

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



Volume 5A

Materials and Infrastructures 1

Edited by

Jean-Michel Torrenti

Francesca La Torre

ISTE

WILEY

Materials and Infrastructures 1

Research for Innovative Transports Set

coordinated by
Bernard Jacob

Volume 5A

**Materials and
Infrastructures 1**

Edited by
Jean-Michel Torrenti
Francesca La Torre

ISTE

WILEY

First published 2016 in Great Britain and the United States by ISTE Ltd and John Wiley & Sons, Inc.

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the Copyright, Designs and Patents Act 1988, this publication may only be reproduced, stored or transmitted, in any form or by any means, with the prior permission in writing of the publishers, or in the case of reprographic reproduction in accordance with the terms and licenses issued by the CLA. Enquiries concerning reproduction outside these terms should be sent to the publishers at the undermentioned address:

ISTE Ltd
27-37 St George's Road
London SW19 4EU
UK

www.iste.co.uk

John Wiley & Sons, Inc.
111 River Street
Hoboken, NJ 07030
USA

www.wiley.com

© ISTE Ltd 2016

The rights of Jean-Michel Torrenti and Francesca La Torre to be identified as the authors of this work have been asserted by them in accordance with the Copyright, Designs and Patents Act 1988.

Library of Congress Control Number: 2016939896

British Library Cataloguing-in-Publication Data

A CIP record for this book is available from the British Library

ISBN 978-1-78630-029-4

Contents

Preface	xix
Acknowledgments	xxiii
Introduction	xxv
Part 1. Materials for Infrastructures	1
Chapter 1. Use of an Ultra-wide Band Radar to Detect Slope Movements Along Transport Infrastructures	3
Jean-Pierre MAGNAN, Jean-Paul DURANTHON, Patrick JOFFRIN, François DEPARDON, Dominique ALLAGNAT, François LEMAÎTRE, Philippe ÉVENAT, Philippe LE STER	
1.1. Introduction	3
1.2. Development of transportable ultra wide-band radar	6
1.3. Conclusion	9
1.4. Acknowledgments	9
1.5. Bibliography	9
Chapter 2. Intelligent Compaction Technology for Geomaterials: A Demonstration Project	11
António GOMES CORREIA, Manuel PARENTE	
2.1. Introduction	11
2.2. Demonstration project	12
2.2.1. Materials	13
2.2.2. Equipment	13

2.2.3. Foundation evaluation and layer construction	14
2.2.4. Results and discussion	16
2.2.5. Soil-rockfill layers	16
2.2.6. Soil layer	21
2.3. Conclusion	23
2.4. Acknowledgments	23
2.5. Bibliography	24

Chapter 3. Geotechnical Challenges Related to Transport Infrastructures on Sensitive Soft Clay Deposits

Vikas THAKUR, Bjorn Kristoffer DOLVA

3.1. Nomenclature	27
3.2. Introduction	28
3.3. Challenges related to the characterization of sensitive clays	29
3.3.1. Sample disturbance	31
3.2.2. Strength anisotropy	33
3.3.3. Strain anisotropy	34
3.4. Challenges related to the assessment of safety margins	35
3.5. Post-failure assessment	37
3.6. Conclusion	40
3.7. Acknowledgments	40
3.8. Bibliography	40

Chapter 4. Performance Control of Bituminous Mixtures with a High RAP Content

Frédéric DELFOSSE, Ivan DROUADAINÉ,

Stéphane FAUCON DUMONT and Sabine LARGEAUD

4.1. Introduction	43
4.2. Impact of the high RAP content in the bituminous mixtures	44
4.3. Normative context	45
4.4. Development of a system to measure the blending degree of the RAP.	47
4.5. Impact of the RAP content on the mechanical properties of the recovered binder	49
4.6. Correlation between laboratory and jobsite production	52
4.7. Rheological model.	53
4.8. Conclusion	56
4.9. Bibliography	56

Chapter 5. Integration of Materials Science-based Performance Models into PMS	59
Altred WENINGER-VYUDIL, Michael WISTUBA, Goran MLADENOVIC, Johan LITZKA, Axel WALTHER and Alexander ALISOV	
5.1. Introduction.	59
5.2. Approach	61
5.3. Integration of material-based performance functions into PMS	61
5.3.1. Background for holistic PMS development	61
5.3.2. Laboratory testing and structural modeling I.	63
5.3.3. Laboratory testing and structural modeling II	65
5.4. Demonstration case studies	68
5.5. Conclusion	71
5.6. Bibliography	72
Chapter 6. Decision Aid Model for Asphalt Mixture Choice	75
Nicolas BUECHE and André-Gilles DUMONT	
6.1. Background and objectives	75
6.2. Model architecture.	76
6.2.1. Lifecycle inventory and performance indicators (model part 1)	76
6.2.2. Global evaluation (model part 2).	79
6.3. Model implementation and results	81
6.3.1. Problem description and method.	81
6.3.2. Results summary	82
6.4. Conclusions and perspectives	85
6.5. Bibliography	85
Chapter 7. Experimental Study of Binder–Filler Interaction Using the Modified Multiple Stress–Strain Creep Recovery Test	87
Mahmoud ELNASRI, Nick THOM and Gordon AIREY	
7.1. Introduction.	87
7.2. Experimental program	89
7.2.1. Materials	89
7.2.2. DSR machines.	90
7.2.3. Sample preparation	91
7.3. The development of multiple stress–strain creep recovery test	91

7.4. Results and discussion	93
7.4.1. Stiffening effect	94
7.4.2. Recovery property	96
7.5. Discussion and conclusions	98
7.6. Bibliography	99

Chapter 8. Reliability of New Shear Design Equations for FRP-strengthened Concrete

Bridge Girders	101
Ayman M. OKEIL, Abdeldjelil BELARBI and Daniel A. KUCHMA	
8.1. Nomenclature	101
8.2. Introduction.	102
8.3. Shear strengthening using composites	104
8.3.1. Design of FRP-strengthened concrete beams	104
8.3.2. Effective FRP strain, ε_{fe}	105
8.4. Reliability study	106
8.4.1. Design space.	107
8.4.2. Design parameters as random variables.	108
8.4.3. Reliability formulation and analysis.	109
8.5. Results and discussion	110
8.6. Conclusions.	112
8.7. Acknowledgments.	112
8.8. Bibliography	112

Chapter 9. Experimental Investigation and Modeling of the Bond between Aramid Fiber-reinforced Polymer Bars and Concrete

Fiber-reinforced Polymer Bars and Concrete	115
Arnaud ROLLAND, Sylvain CHATAIGNER, Karim BENZARTI, Marc QUIERTANT, Pierre ARGOUËL and Jean-Marc PAUL	
9.1. Introduction.	115
9.2. Material properties at ambient temperature	116
9.2.1. Microscopic observations	116
9.2.2. Tensile tests	117
9.2.3. Glass transition temperature	118
9.2.4. Thermal expansion	118
9.3. Bond tests.	119
9.3.1. Geometry and preparation of the pull-out specimens	120
9.3.2. Test procedure.	120
9.4. Results.	121
9.5. Modeling	123
9.5.1. Analytical law	123

9.5.2. Parameter identification method	124
9.5.3. Results	125
9.6. Conclusions.	126
9.7. Acknowledgments	127
9.8. Bibliography	127
Chapter 10. Innovative Use of FRP for Sustainable Precast Concrete Structures	129
Sami RIZKALLA	
10.1. Introduction	129
10.2. Double-tees	130
10.3. Precast concrete wall panels	133
10.3.1. Fully composite sandwich wall panels.	133
10.3.2. Non-composite sandwich wall panels	134
10.4. Architectural cladding.	136
10.5. Precast concrete piles (CFFT)	136
10.6. Bridge girders.	139
10.7. Future opportunities	140
10.8. Conclusions	141
10.9. Acknowledgments	142
10.10. Bibliography.	142
Part 2. Auscultation and Monitoring	145
Chapter 11. 3D Extraction of the Relief of Road Surface through Image Analysis.	147
Majdi KHOUDEIR and Benjamin BRINGIER	
11.1. Introduction	147
11.2. Photometric models	148
11.2.1. Lambert’s model	148
11.2.2. Phong model	149
11.2.3. Blinn–Phong model.	150
11.2.4. Mixed model	150
11.3. Extraction of gradient field.	151
11.3.1. The suggested global approach	151
11.3.2. Gradient extraction based on the Lambertian model	151
11.3.3. Gradient field of specular area	153
11.4. Relief extraction	154
11.4.1. Limits of the classical approach	154
11.4.2. Results of the suggested approach	155
11.5. Conclusion and perspectives	157
11.6. Bibliography	157

Chapter 12. Measurement Error Models (MEMs) Regression Method to Harmonize Friction Values from Different Skid Testing Devices	159
Azzurra EVANGELISTI, Samer W. KATICHA, Edgar DE LEÓN IZEPPi, Gerardo W. FLINTSCH, Mauro D'APUZZO and Vittorio NICOLosi	
12.1. Introduction	159
12.2. Objective	161
12.3. MEM: background and modeling	161
12.3.1. MEM modeling for pavement friction applications	162
12.4. Data collection	165
12.5. Results and analysis	166
12.5.1. Repeatability evaluation	166
12.5.2. Relationship between two of the same measuring principles devices	166
12.5.3. Relationship between two different measuring principles devices	168
12.6. Conclusion	171
12.7. Acknowledgments	172
12.8. Bibliography	172
 Chapter 13. Accurate and Up-to-Date Evaluation of Extreme Load Effects for Bridge Assessment	 175
Xiaoyi ZHOU, Franziska SCHMIDT, François TOUTLEMONDE and Bernard JACOB	
13.1. Introduction	175
13.2. WIM data files	178
13.3. Extrapolated values for the considered WIM data	181
13.4. Conclusion	182
13.5. Acknowledgments	183
13.6. Bibliography	183
 Chapter 14. Transportation Infrastructure Monitoring Using Satellite Remote Sensing	 185
Edward HOPPE, Brian BRUCKNO, Elizabeth CAMPBELL, Scott ACTON, Andrea VACCARI, Michael STUECHELI, Adrian BOHANE, Giacomo FALORNI and Jessica MORGAN	
14.1. Introduction	185
14.2. Purpose and scope	187
14.3. Methodology	187
14.3.1. Selection of processing algorithm	187

14.3.2. Selection of satellite system	187
14.3.3. Selection of area of interest	188
14.4. Results	188
14.4.1. Data	188
14.4.2. Scatterer density and distribution	189
14.4.3. Sinkhole detection	190
14.4.4. Rock slope monitoring	193
14.4.5. Bridge monitoring	194
14.4.6. Pavement monitoring	194
14.7. Discussion	196
14.8. Conclusions	197
14.9. Acknowledgments	197
14.10. Disclaimer	198
14.11. Bibliography	198

**Chapter 15. Monitoring of Scour Critical
Bridges using Changes in the Natural
Frequency of Vibration of Foundation Piles:
A Preliminary Investigation**

199

Luke J. PRENDERGAST and Kenneth GAVIN

15.1. Nomenclature	199
15.2. Introduction	200
15.3. Scour monitoring using fixed instruments	201
15.4. Scour monitoring using structural response measurement	203
15.5. Field investigation at UCD dense sand test site	204
15.5.1. Field test	204
15.5.2. Numerical modeling	205
15.6. Results and conclusions	207
15.7. Acknowledgments	208
15.8. Bibliography	208

**Chapter 16. Evaluation of Multilayer
Pavement Viscoelastic Properties from
Falling Weight Deflectometer using Neural Networks**

211

José Manuel GONZALEZ, Josep Maria CARBONELL and

Wouter VAN BIJSTERVELD

16.1. Nomenclature	211
16.2. Introduction	212
16.3. Methodology	213
16.3.1. Backcalculation process	213
16.3.2. Constitutive model	214
16.3.3. Development of an artificial neural network	215

16.4. Calibration process	216
16.4.1. Input data: load function and deflection curves	216
16.4.2. Numerical simulation of the FWD problem	218
16.4.3. Calibration process results	220
16.5. Backcalculation process: artificial neural network	222
16.6. Conclusions	223
16.7. Acknowledgments	224
16.8. Bibliography	224

Chapter 17. Accuracy of Ground-penetrating Radar in Pavement Thickness Evaluation: Impact of Interpretation Errors

227

Anne LALAGÜE, Matthew A. LEBENS and Inge HOFF

17.1. Introduction	227
17.1.1. Context	227
17.1.2. Research objective	228
17.2. Ground-penetrating radar technology	228
17.2.1. Measuring principle	228
17.2.2. GPR systems	229
17.3. Data collection and interpretation	230
17.3.1. GPR measurements	230
17.3.2. Soil sample collection	231
17.3.3. Calibration	231
17.3.4. Data interpretation	232
17.4. Results	233
17.4.1. Hot mix asphalt layer	233
17.4.2. Base layer	235
17.5. Discussion and conclusion	236
17.6. Bibliography	237

Chapter 18. Full-scale Test on Prefabricated Slabs for Electrical Supply by Induction of Urban Transport Systems

239

Mai-Lan NGUYEN, Pierre HORNYCH,

Jean-Pierre KERZRHÉHO and Sergio PEREZ

18.1. Introduction	239
18.2. Design of the full-scale test	241
18.3. Construction of the full-scale test and solution for installation of the prefabricated slabs	243
18.3.1. Procedure for installation of the slabs A, B, C and D	243
18.3.2. Procedure for installation of slab E	245

18.4. Test conditions and parameters measured during the test	245
18.4.1. Test conditions.	245
18.4.2. Parameters measured during the test	246
18.5. First results and interpretation	247
18.5.1. Deflections of concrete slab pavement measured at joints	247
18.5.2. Vertical subgrade strains under the prefabricated slabs	249
18.5.3. Horizontal strains at the bottom of the prefabricated slab	250
18.6. Conclusions and perspectives	251
18.7. Bibliography	252
Part 3. Durability and Maintenance Repair	253
Chapter 19. The Poroelastic Road Surface (PERS): Is the 10 dB Reducing Pavement within Reach?	255
Luc GOUBERT, Hans BENDTSEN, Anneleen BERGIERS, Björn KALMAN and Darko KOKOT	
19.1. Introduction	255
19.2. The PERSUADE project	257
19.3. Mix design	258
19.4. Safety issues	260
19.5. Cost–benefit analysis	261
19.6. Test tracks on the road	262
19.6.1. Test tracks in Denmark.	262
19.6.2. Test tracks in Belgium	265
19.6.3. Test tracks in Slovenia	266
19.7. Conclusions	267
19.8. Acknowledgments	267
19.9. Bibliography	267
Chapter 20. Modeling Subjective Condition Data of Asphalt Surfaced Urban Pavements	269
Rayya HASSAN, Oliver LIN and Amutha THANANJEYAN	
20.1. Introduction	269
20.2. Regression and Markov chain modeling	270
20.3. Data description and preparation	271
20.3.1. Calculation of SIR	272
20.4. Modeling using deterministic regression analysis	273

20.5. Modeling surfacing deterioration using Markov chains	274
20.5.1. Number of states	274
20.5.2. State vector	275
20.5.3. Stage or duty cycle definition	276
20.5.4. The transition probability matrix	276
20.6. Markov models for sample AC network	279
20.6.1. Validation of Markov models	281
20.6.2. Markov models using initial vector and average condition values	281
20.7. Comparison of models	283
20.8. Conclusions	284
20.9. Acknowledgments	284
20.10. Bibliography	284

Chapter 21. Modeling of Aging of

Low-noise Road Surfaces 287

Gijsjan VAN BLOKLAND, Ronald VAN LOON
and Christiaan TOLLENAAR

21.1. Introduction	287
21.2. Noise reduction over time	289
21.3. Mechanisms of noise reducing surfaces	292
21.4. Deterioration process	294
21.5. Parameters	295
21.6. Discussion	297
21.7. Acknowledgments	299
21.8. Bibliography	299

Chapter 22. Evaluation of Load-carrying Capacity of Asphalt Superstructures from Deflection Measurements 301

J. Stefan BALD and Anh-Duc NGUYEN

22.1. Nomenclature	301
22.2. Introduction	302
22.3. Theoretical analysis	303
22.3.1. Implementation of plate theory for determining deflection at surface of an asphalt structure	303
22.3.2. Interpretation the load behavior of asphalt pavement slab as load distributing layer of superstructure	306
22.3.3. Back-calculation for evaluating FWD data of asphalt structure using regression method	309

22.4. Validation of theoretical analysis	310
22.4.1. Experimental data	310
22.4.2. Verification of the regressive back-calculated mechanical parameters	312
22.5. Conclusion and recommendation	314
22.6. Bibliography	315

Chapter 23. Durable Pothole Repairs 317

Cliff NICHOLLS, Kathrin KUBANEK,
Carsten KARCHER, Andreas HARTMANN,
Adewole ADESIYUN, Aleksander IPAVEC,
Jozef KOMAČKA and Erik NIELSEN

23.1. Introduction	317
23.2. Definition of the term “pothole”.	318
23.3. Tests and evaluation methods for use in the laboratory and <i>in situ</i>	319
23.4. Existing standards, techniques, materials and experience with them on the European market.	320
23.5. Experience from trial sections	322
23.6. Laboratory tests	325
23.6.1. Materials tested	325
23.6.2. Cold asphalts.	325
23.6.3. Analysis of results.	327
23.6.4. Synthetic binders	328
23.7. Whole lifecycle costs and benefits	329
23.8. Conclusions	331
23.9. Acknowledgments	332
23.10. Bibliography.	332

Chapter 24. Application of Multicriteria Assessment for the Selection of At-grade Intersections 335

Jan HRADIL, Michal UHLÍK and Petr SLABÝ

24.1. Introduction.	335
24.2. MCA application in the choice of at-grade intersections.	336
24.2.1. MCA fundamentals	336
24.2.2. MCA alternatives	337
24.2.3. Decision tree	338
24.2.4. Evaluated criteria in MCA.	339
24.2.5. Weight of criteria	341

24.3. Selected intersection and its alternative design	342
24.3.1. Existing state	342
24.3.2. Design of layout alternatives and their MCA evaluation	344
24.3.3. Evaluation of the MCA analysis results	346
24.4. Conclusion	346
24.5. Acknowledgments	347
24.6. Bibliography	347

Chapter 25. Low-energy and Environmentally-friendly Solutions for Road Maintenance. 349

Bernard ECKMANN, Frédéric DELFOSSE,
Philippe POILANE and Bruno TAILLIS

25.1. Introduction	349
25.2. Flexible bituminous mixtures for the maintenance of flexible low traffic roads	350
25.2.1. The specific needs of maintenance on low traffic roads	350
25.2.2. Wearing course mixes	351
25.2.3. Re-profiling works	353
25.2.4. Small repair works	353
25.3. Emulsion-based cold bituminous mixtures.	354
25.3.1. Specific problems raised by emulsion-based mixes to be used in wearing courses	354
25.3.2. Development of emulsion-based wearing course mixes	355
25.3.3. Experimental trial sections.	356
25.3.4. Experimental trials: what they told us	360
25.4. Conclusion	361
25.5. Bibliography	362

Chapter 26. 3D Longitudinal and Transverse Cracking and the Influence of Non-Uniform Contact Pressure on the Stress Intensity Factors of these Cracks. 365

Dermot B. CASEY, James R. GRENFELL and Gordon AIREY

26.1. Introduction	365
26.2. Objectives	367
26.3. Methodology	367
26.3.1. Mesh setup	367
26.3.2. Loading scenarios	369
26.3.3. Stress intensity factor calculations	370
26.4. Results and discussion.	371
26.4.1. Longitudinal crack	371
26.4.2. Transverse crack.	373

26.5. Conclusions	376
26.6. Acknowledgments	377
26.7. Bibliography	377

Chapter 27. Selecting a Road Network Maintenance Strategy to Achieve the Operator’s Objectives 381

Pierre HANKACH and Philippe LEPERT

27.1. Introduction	381
27.2. Maintenance strategies	382
27.2.1. Definition	382
27.2.2. Computing evaluation criteria	383
27.2.3. Evolution models of distress indicators	384
27.3. Choosing a maintenance strategy	385
27.4. An ELECTRE III-based approach	386
27.4.1. Introduction	386
27.4.2. Pseudo-criteria	387
27.4.3. Concordance and discordance indices	388
27.4.4. Degree of credibility	389
27.4.5. Distillation procedures	390
27.5. Example	391
27.6. Conclusion	393
27.7. Bibliography	394

List of Authors 397

Index 409

Contents for Volume 5B 411

Preface

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 21st 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

Acknowledgments

The European Commission, DG MOVE and RTD, the Conference of European Road Directors (CEDR), the European Road Transport Research Advisory Council (ERTRAC), the European Rail Research Advisory Council (ERRAC) and the European technology platform WATERBORNE-TP are acknowledged for their support and active contribution to the Programme Committee of the TRA2014, in charge of reviewing and selecting the papers presented at the conference, which forms the main input of this volume.

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.

Francesca La Torre

Professor Francesca La Torre is a Full Professor of roads, railways and airports at the University of Florence (Italy). She has been working in the field of transportation infrastructures for over 20 years. She obtained her PhD in 1998 at the University of Rome and she served as an assistant researcher at the University of

Illinois at Urbana-Champaign (USA). She is a member of the EC Horizon 2020 advisory group for “Smart, Green and Integrated Transport” and the infrastructures representative for academia in ERTRAC.

Jean-Michel Torrenti

Jean Michel Torrenti is the R&D director of the Materials and Structures Department of IFSTTAR. He is also professor at Ecole Nationale des Ponts et Chaussées. His research concerns mechanics of concrete and its coupling with durability aspects: behavior of concrete at early age, creep, leaching. It is applied to model the behavior of structures such as bridges, nuclear power plants and nuclear waste storage. He is the co-author of several books concerning concrete and concrete structures.

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.

Introduction

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.