfields
Reed B. Freeman, L. Webb Mason, Lucy Phillips Priddy, Travis Mann (U.S. Army Engineer Research and Development Center) 301

C.3 Pavement Evaluation

1 Infrared Thermagraphic Inspection of De-Bonding Between Layers of Airport Flexible Pavement
Yukitomo Tsubokawa, Junicht Mizukami, Toru Esaki (National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport — Japan), Kimitoshi Hayano (Port and Airport Research Institute — Japan) 307

2 Measurements of Pavement Macrotexture With Stationary and Mobile Profilometers
M. Losa, P. Leandri, R. Bacci (University of Pisa — Italy) 313

3 Development of Laser Pavement Image Processing System to Enhance Existing Automated Pavement Distress Detection Process
Jungyong “Joe” Kim, Hosin “David” Lee (The University of Iowa), Duk-Geun Yun, Jung-Gon Sung (Korean Institute of Construction Technology — Korea) 319

4 Evaluation of Pavement Smoothness Through the Simulation Model of 3-Meter Straightedge
Chia-pei Chou, Hong-chang Chen (National Taiwan University — Taiwan) 325

5 Macro and Microtexture Evaluation of an Urban Road
Charles Silva de Aguiar, Paulo Roberto Farias Falcão, Li Chong Lee Barcelar de Castro, Márcio Muniz de Farias (Researches of the Road Engineering Laboratory, CEFTRU/UnB — Brazil) 331

6 Correcting the DCP Indices to Incorporate Skin-Friction Effects
Moshe Livneh (Technion-Israel Institute of Technology — Israel) 337

A.4 Asphalt Pavement Recycling I

1 Aging and Recycling Properties of Rubberized Binders
Soon-Jae Lee, Serji N. Amirkhanian (Clemson University), Seung-Zoon Kwon (Kangwon National University — Korea) 343

2 Full Depth Pavement Reclamation Using Lime Kiln Dust
Lawrence W. Cole (Carmeuse Lime Company) 349

3 Long-Term Performance of Recycled Asphalt Mixtures in Cold, Snowy Regions
Chigusa Ueno, Jun Tako, Ryuji Abe (Civil Engineering Research Institute for Cold Region — Japan) 355
4 Freeze-Thaw Durability of Cement-Stabilized Aggregate Base Material Blended with Reclaimed Asphalt Pavement
Rebecca A. Crane (Smith Geotechnical Engineering Consultants), W. Spencer Guthrie (Brigham Young University) 361

5 Performance Testing for Cold In-place Recycling with Foamed Asphalt
Hosin “David” Lee, Yongjoo Kim (The University of Iowa), Michael Heitzman (Iowa Department of Transportation) 367

B.4 Pavement Noise and Safety
1 Evaluating Improvement Measures for Wet-Weather Operational Safety
Ghim Ping Ong (Purdue University), Tien F. Fwa (National University of Singapore — Singapore) 373

2 Traffic Noise Study to Analyse the Effects of Vehicles and Pavement Surface Types
Sungho Mun, Kwang Ho Lee (Korea Expressway Corporation — Korea) 379

3 Using the Driving Simulator to Evaluate Road Surface Roughness
Tateki Ishida (Civil Engineering Research Institute for Cold Region, Public Works Research Institute — Japan), Akira Kawamura (Kitami Institute of Technology — Japan), Jun Tako (Civil Engineering Research Institute for Cold Region, Public Works Research Institute — Japan) 385

4 A Solution to the Pavement Edge Drop Off Problem
Ronald W. Gamache (TransTech Systems, Inc.) 391

5 Road Pavements Design and Traffic Safety – Evaluation of Relationships Between Accident Risk and Functional Properties of Road Pavements
José Manuel Coelho das Neves, Ana Isabel Capote Fernandes (Technical University of Lisbon — Portugal) 397

6 Acoustic Absorption Potential of Porous Wearing Course Mixtures
Ezio Santagata, Stefano Damiano Barbati (Politecnico di Torino — Italy) 403

C.4 Pavement Management
1 Applying Value Engineering Techniques to Pavement Rehabilitation Design Procedures
Sameh Zaghloul (Formerly of Stantec Consulting, now of H.W. Lochner, Inc.), Mohamed Elfino (Virginia Department of Transportation) 409

2 Development and Use of Pavement Performance Prediction Model in Small Towns Network Rehabilitation Management
Hesham Mahgoub, Ali A. Selim (South Dakota State University) 415

3 Comparison of Laboratory Skid Resistance Measurement Techniques
Bob Allen, Paul Phillips ( Aggregate Industries — UK), David Woodward (University of Ulster — UK) 421

4 Project-Level Use of Asphalt Pavement Performance Curve
Masaki Seino, Jun Tako, Kimio Maruyama (Civil Engineering Research Institute for Cold Region, Public Works Research Institute — Japan) 427

5 Development and Implementation of a New Pavement Management System
Luis Picado-Santos, Adelino Ferreira (University of Coimbra — Portugal) 433

6 Actual Applications of LTPP Data for Pavement Research and Management Purposes
Sameh Zaghloul (Formerly of Stantec Consulting, now of H.W. Lochner), Jack Springer, (US Department of Transportation, Federal Highway Administration) 439

A.5 Asphalt Pavement Recycling II
1 Laboratory Investigation of Utilizing High Percentage of Rap in Rubberized Asphalt Mixtures
Feipeng Xiao, Serji N. Amirkhanian (Clemson University) 445

2 Mixing Method Renovation for Reducing Stiffness of Recycled Asphalt Mixture
Tae W. Park, Sung U. Kim, Nam W. Park, Kwang W. Kim (Kangwon National University — Korea) 451
3 Laboratory Study of Recycled Asphalt Pavement Materials as Base Course
Haifang Wen, Tuncer B. Edil (University of Wisconsin at Madison) 457

4 Experimental Investigation for the Analysis of Cold-Recycled Bituminous Mixtures
Ezio Santagata, Giuseppe Chiappinelli, Pier Paolo Riviera (Politecnico di Torino — Italy) 463

5 Laboratory Investigation of Recycled Aged CRM Mixtures
Soon-Jae Lee, Hakseo Kim, Chandra K. Akisetty, Serji N. Amirkhanian (Clemson University) 469

B.5 Sustainable Pavement Materials

1 Laboratory Investigation of Warm Asphalt Binder Properties – A Preliminary Analysis
Tejash S. Gandhi, Serji N. Amirkhanian (Clemson University) 475

2 Use of Warm Mix Asphalt Additives for Cold In-Place Recycling Using Foamed Asphalt
Hosin “David” Lee (The University of Iowa), Youngjoo Kim (Iowa Department of Transportation), Song-Do Hwang, Kyudong Jeong (Korean Institute of Construction Technology — Korea) 481

3 Development of a Simplified Design Procedure for Determining Layer Thickness in Long Life Pavements
Hyun Jong Lee, Jung Hun Lee (Sejong University — Korea), Hee Mun Park, Soo Ahn Kwon (Korean Institute of Construction Technology — Korea) 487

4 Asphalt Concrete “Inverted Section” Pavements for Long-Life Roads
Michela Agostinacchio (DIIAR - Politecnico di Milano — Italy), Saverio Olita (University of Basilicata — Italy) 493

5 Sustainability and Highway Surfacing Materials in the UK
W. Alan Strong, David Woodward, Alan R Woodside (University of Ulster — UK) 499

6 Performance and Durability of Grouted Open Grade Asphalt Concretes
Giovanni Da Rios, Michela Agostinacchio, Federico Fiori (DIIAR - Politecnico di Milano — Italy) 505

C.5 Pavement Preservation

1 Quantifying the Benefits of Flexible Pavement Preventive Maintenance Techniques – A Synthesis and Survey
Eli Cuelho, Robert Mokwa, Michelle Akin (Montana State University) 511

2 A Network-Level Optimization Model for Pavement Maintenance and Rehabilitation Programming
Zheng Wu, Gerardo W. Flintsch (Virginia Polytechnic Institute and State University) 517

3 Soil Stabilization Studying of Tropical Brazilian Soil by Unconfined Strength Compression Tests
Daniela Massami Ide, Anna Silvia Pacheco Peixoto, Sérgio Silva Macedo (UNESP/FEB — Brazil) 523

4 The Possibility of Building a Road Maintenance Fund Scheme to Initiate Pavement Smoothness Incentive in Taiwan
Isaac I.C. Chen (National Taiwan University, MOTC Institute of Transportation — Taiwan) 529

5 Maintenance and Preservation of the District of Columbia’s National Highway System Pavement Assets
Gonzalo R. Rada, Amy L. Simpson, Jonathan L. Groeger (MACTEC Engineering & Consulting, Inc) 535

6 Predicting Chip Seal Embedment
Haryati Yaacob (University of Technology — Malaysia), David Woodward, Alan Woodside (University of Ulster — UK) 541

Author Index 547
**STUDY OF AGGREGATE-MASTIC BOND PROPERTIES IN BITUMINOUS MIXTURES**

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**Abstract:** The durability of bituminous mixtures in the pavement depends on their characteristics (particularly, the voids content) and on weather conditions. In fact, the premature distress of pavements usually occurs in poorly compacted mixtures, especially in the presence of water. The intrusion of water in the bituminous mixtures strips the mastic binder from the aggregates, thus leading to the rupture of the aggregate-mastic bonds, which in the most severe cases is manifested by the disaggregation of the mixture in the surface layer of the pavement. Consequently, the main objective of this work is the study of the aggregate-mastic bond strength of different mixtures and the evaluation of the influence of water and aging on that bond strength. The bond between the mastic and the aggregates is evaluated by using two monotonic tests (tensile and shear). The influence of water and aging is evaluated by comparing the strength of conditioned and unconditioned samples. The main conclusions of this work result from the analysis of the aggregate-mastic bond strength under different test conditions. The influence of the mixtures composition, water and aging conditioning on the bonding properties is observed, as well as the main causes of the aggregate-mastic stripping in dense mixtures, usually applied *in situ*.

**INTRODUCTION**

In this work, two test methods were developed to study the aggregate-mastic bond strength – a property of bituminous mixtures which influences their behaviour in service. According to Scholz (1995), the primary effects of lower bond strength between the mastic and the aggregates are a higher propensity of the mixture for disaggregation, a reduced stiffness modulus of the mixture and a smaller capability to resist to tensions caused by traffic (increasing rutting and cracking in pavements). Furthermore, the observation of several specimens showed that the trajectory of the cracks usually evolves in the bonding areas between the binder and the aggregates. This fact, as well as other studies (Scholz, 1995; Curtis et al., 1993), confirms that distresses in bituminous mixtures often occurs in areas of reduced mechanical strength of the aggregate-binder bond. So, the main objective of this study is to prevent failure in pavements due to weak aggregate-mastic bond strength, by evaluating the main parameters which influence that property of the bituminous mixtures, including ageing and water sensitivity procedures.

**KEY FACTORS IN THE BEHAVIOR OF THE AGGREGATE-MASTIC BOND**

In order to define the conditions to be used in laboratorial tests to study the aggregate-mastic bond, the following factors were considered:

- The loss of aggregate-mastic bond mainly occurs due to tensile and shear stresses;
The tests to be carried out should represent, in a high degree, the in-service conditions in the pavement, since the aggregate-mastic bond must be evaluated when the bituminous mixtures are submitted to the traffic loads;
- These tests should be fast and easily carried out and have low operation costs;
- The bitumen is not isolated in a bituminous mixture, but it is associated with fine aggregates, thus forming a mastic which serves as a binder to the coarser aggregates (Curtis et al., 1993).

Therefore, two tests were implemented, which, together, allow the characterization of the aggregate-mastic bond of bituminous mixtures: i) tensile test; ii) shear test. As the tests should be rapid and easy to perform, a direct and monotonic loading, by imposing a growing deformation until rupture occurs was used.

**EXPERIMENTAL METHOD TO EVALUATE THE AGGREGATE-MASTIC BOND**

The eight mastics used in the preparation of specimens to study the aggregate-mastic bond (Silva, 2006) and their respective characteristics are presented in Table 1. The main variables in study are: binder penetration grade and content, aggregate gradation, filler source and ageing.

<table>
<thead>
<tr>
<th>Bituminous mastic</th>
<th>Mastic 1</th>
<th>Mastic 2</th>
<th>Mastic 3</th>
<th>Mastic 4</th>
<th>Mastic 5</th>
<th>Mastic 6</th>
<th>Mastic 7</th>
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<td>100.0</td>
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<td>100.0</td>
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<tr>
<td>% Passing #20</td>
<td>73.8</td>
<td>73.8</td>
<td>73.8</td>
<td>73.8</td>
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<td>83.0</td>
<td>52.3</td>
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<td>52.1</td>
<td>52.1</td>
<td>52.1</td>
<td>68.8</td>
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<td>28.9</td>
<td>40.9</td>
<td>15.1</td>
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<td>16.2</td>
<td>23.3</td>
<td>9.2</td>
<td>16.2</td>
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<tr>
<td>Binder content</td>
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<td>13.6 %</td>
<td>18.2 %</td>
<td>15.9 %</td>
<td>15.9 %</td>
<td>19.9 %</td>
<td>9.8%</td>
<td>15.9 %</td>
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<tr>
<td>Binder pen grade</td>
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<td>35/50</td>
<td>50/70</td>
<td>35/50</td>
<td>35/50</td>
<td>35/50</td>
<td>35/50</td>
</tr>
<tr>
<td>Filler source</td>
<td>Limestone</td>
<td>Limestone</td>
<td>Limestone</td>
<td>Limestone</td>
<td>Granite</td>
<td>Limestone</td>
<td>Limestone</td>
<td>Limestone</td>
</tr>
<tr>
<td>Aging</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Objective of the study</td>
<td>Base compos.</td>
<td>Lower BC</td>
<td>Higher BC</td>
<td>Binder Pen grade</td>
<td>Filler source</td>
<td>Finer gradation</td>
<td>Coarser gradation</td>
<td>Aging</td>
</tr>
</tbody>
</table>

The short term ageing method (Von Quintus et al., 1991), to which the mastic 8 was submitted, tried to simulate that phenomenon in the pavement, and it involved heating the loose mastic, for 24 hours, in a ventilated oven at 135 °C.

To study the aggregate-mastic bond, specimens with 5×5×8 cm³ were prepared with two mastic layers and one with coarse aggregates (with dimensions between 9.5 and 12.5 mm), in which it is easy to identify the bond area between aggregates and mastic. The apparent density of the specimens varied between 1.98 and 2.20 g/cm³. The use of granitic filler and a coarser mastic with a reduced binder content hindered the bond between the mastic and coarse aggregates and reduced the density of the specimens.

The monotonic shear and tensile tests, which allowed the determination of the required parameters for a constitutive model of the behaviour of the aggregate-mastic bond, and that were used in this phase of the work, are presented in Figure 1.
Five different test configurations (Airey et al., 2002) and 3 repetitions for every one of them were performed (to find a mean value). These tests were carried out in strain control. The “base temperature” selected was 15 ºC, although other tests were performed at 25 ºC. A “base strain rate” of 0.001 s\(^{-1}\) was selected, as well as a higher (0.01 s\(^{-1}\)) and lower strain rate (0.0001 s\(^{-1}\)).

Finally, tests were carried out on specimens under a previous water conditioning (1 hour under water with partial vacuum, followed by a period of 3 days immersed in water at 15 ºC), by trying to simulate the specimens sensibility to the presence of water. This conditioning, which is based on the "short term ratios" of Lottman (1982), was modified due to the high sensibility of the mastic to high temperatures. To sum up, five test configurations were used: i) Strain Rate (SR)= 0.01 s\(^{-1}\), Temperature (T)= 15 ºC, without Water Conditioning (WC); ii) SR= 0.001 s\(^{-1}\), T= 15 ºC, without WC; iii) SR= 0.0001 s\(^{-1}\), T= 15 ºC, without WC; iv) SR= 0.001 s\(^{-1}\), T= 25 ºC, without WC; v) SR= 0.001 s\(^{-1}\), T= 15 ºC, with WC.

**BEHAVIOR OF AGGREGATE-MASTIC BOND IN SHEAR AND TENSILE TESTS**

Next, the results of the monotonic shear and tensile tests are presented. The main results were the shear and the tensile strength, the strain in the rupture and the tangent modulus of the bond between aggregates and the different mastics in the several test configurations.

In Figures 2 and 3, the results of the monotonic tests for the five used test configurations (left) and the results obtained in the base configuration for all the bituminous mastics (right) are presented, in the shear test and in the tensile respectively.
On one hand, the shear strength of the aggregate-mastic bond is obtained for a relatively high strain (10 to 15%). This value is higher when the binder content increases. The slowest tests and the tests at 25 ºC caused smaller shear strength, while the maximum shear strength was obtained for the highest strain rate test (configuration 1).

On the other hand, the tensile strength of the aggregate-mastic bond is obtained for a very small strain (inferior to 1%). The strain in the rupture is statistically higher and the tensile strength is statistically smaller when the binder content is high or when the tests are carried out at a reduced strain rate or at 25 ºC. The highest strain rate test (configuration 1) clearly increases the mean value of the tensile strength of the aggregate-mastic bond.

Figure 4 presents examples of the rupture of specimens in the shear test (left) and in the tensile test (right). Rupture occurred in the aggregate-mastic bond area. This is an essential condition which allowed the validation of the used tests to evaluate the bond between these two materials.

The comparison between the specimens with different binder contents shows that the tensile strength frequently increases when the binder content rises, in opposition to what occurs in the shear test. This indicates that the bitumen intervention is crucial to bond the aggregates by increasing the tensile strength. However, at the same time, it is a "lubricant" between aggregates, thus reducing the shear strength. The shear and tensile strength of the aggregate-mastic bond almost always decrease by using of softer bitumen (50/70).

The use of a finer gradation of the aggregates in the mastic and of a granitic filler visibly causes a reduced shear and tensile strength of the aggregate-mastic bond.
The influence of ageing (left) and of water presence (right) in the behaviour of the aggregate-mastic bond is presented in Figures 5 (shear test) and 6 (tensile test).

Figure 5. Influence of the mastic ageing and of the water conditioning in the shear strength of the aggregate-mastic bond

Figure 6. Influence of the mastic ageing and of the water conditioning in the tensile strength of the aggregate-mastic bond

The aged mastic statistically improves the shear and tensile strength of the aggregate-mastic bond. This result appears as the aged mastic has a higher stiffness, thus hindering the shear deformation of the mastic in its bond to the aggregates. Moreover, the ageing procedure allowed the bitumen to be deeply bonded to the aggregates, thus increasing the tensile strength of the aggregate-mastic bond.

The water influence is not very noticeable, because the specimens have a reduced porosity. However, most specimens reduced their shear and tensile strength (mean value) after water conditioning, mainly in the tensile test. The specimens with reduced binder content were the most harmed by water in both tests. The water sensibility was also slightly high, not only for the aged mastic in shear tests, but also for the mastics with granitic filler and with softer bitumen in tensile tests. In Figure 7 it is clear that water removed mastic from the surface of the coarse aggregates in some specimens. This demonstrates the influence of water in reducing the aggregate-mastic bond.

The shear and tensile strength of the aggregate-mastic bond is very susceptible to the variation of temperature as that strength at 25 °C drops to about a half of its value at 15 °C. Finally, an obvious increase of the shear and tensile strength of the aggregate-mastic bond was observed with the raise of strain rate, which seems to stabilize for higher strain rates.
CONCLUSIONS

The conditions/configurations of the shear and tensile tests performed in this study can be used to characterize the aggregate-mastic bond strength in the bituminous mixtures as they cause the rupture in the bond area under study. The results of the tests carried out to establish the influence of the composition and test parameters in the strength of the aggregate-mastic bond allowed the following conclusions and recommendations, based on statistical tendencies of the results:

- The shear strength rises when the binder content is reduced (in opposition to the tensile tests);
- The use of a softer bitumen (50/70), finer gradations of aggregates in the mastic and granitic filler (in comparison with limestone) are not recommended;
- The ageing improved the strength of the aggregate-mastic bond, due to the increase of the mastic stiffness and to a better bond between the mastic and the aggregates;
- The water conditioning of the specimens usually reduced the strength of the aggregate-mastic bond, mainly in the tensile tests and in the specimens with low binder content, in which it was evident (by observation) the stripping in the bond area between the mastic and the aggregates;
- Temperature and strain rates have a great influence in the behaviour of the aggregate-mastic bond, mainly in specimens with higher binder contents and without ageing conditioning.

REFERENCES


