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)  
   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, Daijirou Matsumoto (Nippon Expressway Research Institute Company — Japan)  
   19

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

   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

   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) 85

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) 91

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) 97

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) 103

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) 109

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) 115

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.) 121

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) 127

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) 133

4 A Study on Temperature Dependent Modulus for Asphalt Concrete
Kunihiro Matsui, Kiyoshi Fujinami, (Tokyo Denki University — Japan), Shigeo Higashi (Kajimaroad Co., Ltd. — Japan), Tasuku Nagae (Sakata Denki Co., Ltd. — Japan) 139

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), Kunihiro Matsui (Tokyo Denki University — Japan) 145

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. McCallfrey (U.S. Army Engineer Research and Development Center) 151

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) 157

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) 163
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), Cäsio 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-Shiu 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, DIIAR — 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, DIIAR — 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 Straigntedge
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 Livnehe (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
EVALUATION OF THE VISCO-ELASTIC PROPERTIES IN ASPHALT RUBBER AND CONVENTIONAL MIXES

Manuel J. C. Minhoto
Polytechnic Institute of Bragança, Bragança, Portugal
E-mail: minhoto@ipb.pt

Paulo A. A. Pereira and Jorge C. Pais*
University of Minho, Guimarães, Portugal
E-mail: ppereira@civil.uminho.pt;jpais@civil.uminho.pt

Abstract: Flexible pavements are subjected to a set of degradations on the pavement surface, such as cracks and other specific types of distress which arise from traffic and temperature variations and which are responsible for the users’ unsafety and discomfort. The occurrence of temperature variations in the pavement leads to a severe aggravation of the reflective cracking phenomenon what implies a premature distress of the overlays. In this way, a theoretical study about the influence of temperature variation in the reflective cracking overlay behaviour was performed. To this end, a thermo-mechanical characterization of bituminous materials was made through a set of tests performed with an asphalt rubber mix and a conventional mix. It is intended to study the relaxation behaviour for four different temperature cases, 25°C, 15°C, 5°C and -5°C, which is a range of temperature variations similar to those that occur in the pavements located in the Northeast of Portugal. This paper presents a study in which the viscoelastic properties of asphalt rubber and conventional mixes, related with long-time loading and thermal loading, were determined through static relaxation tests using different test configurations. It also describes the material used, the test configurations applied to evaluate the viscoelastic properties and it finally establishes a comparison between the two mixes studied.

INTRODUCTION

The study of the influence of temperature variations in the behaviour of bituminous mixes requires a simulation of the relaxation effect subjected to long-time loading, such as thermal shrinkage associated to temperature variations (Minhoto et al, 2005). For that purpose, a set of tests was performed in bituminous mixes samples to obtain relaxation capability evaluation, expressed by relaxation properties estimated for a set of temperatures. A constant strain was applied to a sample during a loading time under constant temperature conditions (Figure 1).

The definition of relaxation models must be developed for its integration in finite elements models used for calculate stress and strain states. The establishment of these models is based on the adjustment of representative curves of the experimental results to the generalized expressions which describe this type of behaviour (Minhoto et al, 2005).
The stress function of a viscoelastic material is given in an integral form. In the context of small strain theory, the constitutive equation for an isotropic viscoelastic material can be written as:

\[
\sigma = \int_0^t 2G(t-\tau) \frac{de}{d\tau} d\tau + I \cdot \int_0^t K(t-\tau) \frac{d\Delta}{d\tau} d\tau
\]

(1)

The viscoelastic properties of the material for what respects to relaxation, used in the numerical simulation through finite elements methodology, had been expressed in an integral form using the kernel function of the generalized Maxwell elements, \(G(t)\) and \(K(t)\), representing the shear and bulk relaxation modulus, respectively, through the following equations:

\[
G(\xi) = G_\infty + \sum_{i=1}^{n_G} G_i e^{-\frac{\xi}{\tau_i^G}}
\]

(2)

\[
K(\xi) = K_\infty + \sum_{i=1}^{n_K} K_i e^{-\frac{\xi}{\tau_i^K}}
\]

(3)

The kernel functions are represented in terms of Prony series which assumes the formulation indicated by the following expressions:

\[
G = G_\infty + \sum_{i=1}^{n_G} G_i \exp\left(-\frac{t}{\tau_i^G}\right)
\]

(4)

\[
K = K_\infty + \sum_{i=1}^{n_K} K_i \exp\left(-\frac{t}{\tau_i^K}\right)
\]

(5)

As the viscoelastic property of materials depends strongly on temperature, the so called thermorheological simplicity is an assumption based on the observation of many glass-like materials, the relaxation curve of which, at high temperature, is identical to that at a low temperature if the time is properly scaled. Thus, the characterization of viscoelastic properties of the mixtures must be expressed in function of the temperature. The consideration of the temperature dependence in the previous models is guaranteed through the adoption of shift factors. For this purpose, the
principle of thermo-rheological simplicity is considered as applicable and it is expressed by the shift factor X=A (T (t)), defined through the expression of William-Landel-Ferry (WLF):

\[ \log_{10} (A(T')) = \frac{C_1 (T - T_r)}{C_2 + T - T_r} \]

In this work the relaxation behaviour of two bituminous mixes types were analysed: Asphalt Rubber gap-graded mix (ARHM) and conventional dense asphalt mix (CM). The material used to obtain the test specimens was extracted from a road pavement after construction.

**TEST DESCRIPTION**

The relaxation tests were performed using prismatic core specimens of 90 mm long by 65 mm thick by 45 mm wide. Each sample was fixed to a shear machine device support, as shown in Figure 2.

![Figure 2 – Sample used in relaxation tests](image)

Each sample is subjected to a constant vertical axial strain through an induced constant displacement. The constant test strain applied a range from 1E-3 to 2E-3 and the test temperatures were -5, 5, 15 and 25 ºC. The time loading for each test was 7200 seconds.

**TESTING RESULTS**

For each test, the values of the three controlled parameters are obtained periodically: temperature, displacement and load. From these parameters only load presents a variation over the time and it is the parameter used for the characterization of the relaxation behaviour of the mixtures. The temperature and deformation were kept constant during the test. The calculation of the bulk relaxation modulus and the shear relaxation modulus was obtained with the parameters measured in the test.

The representative curves of each observed modulus type were obtained and were used as a basis for the adjustment to the functions kernel, in the form of Prony series. The Prony series obtained must be representative of the viscoelastic behaviour of the studied mixtures.
In Figure 3 a representative graph of the curves obtained for each test (or for each sample) is presented, involving the asphalt rubber hot mix. In Figure 4 the same type of representation is presented for the conventional mixture.

**Figure 3 – Relaxation bulk modulus for AR-HMA mix**

**Figure 4 – Relaxation bulk modulus for conventional mix**
FITTING BEHAVIOUR CURVE

The adjustment of curves to the experimental results is made through the establishment of the Prony’s series constants (of Bulk and shear) and of the order of the series, which characterize the models of no-linear materials. These constants were established to guarantee the best approach to the experimental results. Three elements of the Prony series to represent the behavior of the studied mixtures were adopted.

Thus 17 parameters of the Prony-series were defined, seven related to the shear expression, \( G(t) \), seven related to the bulk expression, \( K(t) \), and three related to the WLF expression.

The Prony constants for a representative relaxation curve, relative to a reference temperature, \( T_r \), and associated to the function WLF parameters, were defined from the curves established for the four test temperatures, establishing a relaxation law which shows a temperature dependence (Table 1).

The obtained parameters constitute a behaviour data set of the studied mixtures which can be considered as input data for the numerical modelling of the overlays behaviour, under thermal loading conditions.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>AR-HMA</th>
<th>CM</th>
<th>Parameters</th>
<th>AR-HMA</th>
<th>CM</th>
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<td>1.38E+01</td>
<td>2.81E+01</td>
<td>( G_1 )</td>
<td>2.09E+02</td>
<td>2.89E+02</td>
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<td>( K_1 )</td>
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<td>7.85E+02</td>
<td>( G_2 )</td>
<td>4.13E+01</td>
<td>9.45E+01</td>
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<tr>
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<td>2.60E+02</td>
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<td>8.85E+00</td>
<td>1.13E+01</td>
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<td>2.39E+01</td>
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<tr>
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<tr>
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</table>

In Figure 5 the relaxation modulus curves for the asphalt rubber mix are presented, compared with the representative points of the laboratorial tests results in which the testing results and the developed models largely match.

CONCLUSIONS

The characterization of the relaxation modulus was made for an asphalt rubber mixture and for a conventional dense hot mixture, through a set of one cycle long duration load. The tests results were fitted in the kernel function of the generalized Maxwell elements, \( G(t) \) and \( K(t) \), representing the shear and bulk relaxation modulus, respectively. The kernel functions were represented in terms of Prony series resulting four relaxation modulus relationships for the considered temperatures.
The curves obtained were used as the basis for the definition of the Prony constants for a representative relaxation curve, relative to a temperature of reference and associated to the function WLF parameters. Thus, a relaxation law which shows temperature dependence can be established.

It was observed that, the asphalt rubber mixture shows a relaxation modulus less than the conventional mixture. The relaxation modulus in an asphalt rubber mixture, for a loading time of 7200 seconds and for a temperature of -5ºC, is 2 times less than the relaxation modulus of conventional mixtures. Thus, the residual thermal stresses in asphalt rubber mixtures at low temperatures are lesser than in conventional mixture.

REFERENCES
