Maintenance and Rehabilitation of Pavements and Technological Control

Proceedings of the Fifth International Conference
Park City, Utah, USA
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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 (MAIntenance 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 i
MAIREPAV5 Committees ii
Contents iii

Keynote Lectures

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

2 Importance of Good Construction on Reducing Maintenance Costs
   Ray Brown (National Center for Asphalt Technology)  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) 13

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

3 Evaluation of the Visco-Elastic Properties in Asphalt Rubber and Conventional Mixes
   Manuel J. C. Minhoto (Polytechnic Institute of Bragança — Portugal), Paulo A. A. Pereira, Jorge
   C. Pais (University of Minho — Portugal) 25

4 Hybridized Modified Asphalt (HMA) With Enhanced PG Plus Characteristics
   G. Mohammed Memon, Terry L. Atha (Hudson Asphalt) 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) 37

6 Effect of Carboniferous-Triassic Rock Dust on the Marshall Stabilities of Hot Bituminous Mixtures
   Osman Nuri Çelik (Selcuk University — Turkey), Seyfullah Ceylan, Mevlüt Kaya
   (Konya City Municipality — Turkey) 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) 49

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

3 Prediction of Reflective Cracking With Stress Intensity Factors Chen-Ming Kuo, Yo-Chuan Yo,
   Hsiao-Han Wang (National Cheng Kung University — Taiwan) 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) 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) 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) 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
Kazuuya Tomiyama, Akira Kawamura, Alimujiang Yiming (Kitami Institute of Technology — Japan), Tateki Ishida (Civil Engineering Research Institute — Japan), Shigenori Nakajima (WAcorn 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
Kunihito Matsui, Kiyoshi Fujinami, (Tokyo Denki University — Japan), Shigeo Higashi (Kajimaroad Co., Ltd. — Japan), Tasuku Nagae (Sakata 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), Kunihito 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 Virgílio 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 Virgílio Merighi, Alex Alves Bandeira (Mackenzie Presbyterian University — Brazil)
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Wavelet-Based Interpretation of Vehicle-Pavement Interaction</td>
<td>H.M. Zelelew, A.T. Papagiannakis, B. Muhunthan</td>
<td>169</td>
</tr>
<tr>
<td>5 Dynamic Time Domain Backcalculation of FWD Data</td>
<td>Ming-Lou Liu, Yi-Fang Chuang, Jui-Chang Chuang</td>
<td>175</td>
</tr>
<tr>
<td>C.2 Pavement Economic Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 A Cost-Comparison Methodology for Selecting Asphalt Concrete Mixtures</td>
<td>Kevin K. McGhee, Trenton M. Clark</td>
<td>181</td>
</tr>
<tr>
<td>2 Life-Cycle Cost Analysis and Use Policies for Modified Asphalt Pavement</td>
<td>Kimio Maruyama, Jun Tako, Masayuki Kaneko</td>
<td>187</td>
</tr>
<tr>
<td>3 Economics Analysis Between Rigid and Flexible Pavement</td>
<td>Silvio Rodrigues Filho, Cássio Eduardo Lima de Paiva</td>
<td>193</td>
</tr>
<tr>
<td>4 Pay Factor Development for Hot Mix Asphalt Pavements Using Fatigue Testing Data</td>
<td>Michael Zelenock, Andrea Kvasnak, Jason Bausano, R. Christopher Williams</td>
<td>199</td>
</tr>
<tr>
<td>6 Models for the Analysis of Maintenance Strategies Effects on Road Pavements Life Cycle Costs</td>
<td>José Manuel Coelho das Neves, João Gomes Morgado</td>
<td>211</td>
</tr>
<tr>
<td>A.3 Asphalt Pavement Rehabilitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Maintenance and Rehabilitation of Low Cost Surface Dressing for Low Volume Roads – Experimental Road Sites</td>
<td>Pétur Pétursson</td>
<td>217</td>
</tr>
<tr>
<td>2 Rehabilitation Study of a Heavily Trafficked Urban Road</td>
<td>Joel R. M. Oliveira, Paulo A. A. Pereira</td>
<td>223</td>
</tr>
<tr>
<td>3 Evaluation of the Rutting Susceptibility of Louisiana Superpave Mixtures</td>
<td>Louay Mohammad, Shadi Saadeh</td>
<td>229</td>
</tr>
<tr>
<td>4 Crack Initiation Assessment of Wearing Course Mixtures Using Aggregate Skeleton Property</td>
<td>Iman Haryanto, Osamu Takahashi</td>
<td>235</td>
</tr>
<tr>
<td>5 Quantify Pavement Segregation</td>
<td>Chieh-Min Chang</td>
<td>241</td>
</tr>
<tr>
<td>6 Evaluation of North Dakota’s Local Superpave Mixes’ Performance Using the Asphalt Pavement Analyzer</td>
<td>Nabil Suleiman</td>
<td>247</td>
</tr>
<tr>
<td>7 Study of Aggregate-Mastic Bond Properties in Bituminous Mixtures</td>
<td>Hugo M.R.D. Silva, Jorge C. Pais, Paulo A.A. Pereira</td>
<td>253</td>
</tr>
<tr>
<td>8 Correlation Between Monotonic and Repetitive Test Results in Bituminous Mixtures</td>
<td>Hugo M.R.D. Silva, Jorge C. Pais, Paulo A.A. Pereira</td>
<td>259</td>
</tr>
</tbody>
</table>
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-Beeding and Water-Blasting Techniques on Micro and Macrotexure
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 Livne
(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
Abstract: The pavement response to traffic repetitive loading is represented and evaluated more accurately in laboratory by using repetitive testing. However, the use of monotonic testing is very common to evaluate the behavior of bituminous mixtures and to control their quality when applied in pavements. Thus, the relationship between the results of monotonic and repetitive tests performed in this work is the main base of analysis of the accuracy of monotonic tests to assess the performance of bituminous mixtures in situ. Fatigue cracking and rutting are the main types of distress in flexible pavements in countries with warm temperatures. Initially, the behavior of several dense mixtures is determined by using normalized repetitive testing, namely bending beam tests in four points (fatigue) and repetitive simple shear tests at constant height (rutting). Then, similar mixtures are tested in a monotonic manner by using compression, tensile and shear testing. The monotonic tests are performed at different temperatures and strain rates, so as to reproduce a wide range of in situ conditions. The main conclusions result from the statistical comparison between the repetitive and the monotonic tests. Essentially, this work intends to evaluate the possibility of characterizing the performance of bituminous mixtures in situ by using the specific monotonic tests herein developed.

INTRODUCTION

The main objective of this work is to analyze the ability of the monotonic tests (tests carried out without load repetition, by applying a gradual and lineal increase of strength or deformation in function of time) developed in this work to evaluate the behavior of the bituminous mixtures, as well as some normalized tests which have already demonstrated their capability of evaluating the behavior of the bituminous mixtures in situ.

The requirement of "new" monotonic tests resulted from the specific conditions which must be represented, since the results of these tests were necessary as data entry for the numeric modelling of the behaviour of the bituminous mixtures. These tests also present other advantages, such as simplicity in the procedures and the low cost operations.

PROCEDURE FOR THE CHARACTERIZATION OF BITUMINOUS MIXTURES

The eight bituminous mixtures studied in this work (Silva, 2006) and the respective characteristics are presented in Table 1.
Table 1. Composition of the studied bituminous mixtures

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<thead>
<tr>
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<td>VMA</td>
<td>15.7%</td>
<td>15.0%</td>
<td>15.4%</td>
<td>14.7%</td>
<td>17.0%</td>
<td>16.5%</td>
<td>17.6%</td>
<td>14.9%</td>
</tr>
<tr>
<td>Binder pen grade</td>
<td>35/50</td>
<td>35/50</td>
<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>Yes</td>
<td></td>
</tr>
</tbody>
</table>

These mixtures were also used to analyse the influence of some parameters (aggregate gradation, binder content and penetration grade, filler source and aging) in the performance of a surface bituminous mixture (Silva, 2006), although it is not extensively presented here. In short, higher binder contents and softer binders increased fatigue life but reduced all other characteristics. The use of granitic filler is not desirable. The aging procedure improved the mixture performance. The “reference” grading curve for the dense mixture is the one with the greatest behaviour, and should not be changed for coarser or finer ones. Voids content values around 4 %, associated with VMA values around 15 %, are ideal for this surface bituminous mixture.

**Monotonic Tests Developed in this Work**

According to Airey et al. (2002), the response of a bituminous mixture depends on its stress state, and the straight relationship between a certain stress state and the respective response of the bituminous mixture must be determined by using tests carried out in a uniform stress state. Thus, it was determined that specimens of bituminous mixture with $5 \times 5 \times 8$ cm$^3$ should be tested in a monotonic manner, in shear, tension and compression (Figure 1), by using a set of uniform stress states which allow the evaluation of the behavior of the bituminous mixture in several situations. These tests were carried out to obtain the minimum basic parameters required for the numeric constitutive modelling of the behaviour of the bituminous mixture.

![Figure 1. Specimens of bituminous mixture used in the monotonic tests](image-url)
strength, the strain in rupture and the tangent modulus for the different tests configurations and bituminous mixtures. Figure 2 presents examples of the results obtained with the three types of monotonic tests used for the characterization of bituminous mixtures.

![Stress-strain curves for the different types of monotonic tests carried out in this work](image)

**Figure 2. Stress-strain curves for the different types of monotonic tests carried out in this work**

**Repetitive Bending and Shear Normalized Tests**

The normalized tests used in this work to verify the behavior of the bituminous mixtures analyzed previously with monotonic tests are the following:

- Repetitive four-point bending beam test for the evaluation of stiffness modulus (EN 12697-26) and fatigue resistance (EN 12697-24; Tayebali et al., 1994);
- Repetitive simple shear test at constant height (RSST-CH) to evaluate the shear modulus and rut resistance (AASHTO TP7-01; Sousa et al., 1994).

The 4-point bending tests were initially carried out at 15 °C using frequencies of 10, 5, 2, 1, 0.5, 0.2 and 0.1 Hz to evaluate stiffness modulus. The procedures used in 4-point bending fatigue tests consisted of using cyclic loading at 20 °C, in strain control (two strain levels of 300E-6 and 700E-6), by carrying out three repetitions for each strain level. Based on the number of cycles which caused the rupture of the specimen (reduction of the stiffness to 50%) and on the applied strain, six points related to the fatigue behavior of the bituminous mixtures are obtained. The best exponential fitting those points is the fatigue law of the bituminous mixture.

The shear modulus tests on the studied bituminous mixtures were carried out at 15 °C by using frequencies of 10, 5, 2, 1, 0.5, 0.2 and 0.1 Hz. To obtain the rut resistance of the studied bituminous mixtures, RSST-CH tests were carried out by using repetitive loading at 50 °C as it is stated in AASHTO TP7-01 provisional standard. The result of this test derives from the permanent shear deformation accumulated during the test and the number of equivalent ESALs.

**RELATIONSHIP BETWEEN THE RESULTS OF MONOTONIC TESTS DEVELOPED IN THIS WORK AND REPETITIVE BENDING/SHEAR NORMALIZED TESTS**

In this part of the work, the results of the monotonic tests (herein developed) are related to the results of the repetitive normalized tests in order to evaluate the confidence degree in the use of monotonic test results to study bituminous mixtures. Although all the results of the first group of tests can be crossed with those of the second group, this would not be logical because some tests
evaluate completely different properties. Thus, comparisons were only established between tests which evaluate similar properties carried out on the same bituminous mixture. The relationships presented in this part of the work will assure the accomplishment of the objectives of this work.

Since the results to be compared were obtained by carrying out tests in very different conditions (monotonic tests and normalized tests with repetitive loading), the coefficients of correlation ($R^2$) will not be presented here, because they will be most likely low. Essentially, this work intends to verify if the monotonic tests herein developed can distinguish the behavior of different bituminous mixtures, like the normalized tests. Thus, the observation of the type of relationship between the results obtained in the two cases is enough for that purpose.

In Figure 3 it is presented the comparison between the shear strength of the studied bituminous mixtures, evaluated in monotonic tests at 15 ºC, and the dynamic shear modulus of the same mixtures, assessed in the RSST-CH at 15 ºC. An excellent relationship between both results can be observed. Thus, the monotonic shear tests developed in this work can accurately evaluate the behavior of bituminous mixtures in the pavement when submitted to shear loading.

![Figure 3. Monotonic shear strength and the dynamic shear modulus relationship](image)

Figure 3. Monotonic shear strength and the dynamic shear modulus relationship

Figure 4 presents the relationship between the monotonic tensile strength at 15 ºC and the stiffness modulus of the studied mixtures obtained in 4-point bending beam tests at 15 ºC.

![Figure 4. Monotonic tensile strength and stiffness modulus (4-point bending) relationship](image)

Figure 4. Monotonic tensile strength and stiffness modulus (4-point bending) relationship

Even without a high correlation between tensile strength and stiffness modulus, it is observed a direct relationship between the increase of the tensile strength of the studied bituminous mixtures
and their stiffness. So, the monotonic tensile test is able to evaluate indirectly and in a fairly precise mode the behavior of mixtures submitted to tensile stresses in situ. The larger dispersion of the monotonic tensile test results derives from its greater sensibility to the strain rate used, thus justifying the development of this monotonic test in the future.

Next, the results of the monotonic compression and shear tests at 25 ºC are related to the results of the RSST-CH test at 50 ºC, in order to evaluate the rut resistance of the studied bituminous mixtures. The relationship between those results is presented in Figure 5. Although the monotonic tests have been carried out at a very low temperature to assess the rut resistance behavior of the studied bituminous mixtures, a good relationship can be verified between the monotonic tests and the RSST-CH test carried out at 50 ºC.

![Figure 5. Monotonic compressive/shear strength and ESALs estimated in RSST-CH relationship](image)

Concerning the two referred monotonic tests, the shear test had a better relationship with the RSST-CH test. This is easily understood, because of their greater similarity when compared with the compression test. Besides, direct relationships were observed between the increase of the compressive and shear strengths of the studied mixtures and the increase in the number of ESALs estimated in the RSST-CH test. Thus, the two monotonic tests carried out at 25 ºC can distinguish, approximately, the rut resistance of the bituminous mixtures studied in this work.

Finally, Figure 6 presents the relationship between monotonic tensile strength at 15 ºC and fatigue life obtained in 4-point bending beam tests at 20 ºC for the studied bituminous mixtures.

![Figure 6. Relationship between monotonic tensile strength and 4-point bending fatigue life](image)
The relationship between the tensile strength (the tensile strain/stress is the control parameter of the fatigue cracking phenomenon in the pavement design and in the study of bituminous mixtures) obtained in the monotonic test and the fatigue life obtained in the repetitive 4-point bending beam test is reasonable.

In fact, it is possible to establish a correlation between the results of these two tests, although some dispersion was observed. Thus, the monotonic tensile test developed in this work has some ability to distinguish the bituminous mixtures, concerning their fatigue cracking resistance.

CONCLUSIONS

In this work, normalized tests results were compared with results of monotonic tests herein developed, in order to validate the “new” tests implemented and their ability to distinguish bituminous mixtures with suitable or unsuitable behavior in the pavement.

Generally, a good relationship between the results of the monotonic tests developed in this work and the results of the normalized tests (repetitive 4-point bending beam test and repetitive simple shear test at constant height – RSST-CH) was observed.

It was concluded that the monotonic tests implemented in this work can accurately evaluate the behavior of the bituminous mixtures in situ, concerning the properties and the mixtures evaluated in this work. Thus, they can constitute a new test method to select the bituminous mixtures to be used in a pavement.

REFERENCES


