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Volume 5A

Materials and Infrastructures 1

Edited by

Jean-Michel Torrenti

Francesca La Torre

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coordinated by
Bernard Jacob

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Contents

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 "transports, 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.

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

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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.