

**SCIENCE, SOCIETY AND NEW TECHNOLOGIES SERIES**  
**RESEARCH FOR INNOVATIVE TRANSPORTS SET**



**Volume 5B**

# **Materials and Infrastructures 2**

**Edited by  
Jean-Michel Torrenti  
Francesca La Torre**

**ISTE**

**WILEY**

## Materials and Infrastructures 2

**Research for Innovative Transports Set**

coordinated by  
Bernard Jacob

Volume 5B

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Infrastructures 2**

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# Contents

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<b>Preface</b> . . . . .	xv
<b>Acknowledgments</b> . . . . .	xix
<b>Introduction</b> . . . . .	xxi
<b>Part 4. Recycling and Sustainability Issues</b> . . . . .	1
<b>Chapter 28. Introduction to European COREPASOL Project on Harmonizing Cold Recycling Pavement Techniques</b> . . . . .	3
Jan VALENTIN, Jan SUDA, Zuzana FORMANOVÁ, Konrad MOLLENHAUER, Michael ENGELS, Fátima BATISTA and Ciaran MCNALLY	
28.1. Introduction . . . . .	3
28.2. Background of European project COREPASOL . . . . .	4
28.2.1. Objectives of the project . . . . .	6
28.2.2. Present situation on cold recycling. . . . .	6
28.3. Methods of cold-recycled asphalt specimen compaction . . . . .	8
28.4. Experimental comparison of compaction methods . . . . .	10
28.4.1. Bulk density . . . . .	11
28.4.2. Indirect tensile strength . . . . .	13
28.4.3. Stiffness modulus . . . . .	14
28.5. Publication policy. . . . .	15
28.6. Acknowledgments . . . . .	16
28.7. Bibliography . . . . .	16

<b>Chapter 29. Technical Performance and Benefits of Recycling of Reclaimed Asphalt Containing Polymer-modified Binder in Premium Surface Layers</b> . . . . .	19
Greet LEEGWATER, Jozef KOMAČKA, Gang LIU, Erik NIELSEN and Eva REMIŠOVA	
29.1. Introduction . . . . .	19
29.2. State of the art on recycling of polymer modified asphalt (PMA) . . . . .	20
29.2.1. Focus and aim of literature review . . . . .	20
29.2.2. Extraction and recovery . . . . .	21
29.2.3. Laboratory mixing . . . . .	21
29.2.4. Experience with utilization of RA-containing PMB in full-scale production. . . . .	21
29.3. Materials. . . . .	22
29.3.1. RA containing polymer modification . . . . .	22
29.3.2. Binder extraction and virgin binders . . . . .	22
29.3.3. Asphalt mixes . . . . .	23
29.4. Properties of extracted and blended binders . . . . .	24
29.5. Performance of asphalt mixtures with RA containing polymer modified binder. . . . .	26
29.6. Microscopy investigations of RA and asphalt mixes containing RA . . . . .	29
29.7. Environmental and economic benefits . . . . .	30
29.8. Conclusions and recommendations . . . . .	31
29.9. Acknowledgments . . . . .	32
29.10. Bibliography. . . . .	32
<b>Chapter 30. Case Study: Increasing the Percentage of Recycled Asphalt</b> . . . . .	33
Marjan TUŠAR and Lidija AVSENIK	
30.1. Introduction . . . . .	33
30.2. Materials and test program . . . . .	34
30.2.1. Materials . . . . .	35
30.2.2. Test program . . . . .	37
30.3. Results and analysis . . . . .	38
30.4. Conclusions . . . . .	42
30.5. Bibliography . . . . .	43

<b>Chapter 31. Evaluation of Long-term Glass-grid Test Section using a Unique Method</b> . . . . .	45
Maciej MALISZEWSKI, Przemysław HARASIM, Dominika MALISZEWSKA and Adam ZOFKA	
31.1. Introduction . . . . .	46
31.1.1. General . . . . .	46
31.1.2. Geosynthetic . . . . .	47
31.1.3. Test section. . . . .	47
31.2. Methodology . . . . .	48
31.2.1. Theory and assumptions . . . . .	48
31.2.2. FWD measurement campaign. . . . .	50
31.2.3. Visual pavement description . . . . .	50
31.3. Analysis . . . . .	50
31.3.1. Presentation of deflection basin. . . . .	50
31.3.2. Comparison of maximum deflections . . . . .	50
31.3.3. Deflection basin indices . . . . .	52
31.3.4. Radius comparison . . . . .	53
31.3.5. Visual pavement description . . . . .	55
31.4. Conclusions and recommendations . . . . .	56
31.5. Bibliography . . . . .	57
<b>Chapter 32. Effect of Using of Reclaimed Asphalt and/or Lower Temperature Asphalt on the Availability of the Road Network</b> . . . . .	59
Cliff NICHOLLS, Matthew WAYMAN, Konrad MOLLENHAUER, Ciaran MCNALLY, Amir TABAKOVIĆ, Amanda GIBNEY, Aikaterini VARVERI, Sean CASSIDY, Rea SHAHMOHAMMADI and Kevin GILBERT	
32.1. Introduction . . . . .	59
32.2. Review of existing knowledge. . . . .	60
32.2.1. Relevant parameters for pavement service life . . . . .	60
32.2.2. Service life of low-temperature asphalt mixtures . . . . .	61
32.3. Trial site . . . . .	63
32.3.1. Need for full-size trials. . . . .	63
32.3.2. Mixture design. . . . .	64
32.3.3. Selection and construction of the test section. . . . .	65
32.3.4. Reclaimed asphalt feedback . . . . .	66
32.3.5. Testing . . . . .	68
32.4. Laboratory testing . . . . .	69
32.5. Assessment of lifecycle cost and carbon footprint . . . . .	71
32.5.1. Assessment on a lifecycle basis . . . . .	71
32.5.2. Formulation of the carbon footprint . . . . .	71

32.6. Conclusions . . . . .	72
32.7. Acknowledgments . . . . .	72
32.8. Bibliography . . . . .	72

### **Chapter 33. Brazilian Road Deterioration Test:**

<b>Final Report</b> . . . . .	75
Gustavo Garcia OTTO, Leto MOMM and Amir Mattar VALENTE	

33.1. Introduction . . . . .	75
33.2. Field analysis . . . . .	77
33.3. Pavement deterioration analysis . . . . .	78
33.3.1. Asphalt mechanical characteristics . . . . .	79
33.4. Analysis model . . . . .	81
33.5. Results . . . . .	82
33.5.1. Axle interaction simulation . . . . .	83
33.5.2. Real traffic composition interaction . . . . .	85
33.6. Conclusions . . . . .	86
33.7. Acknowledgments . . . . .	86
33.8. Bibliography . . . . .	87

### **Part 5. Railways and Inland Navigation** . . . . . 89

#### **Chapter 34. Application of Different Methods for Rehabilitation of Existing Transition Zones on Old Railway Lines.** . . . . . 91

Marko VAJDIĆ, Duo LIU, Stanislav LENART and  
Irina STIPANOVIĆ OSLAKOVIĆ

34.1. Introduction . . . . .	91
34.2. Transition zones . . . . .	92
34.2.1. Negative mechanisms that occur in the transition zones. . . . .	93
34.2.2. Role of transition zones . . . . .	93
34.3. Case study: transition zones at the “Buna” bridge . . . . .	94
34.3.1. Technical characteristics of the track section. . . . .	94
34.3.2. Traffic data . . . . .	95
34.3.3. Performed geotechnical and geophysical investigation works. . . . .	95
34.4. Modeling . . . . .	96
34.4.1. Calculations with Plaxis . . . . .	98
34.4.2. Interpretation of the results . . . . .	98
34.4.3. Final design: direction towards Zagreb . . . . .	99
34.4.4. Final design: direction towards Sisak . . . . .	100



34.5. Construction process . . . . .	100
34.6. Monitoring . . . . .	102
34.7. Conclusions . . . . .	103
34.8. Acknowledgments . . . . .	103
34.9. Bibliography . . . . .	103

**Chapter 35. CAPACITY4RAIL: Toward a Resilient, Innovative and High-capacity European Railway System for 2030/2050 . . . . . 105**

Laurent SCHMITT, Fabien LÉTOURNEAUX,  
Isabelle DE KEYZER and Paul CROMPTON

35.1. Introduction . . . . .	105
35.2. Project objectives . . . . .	106
35.3. Project approach . . . . .	109
35.3.1. Infrastructure . . . . .	109
35.3.2. New concepts for efficient freight systems . . . . .	110
35.3.3. Operations for enhanced capacity . . . . .	111
35.3.4. Advanced monitoring . . . . .	112
35.3.5. System assessment and migration to 2030/2050 . . . . .	112
35.4. Conclusions . . . . .	114
35.5. Acknowledgments . . . . .	114

**Chapter 36. Secondary Stiffness of Fastening Clips: Influence on the Behavior of the Railway Track Panel . . . . . 115**

Konstantinos GIANNAKOS

36.1. Introduction . . . . .	115
36.2. The railway track panel . . . . .	117
36.3. The system “railway track–railway vehicle” as an ensemble of springs and dashpots . . . . .	118
36.4. The static stiffness coefficient of the railway track in the vertical direction . . . . .	120
36.5. Compatibility of clip and pad . . . . .	122
36.6. Influence of pad stiffness on the stresses on ballast . . . . .	123
36.7. Requirements for the fastenings and pads due to their role in the track panel . . . . .	123
36.8. Secondary stiffness of the fastening clip and behavior of the track panel . . . . .	125
36.9. Conclusions . . . . .	127
36.10. Bibliography . . . . .	127

<b>Chapter 37. A New Asset Management Approach for Inland Waterways</b> . . . . .	131
Markus HOFFMANN, Katrin HASELBAUER, Alexander HABERL, Ronald BLAB, Markus SIMONER, Klaus DIEPLINGER and Thomas HARTL	
37.1. Overview waterway asset management . . . . .	131
37.2. Maintenance measures and fairway availability. . . . .	132
37.2.1. Fairway parameters and availability . . . . .	132
37.2.2. Measure overview with decision tree and impact . . . . .	134
37.2.3. Measure costs, impact and duration . . . . .	135
37.2.4. Optimization for continuous fairway parameters . . . . .	136
37.2.5. Measure program, priorities, budget and market capacity. . . . .	137
37.3. Fairway availability and transport costs . . . . .	138
37.3.1. Transport development, vessel types and fairway utilization . . . . .	138
37.3.2. Impact of fairway depth on utilization of loading capacity and transport costs. . . . .	139
37.3.3. Utilization-based transport costs and market competition. . . . .	139
37.3.4. Transport costs and fairway availability optimization. . . . .	140
37.4. Pilot implementation and first results. . . . .	141
37.5. Summary and outlook . . . . .	145
37.6. Bibliography . . . . .	145
 <b>Chapter 38. 3D Numerical Simulation of Convoy-generated Waves and Sediment Transport in Restricted Waterways</b> . . . . .	 147
Abdellatif OUAHSINE, Ji SHENGCHENG, Hassan SMAOUI, Philippe SERGENT and Nicolas HUYBRECHTS	
38.1. Introduction . . . . .	147
38.2. Numerical model and governing equations . . . . .	148
38.2.1. Free surface capturing . . . . .	149
38.3. Suspended sediment transport . . . . .	150
38.4. Boundary conditions. . . . .	151
38.5. Computational procedures and hydrodynamical model results. . . . .	152
38.6. Navigation influences on sediment transport . . . . .	154
38.7. Conclusions . . . . .	157
38.8. Bibliography . . . . .	157

<b>Part 6. Climate Resilient Roads</b> . . . . .	159
<b>Chapter 39. Potential Impact of Climate Change on Porous Asphalt with a Focus on Winter Damage</b> . . . . .	161
Kyle KWIATKOWSKI, Irina STIPANOVIC OSLAKOVIC, Andreas HARTMANN and Han TER MAAT	
39.1. Introduction . . . . .	161
39.1.1. Climate change and road national authorities. . . . .	162
39.1.2. Climate change adaptation and road infrastructure . . . . .	164
39.2. Porous asphalt . . . . .	164
39.2.1. PA background . . . . .	164
39.2.2. Historical behavior of PA in winter . . . . .	165
39.2.3. Temperature monitoring . . . . .	167
39.3. Modeling of climate change impact. . . . .	168
39.3.1. Infrastructure Planning Support System. . . . .	169
39.3.2. Climate modeling . . . . .	170
39.3.3. Modeling frost damage. . . . .	171
39.4. Conclusions . . . . .	173
39.5. Acknowledgments . . . . .	174
39.6. Bibliography . . . . .	174
<b>Chapter 40. Risk Assessment of Highway Flooding in the Netherlands</b> . . . . .	177
Dirk PEREBOOM, Kees VAN MUISWINKEL and Thomas BLES	
40.1. Introduction . . . . .	177
40.2. Background – climate change and the mission of Rijkswaterstaat. . . . .	178
40.3. Development of methods to investigate vulnerability and to assess risks related to climate change . . . . .	179
40.4. Summary of the “Blue spots” study . . . . .	179
40.4.1. Flooding due to failure of flood defenses . . . . .	181
40.4.2. Flooding by intense rain and changing groundwater levels . . . . .	181
40.4.3. Flooding by incapacity of storm water drainage and road surfaces . . . . .	181
40.5. Flooding events and their frequency of occurrence. . . . .	181
40.6. Consequences of flooding . . . . .	182
40.7. Scoring effects of events . . . . .	183
40.8. Analysis and interpretation . . . . .	184

40.9. Risk evaluation (RIMAROCC step 4) . . . . .	186
40.9.1. Results on availability, flooding events 1 and 4 . . . . .	187
40.9.2. Results on availability, flooding event 3: increase in groundwater levels due to climate change . . . . .	189
40.10. Conclusions . . . . .	189
40.11. Recommendations . . . . .	190
40.12. Implementation of results in the Netherlands and other European countries . . . . .	191
40.13. Acknowledgments . . . . .	191
40.14. Bibliography. . . . .	192

**Chapter 41. Adaptation of the Road Infrastructure to Climate Change** . . . . . 193

Markus AUERBACH and Carina HERRMANN

41.1. Introduction . . . . .	193
41.2. Strategies of adaptation to climate change . . . . .	194
41.2.1. The German adaptation strategy . . . . .	194
41.2.2. The strategy of the Federal Highway Research Institute. . . . .	195
41.3. The AdSVIS projects . . . . .	198
41.3.1. The RIVA project . . . . .	198
41.3.2. Comparison of meteorological parameters and grid data of climatologic prediction models . . . . .	199
41.3.3. Cross-linking of the AdSVIS projects . . . . .	199
41.3.4. AdSVIS server. . . . .	199
41.3.5. Development of climate impact models and design parameters for bridges and tunnels . . . . .	199
41.3.6. Vulnerability analysis for bridges and tunnels . . . . .	200
41.3.7. Analysis of measures to reduce the vulnerability of bridge and tunnel structures . . . . .	200
41.3.8. Development of a model for estimating landslide risk areas and development of a national hazard map . . . . .	200
41.3.9. Evaluation of the design of road drainage systems regarding climate change . . . . .	200
41.3.10. Inventory of road drainage systems in selected sections of the TEN-T. . . . .	201
41.3.11. Adaptation of pavement design for asphalt and concrete constructions . . . . .	201
41.3.12. Standardized asphalt pavements due to changing temperature boundary conditions . . . . .	201
41.3.13. Asphalt pavements and extreme temperatures . . . . .	202

41.3.14. Impacts of weather extremes on concrete road pavements . . . . .	202
41.3.15. Impacts of climate change on road maintenance . . . . .	202
41.4. International cooperation . . . . .	202
41.4.1. Forever open road . . . . .	203
41.4.2. CEDR call 2012 . . . . .	204
41.5. Conclusions . . . . .	204
41.6. Bibliography . . . . .	205

## **Chapter 42. The Impacts of Climate Change on Pavement Maintenance in Queensland, Australia . . . . . 207**

Gary CHAI, Rudi VAN STADEN, Hong GUAN,  
Greg KELLY and Sanaul CHOWDHURY

42.1. Introduction . . . . .	207
42.2. Climate change trends in Australia . . . . .	209
42.2.1. Temperature . . . . .	209
42.2.2. Precipitation . . . . .	210
42.3. HDM-III road deterioration model . . . . .	210
42.4. Thornthwaite moisture index . . . . .	213
42.5. Road environment and climate data of the study area . . . . .	215
42.6. Economic impacts on pavement maintenance . . . . .	216
42.7. Conclusions . . . . .	219
42.8. Acknowledgments . . . . .	220
42.9. Bibliography . . . . .	220

## **Chapter 43. Design Guideline for a Climate Projection Data Base and Specific Climate Indices for Roads: CliPDaR . . . . . 223**

Christoph MATULLA, Joachim NAMYSLO, Konrad ANDRE,  
Barbara CHIMANI and Tobias FUCHS

43.1. Introduction . . . . .	223
43.2. Data and methods . . . . .	224
43.2.1. Data . . . . .	224
43.2.2. Methods . . . . .	225
43.3. The ensemble approach . . . . .	228
43.4. Results and discussion . . . . .	230
43.4.1. General comments . . . . .	230
43.4.2. Distinct zero temperature crossings (freezing-thaw crossings) . . . . .	231
43.4.3. Precipitation totals above 30 mm . . . . .	232
43.4.4. Temperature indices isolating meteorological phenomena causing rutting . . . . .	234

43.5. Conclusions . . . . .	235
43.5.1. Outlook . . . . .	235
43.6. Acknowledgments . . . . .	236
43.7. Bibliography . . . . .	236
<b>List of Authors . . . . .</b>	<b>237</b>
<b>Index . . . . .</b>	<b>249</b>
<b>Contents for Volume 5A. . . . .</b>	<b>251</b>

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## Preface

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The transport sector is very much concerned about environmental adaptation and mitigation issues. Most of these are related to the objective of curbing GHG emission by 20% by 2020, alternative energy and energy savings, sustainable mobility and infrastructures, safety and security, etc. These objectives require the implementation of advanced research works, to develop new policies, and to adjust education and industrial innovations.

The theme and slogan of the Transport Research Arena held in Paris (TRA2014) were respectively: “Transport Solutions: From Research to Deployment” and “Innovate Mobility, Mobilise Innovation”. Top researchers and engineers, as well as private and public policy and decision-makers, were mobilized to identify and take the relevant steps to implement innovative solutions in transport. All surface modes were included, including walking and cycling, as well as cross modal aspects.

Policies, technologies and behaviors must be continually adapted to new constraints, such as climate change, the diminishing supply of fossil fuels, the economic crisis, the increased demand for mobility, safety and security, i.e. all the societal issues of the 21<sup>st</sup> Century. Transport infrastructures and materials, modal share, co-modality, urban planning, public transportation and mobility, safety and security, freight, logistics, ITS, energy and environment issues are the subject of extensive studies, research works and industrial innovations that are reported in this series of books.

This book is part of a set of six books called the *Research for Innovative Transports* set. This collection presents an update of the latest academic and applied research, case studies, best practices and user perspectives on transport carried out in Europe and worldwide. The presentations made during TRA2014 reflect on them. The TRAs are supported by the European Commission (DG-MOVE and DG-RTD), the Conference of European Road Directors (CEDR), and the modal European

platforms, ERRAC (rail), ERTRAC (road), WATERBORNE, and ALICE (freight), and also by the European Construction Technology Platform (ECTP) and the European Transport Research Alliance (ETRA).

The volumes are made up of a selection of the best papers presented at TRA2014. All papers were peer reviewed before being accepted at the conference, and were then selected by the editors for the purpose of the present collection. Each volume contains complementary academic and applied inputs provided by highly qualified researchers, experts and professionals from all around the world.

Each volume of the series covers a strategic theme of TRA2014.

Volume 1, *Energy and Environment*, presents recent research works around the triptych “transport, energy and environment” that demonstrate that vehicle technologies and fuels can still improve, but it is necessary to prepare their implementation (electro-mobility), think about new services and involve enterprises. Mitigation strategies and policies are examined under different prospective scenarios, to develop and promote alternative fuels and technologies, multi-modality and services, and optimized transport chains whilst preserving climate and the environment. Evaluation and certification methodologies are key elements for assessing air pollution, noise and vibration from road, rail and maritime transports and their impacts on the environment. Different depollution technologies and mitigation strategies are also presented.

Volume 2, *Towards Innovative Freight and Logistics*, analyzes how to optimize freight movements and logistics, introduces new vehicle concepts, points out the governance and organization issues, and proposes an assessment framework.

Volumes 3 and 4 are complementary books covering the topic of traffic management and safety.

Volume 3, *Traffic Management*, starts with a survey of data collection processes and policies and then shows how traffic modeling and simulation may resolve major problems. Traffic management, monitoring and routing tools and experience are reported and the role of traffic information is highlighted. Impact assessments are presented.

Volume 4, *Traffic Safety*, describes the main road safety policies, accident analysis and modeling. Special focus is placed on the safety of vulnerable road users. The roles of infrastructure and ITS on safety are analyzed. Finally railway safety is focused upon.



Volume 5, *Materials and Infrastructures*, split into two sub-volumes, investigating geotechnical issues, and pavement materials' characterization, innovative materials, technologies and processes, and introducing new techniques and approaches for auscultation and monitoring. Solutions to increase the durability of infrastructures and to improve maintenance and repair are shown, for recycling as well as for ensuring the sustainability of the infrastructures. Specific railways and inland navigation issues are addressed. A focus is put on climate resilient roads.

Volume 6, *Urban Mobility and Public Transport*, highlights possible innovations in order to improve transports and the quality of life in urban areas. Buses and two-wheelers could be a viable alternative in cities if they are safe and reliable. New methodologies are needed to assess urban mobility through new survey protocols, a better knowledge of user behavior or taking into account the value of travel for public transport. The interactions between urban transport and land planning are a key issue. However, these interactions have to be better assessed in order to propose scenarios for new policies.

Bernard JACOB, Chair of the TRA2014 Programme Committee

Jean-Bernard KOVARIK, Chair of the TRA2014 Management Committee  
March 2016

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The French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR) is acknowledged for having organized the TRA2014, in which 600 high-quality papers were presented, successfully.

Anne Beeldens, Pierre Marchal, Manuel Pereira, and Jon Krokeborg; coordinators of the topic on Materials and Infrastructure; all the other members of the Programme Committee; the reviewers who actively contributed to review and select the papers; and the authors who wrote them are acknowledged for their great job that produced the material for this volume.

Joëlle Labarrère, secretary of the Programme Committee of TRA2014, is acknowledged for her valuable help to the editors and for her support to prepare this volume.

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### **Bernard Jacob**

Bernard Jacob, chair of the Programme Committee of TRA2014, is deputy scientific director for transport, infrastructures and safety with IFSTTAR. His research works are in bridge and road safety, traffic loads on bridges, heavy vehicles and weigh-in-motion. He has coordinated a number of European and International research projects. He is an active member in several scientific and technical committees (OECD/ITF, PIARC, TRB, etc.) and provided expertise to the European Commission. He is professor at Ecole Nationale des Travaux Publics de l’Etat and the president of the International Society for WIM (ISWIM). He has published more than 100 scientific papers and edited 10 published volumes of international projects and conference proceedings.

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# Introduction

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The infrastructures of the future will have to be sustainable, seamless, resilient and durable, will respect the principles of circular economy and will have to be easy to monitor and manage. New technologies are currently available or under development to reduce the carbon footprint of infrastructures and to increase the overall sustainability and recyclability of transport while maintaining the utility and value of the infrastructures. However, the impact of these new solutions will only be effective once these are thoroughly disseminated and extensively deployed.

This volume presents a series of the most promising solutions and aims at disseminating them to improve the performances and efficiency of materials and infrastructures, through a choice of updated papers from the TRA2014 Conference. Selection is primarily based on a quality criterion, also taking into account the geographical diversity of papers in order to restore the originality and richness of current research.

## **I.1. Main findings**

The papers contained in this volume demonstrate how technological solutions and new design and management methodologies can be implemented in different surface transport modes (roads, railways and waterways) to increase transport sustainability by improving infrastructures design, maintenance, recyclability and management. Both theoretical research and practical case studies explore topics such as characterization of pavements, bridges and soils, use of recycled and warm mix asphalts as well as high-performance materials to increase durability or to reduce the noise impact.

New management techniques for improving infrastructure resilience both roads and railways is a very timely topic that has been selected by the European Commission and the U.S. Department of Transportation as the subject of further Euro-American cooperation. This topic is extensively covered in this volume for a number of different transport modes.

Road infrastructures are typically “low technology” structures but timely, cost-effective and seamless monitoring is essential for the implementation of effective maintenance and management concepts. New solutions for pavement and soil characterization are being developed by implementing seamless technologies. These range from well-established techniques, such as ground penetrating radars (GPR) and weigh-in-motion (WIM) techniques, to innovative radar remote sensing techniques.

The development of new pavement materials is always a key topic for road and airport engineers and the implementation of recycled materials and warm mix asphalt will be the standard solution of the future. However, there is still a strong need for understanding the long-term performance of these materials *in situ* and for developing performance models that the designers can implement for adopting these technologies. This volume will help the designers and road managers interested in implementing these solutions and presents different case studies that will make the potential users feel more confident.

It is interesting to observe that infrastructure performances often conflict and therefore solutions such as porous asphalt, that can be very effective for noise reduction, is more sensitive to climatic changes due to the effect of freeze-thaw cycles.

Durability and maintenance are core issues for road researchers with the final aim in mind that the road of the future will have to be “Forever Open”. However, local authorities are often faced with the issue of effective day to day maintenance. Infrastructure research too often focuses on highly trafficked motorways or primary road networks; therefore, it is extremely important that a research effort be specifically devoted to develop guidelines for the maintenance and repair of low volume roads, which represent a large portion of the whole road networks.

Railway and road infrastructures issues are usually tackled as separate but the recent work conducted by the joint roadmap for cross-modal transport infrastructure innovation toward a performing infrastructure has recently shown that a number of infrastructure research issues are cross-modal and therefore lessons can be learned across modes. This is clearly shown in this volume in which resilience to climatic changes covers both roads and railways and integrated modes are needed to achieve a truly resilient transport system.

This volume will be of interest not only for the research community and in higher education but also for professionals in the area of infrastructure design and management as well as economic and institutional decision makers. They will find state-of-the-art studies of key research issues, new advanced methods and illustrative case studies.

Volume 5 of the *Research for Innovative Transports* set is divided into two sub-volumes containing three parts each: five parts focus on roads but cover potentially cross-modal topics dealing with materials for infrastructures, auscultation and monitoring, durability and maintenance repair, recycling and sustainability issues and climate resilient roads. One part is specifically devoted to railways and inland navigation.

Sub-volume 1 contains parts 1–3. Part 1 deals with geotechnical issues and pavement materials' characterization. In this part researchers and practitioners can find new test methods and materials characterization techniques for non-conventional materials including recycled asphalt mixtures, warm mix asphalts but also fiber reinforced concrete materials.

Part 2 presents novel and high-tech solutions to monitor and assess pavement conditions to assist road authorities in this key management activity. These techniques include 3D mapping, remote sensing, GPR evaluation of pavement structural capacity and WIM monitoring solutions. The reader will also find a highly specialized study on integrating the electrical supply cables for public transport, for creating an electromagnetic induction field, in a prefabricated concrete slab.

Part 3 deals with the key road management issues of durability and maintenance repair. The recurrent theme of noise reduction has been tackled and designers and road authorities will be able to consider and compare the effectiveness of different solutions including non-conventional materials. Attention is also paid to noise issues in non-conventional analysis locations as level intersections in urban and rural areas. A very important issue for road managers is pothole repair. The guidelines developed in the POTHOLE project will be extremely helpful for local authorities looking for effective maintenance solutions.

Sub-volume 2 contains parts 4–6. Part 4 addresses recycling and sustainability issues, presenting case studies and full-scale tests. Asphalt recycling is a core issue for reducing the carbon footprint of transportation infrastructure. Road administrations and designers will find a very interesting overview of three transnational research projects on this topic as well as a case study from Slovenia.

Part 5 analyzes railways and inland navigation issues. New concepts for low maintenance and resilient infrastructure as well as optimizing operation and

intermodal integration within the global transport system are proposed for technicians dealing with resilient infrastructure in any transport mode. Highly specialized railway experts will find studies on clip stiffness and on new innovative solutions for transition zones between the “normal” open tracks and “rigid” track sections. Waterways researchers will find an interesting new management approach to deal with suspended sediments.

Part 6 focuses on a key infrastructure issue of the future: resilience to extreme climatic conditions. Input from three continents (Australia, Europe and North America) highlight that this global issue needs trans-national solutions. An interesting overview of two transnational projects (RIMAROCC and SWAMP) introduces the topic followed by specific solutions adopted by single countries. The effect of climatic changes on pavements is assessed to answer questions of specialized pavement engineers.

## **I.2. Conclusions**

This volume provides an insight on research, best practices and transport policies with a focus on state-of-the-art advances in the fields of infrastructures and materials. The progress made in the implementation of new materials in pavement design as well as the evolution in the process of data collection and assessment, modeling and management, assisting academics, transport professionals, practitioners and decision makers to a better understanding of the current and future trends are demonstrated.

Future infrastructure monitoring techniques will be seamless, and this volume shows that there is a significant shift of the research world in this direction. These solutions now need to become current practices to really improve the transport system.

Reducing the infrastructure carbon footprint and increasing its resilience is possible but road managers and designers need to have design and management tools as well as case studies that will allow them to gain more confidence in the adoption of new and less impacting solutions.