Proceedings of the
17th SIIV International Summer School
and 5th International SIIV Arena

San Marino, Republic of San Marino
16-20 September 2019

Resilient road infrastructures

Climatic changes and perspective of
road infrastructures

Edited by:
Felice A. Santagata, Honorary President of SIIV, Italy
Antonio Montepara, University of Parma, Italy
Andrea Grilli, University of the Republic of San Marino, San Marino

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Acknowledgement

The organization is very grateful to Prof. Felice A. Santagata for suggesting and supporting the Republic of San Marino as location for this Summer School. His management, supervision and teaching, his role of motivator and leader, were of paramount importance for this event and for future activities.

Editors wish to thank the speakers and authors for their efforts in producing contributions of high scientific quality and in sharing concepts for the future development of research studies facilitating new international relationships.

Preface

SIIV (Società Italiana Infrastrutture Viarie) is an Italian scientific association that deals with road, railways and airport engineering.

In the field of transportation infrastructures, the aim of SIIV is mainly addressed to promote learning and technical-scientific knowledge, to encourage debates and to establish relationships and strategic experience exchanges with other institutions.

Working as a non-commercial association since 1990, SIIV organises technical committees, research groups, meetings and supports scientific and teaching initiatives, leading to the improvement of knowledge on transportation infrastructures.

The SIIV Summer School takes place every September as a specific event that involves and brings closely into contact the most representative leaders from the academic field and PhD students, research fellows and young researchers to facilitate exchange of skills, discussion and interaction.

The 17th SIIV Summer School was organised by University of Parma, University of the Republic of San Marino and the San Marino state-owned enterprise for public works (Azienda Autonoma di Stato per i Lavori Pubblici, AASLP). The Summer School was sponsored by AASLP, Ecopneus, MARINI-Fayat Group and TEMA experimental laboratory for building materials and organised under the patronage of three international scientific associations (EATA, ISAP TC APE and RILEM) and three government institutions bodies.

As a part of the SIIV Summer School, the SIIV Arena (PhD symposium) represents the platform in which PhD students, young researchers and scholars present their scientific research, inducing interaction and discussion inside the scientific community. The SIIV Arena offers a stage where young researchers paly a leading role promoting ideas and knocking down frontiers in order to exchange knowledge worldwide and extend scientific developments.

The 5th SIIV Arena consisted of selected extended abstracts and presentations on several topics such as life cycle assessment, recycling, crumb rubber modified asphalt binders, eco-friendly modified asphalt

mixture, “green” binder extenders, coloured pavements, information modelling and pavement management system.

The Proceedings of the 5th SIIV Arena intends to be a reference of the newest research topics in the field of transportation infrastructures and offers suggestions for future development of research studies and international relationships.

Contents

17th SIIV Summer School

Resilient road infrastructures: climatic changes and perspective of road infrastructures

In the last decade, extreme natural phenomena have become more and more frequent, entailing a significant impact on social life. Severe natural events such as drier and hotter weather, heavier precipitations, sea level increase and fluctuations, have disrupted or got inaccessible infrastructure networks, increasing repair and management costs. Indeed, the estimation of damage on infrastructures is expected to increase significantly over time, till ten times in sixty years reaching about forty billion euros of expenses in Europe. Therefore, new complex aspects have to be considered in infrastructure design, construction, maintenance and management, shifting from historical climate data to future predictions and involving road authorities, interdisciplinary experts, investment managers, policy makers, stakeholders and suppliers.

Since road infrastructures are the most used communication facilities which drive economy and social needs of every country, the 17th Summer School focused on new design approaches and synergies for resilient roads, taking into account hazards, exposure and vulnerability of a country to determine risks and responses related to climatic variables and uncertain weather cycles.

Lessons dealt with the following main topics: climate change and risk mitigation by prediction and preventive measures, geometrical design of road infrastructures considering the effect of climate changes on surrounding areas, stability of road beds and embankments under critical conditions, resilient materials and road pavements, information modelling, direct and indirect monitoring to adapt the management system to climatic factors not considered in traditional methods.

The Summer School also included a workshop in collaboration with the Misano World Circuit Marco Simoncelli specifically focused on high-performance mixtures for race track wearing courses.

Program

Monday 16th September 2019		
14.30 – 15.00	Registration/Reception	
15.00 – 15.30	Welcome to 17th SIIV Summer School	San Marino Authorities, SIIV board
15.30 – 17.30	*Key lecture on the effect of climate change on the input of road design and management*	Prof. Maria R. De Blasiis University of Roma Tre
18.00 – 19.30	Touristic tour to San Marino historic centre	
19.30	Welcome dinner	Ristorante Cesare, San Marino

Tuesday 17th September 2019		
08.15 – 08.30	Introduction	Prof. Antonio Montepara University of Parma
08.30 – 10.00	*Climate change and its impacts on transport infrastructures*	Eng. Domenico Gaudioso IPCC/UNFCCC methodology expert
10.00 – 10.30	Coffee break	
10.30 – 12.00	*Influence of climatic changes on infrastructures design, construction and management*	Eng. Marco Garozzo – President of PIARC CT E.1 Adaptation strategies and resilience of infrastructures to climate changes
12.00 – 13.30	*Recycling techniques to reduce the environmental impact of road construction*	Prof. Kamilla Vasconcelos Savasini - University of São Paulo
13.30 – 15.00	Lunch	
15.00 – 17.00	5th SIIV Arena (PhD symposium)	PhD Student presentations
20.00	Dinner	Ristorante Beccafico, San Marino

Wednesday 18th September 2019		
08.15 – 08.30	Introduction	Prof. Antonio Montepara University of Parma
08.30 – 10.00	*Use of procedural modelling for the enrichment of BIM models with pavement material property sets*	Prof. Andrej Tibaut University of Maribor
10.00 – 10.30	Coffee break	
10.30 – 12.00	*Asphalt road pavements and adaptation to climatic changes*	Prof. Gabriele Tebaldi University of Parma
12.00 – 13.30	*The use of crumb rubber modified asphalt binders in high traffic volume highways*	Prof. Fernando Moreno Navarro University of Granada
13.30 – 15.00	Lunch	
20.00	Dinner	Ristorante La Fratta, San Marino

Thursday 19th September 2019 – Marco Simoncelli World Circuit		
08.00	Transfer to Marco Simoncelli World Circuit (Misano)	
08.45 – 09.00	Introduction	Dr. Andrea Albani Marco Simoncelli World Circuit Managing Director
09.00 – 10.00	*Characteristics and activities of the Marco Simoncelli world circuit*	by Marco Simoncelli World Circuit
10.00 – 10.30	Coffee break	
10.30 – 12.30	*High-performance mixtures for race track wearing courses*	Prof. Ezio Santagata Politecnico di Torino
12.30 – 13.30	Lunch	
13.30 – 15.00	Visit to the Marco Simoncelli World Circuit	
15.00	Transfer to hotel	
17.30	SIIV meeting	
19.30	Musical show with Emanuele Rastelli (accordion) and Diana Monaldi (soprano) in collaboration with Camerata del Titano, Piazza della Libertà, San Marino	
20.00	Gala Dinner	Ristorante Righi, San Marino

Friday 20th September 2019		
09.00 – 09.30	SIIV Arena Awards	Prof. Antonio Montepara University of Parma PhD. Andrea Grilli University of San Marino
09.30 – 12.30	Panel discussion - Tavola rotonda	Prof. Felice A. Santagata Honorary President of SIIV Prof. Donato Carlea President of the Superior Council of Public Works (Consiglio Superiore dei Lavori Pubblici)
12.30 – 13.00	Closing ceremony	

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Speaker biographies and lesson abstracts

Maria Rosaria De Blasiis
Full Professor
University of Roma TRE, Italy

Maria Rosaria De Blasiis is Professor of "Roads, Railways and Airports" at the Department of Engineering of Roma Tre University and she is a member of the Council of the Ph. D. program in civil engineering.

Her main objects of study concern the environmental aspects of infrastructures, the project management for safety, the road pavement technologies with special attention to the rehabilitation and maintenance. She has been studying the application of advanced methods and technologies for the infrastructure analysis: neural network for accident predictions, quality standard of road assessment in Virtual Reality, pavement diagnosis with advanced technologies, monitoring, and managing using emerging sensing such as 2D imaging, 3D laser and Lidar. About these subjects, she published many papers on sectorial journals and held international conferences.

The effect of climate change on the input of road design and management

The lecture showed several methods for the assessment of vulnerability, correlating them to more traditional design analyses, through which indicators allow describing the effects of the vulnerability of road works due to climate change and understanding what efforts one has to make to increase the resilience capacity of the infrastructure. Case studies analysis allowed highlighting the peculiar sensitivities of the specific work-environment system and made students aware of limits of the "standard" design procedure.

Domenico Gaudioso
IPCC/UNFCCC methodology expert

Domenico Gaudioso has a degree in Chemical Engineering, University of Rome "La Sapienza". He has been responsible of the activities concerning air quality and climate change at the Italian National Institute for Environmental Protection and Research (ISPRA). He has been a contributing author for the Nobel Peace Prize winning Intergovernmental Panel on Climate Change since 1996 (namely for the "1996 IPCC Revised Guidelines on Greenhouse Gas Inventories" and for the "2006 IPCC Guidelines on Greenhouse Gas Inventories") and is actively engaged in the review activities of the UN Climate Change Secretariat. He has participated in most of the Conferences of the Parties and the meetings of the subsidiary bodies of the UNFCCC. In the framework of the preparation of the Italian National Strategy for Adaptation to Climate Change, he has been appointed co-ordinator of the chapters concerning Energy and Transport Infrastructures; he has also coordinated the preparation of the chapter concerning Energy of the Italian National Plan for Adaptation to Climate Change.

Climate change and its impacts on transport infrastructures

The lesson analysed the phenomena of climate change, identifying the main parameters that characterize them. The role of the transport sector was therefore analysed: on one hand, transport activities release significant emissions of greenhouse gases, but at the same time, they are particularly vulnerable to the impacts of climate change. The methodology proposed by the IPCC for the assessment of impacts and vulnerability was then presented. Finally, adaptation measures were reviewed, with particular reference to those provided for by the Italian Strategy and Plan for Adaptation to Climate Change.

Marco Garozzo
R&D Manager, Sina S.p.A. Milano
PIARC CT E.1 Strategy for Adaptation and resilience

Marco Garozzo has acted as designer, work supervisor and researcher and for almost 20 years has been involved in different World Road Association-PIARC research programs. In particular, he has been the President of Italian Technical Committee and Representative Member of the International Committee for the last four-year framework programs and specifically: "Climate change, environmental impacts and alternative to fossil fuel" for the period 2008-2011; "Climate Change and sustainability" for the period 2012-2015 and "Adaptation strategies and resilience of infrastructures to Climate Changes" for the period 2016-2019.

Marco Garozzo is in charge of the Research and Market Development Department of SINA S.p.A. SINA is one of the most important engineering company in Italy and it is part of ASTM Group, one of the main industrial Group active in the sector of Trasportation and infrastructures.

Influence of Climate Changes on Infrastructure Design, Construction and Management from Mitigation to Adaptation

The lecture showed the evolution of scientific and technical thought on climate changes and a variety of approaches of different countries to both mitigate climate change by reducing greenhouse gas emissions from transport and adapting transportation systems and infrastructure to the impacts of climate change. Actions include legal, regulatory and institutional measures; promoting other transport modes; introducing new and "green" technologies; undertaking permanent supervision of embankments and slopes to reduce risks of collapse, accidents and interruptions of service, as well as developing new methodologies and analytical tools to identify, assess and mitigate risks and thus reduce the vulnerability of the road infrastructure.

Kamilla Vasconcelos Savasini
Associate Professor
University of São Paulo, Brazil

Kamilla Vasconcelos is Associate Professor in the Graduate Program in Transportation Engineering (PPGET) of the Polytechnic School of the University of São Paulo (POLI-USP), Brazil. She has bachelor in Civil Engineering (2003) at the Federal University of Ceará (UFC), Brazil, with 1 year of exchange program (2000) in Germany, Masters (2004) in Transportation Engineering also at UFC, PhD in Civil Engineering (2009) at Texas A&M University, and Pos Doc (2010) at Department of Transportation Engineering, POLI-USP, Brazil. Professor Kamilla Vasconcelos is co-chair of the Technical Group "Degree of Binder Activation" of the RILEM Technical Committee 264 RAP and is involved in different research projects related to Transportation Infrastructure at the Laboratory of Pavement Technology, POLI-USP. She has published more than 80 papers.

Recycling techniques to reduce the environmental impact of road construction

Reclaimed asphalt pavement (RAP) can be used for several applications, such as granular bases or subbases, stabilized base materials, and it has also the potential to replace more expensive materials, like virgin asphalt binder, when used for wearing course mixtures. The lecture was divided in two sections:

- Cold recycling: stiffness dependency regarding temperature, load frequency, stress-state and moisture content variation;
- Hot/Warm recycling: evaluation of the feasibility of using warm-mix asphalt technology to produce asphalt mixtures with RAP for surface courses, along with the degree of binder activation and blending analysis.

Andrej Tibaut
Head of the Chair of Construction
and Transportation Informatics
University of Maribor, Slovenia

Andrej Tibaut is an Associate Professor in Construction Informatics at the University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture and Head of the Chair of Construction and Transportation Informatics. He has been active in construction and transportation informatics with research focused on infrastructure and building information modelling (BIM), knowledge engineering, digital interoperability and the use of e-learning in engineering. He is an active member of CEN/TC 278/WG3 standardization groups. He is also the founding member and Vice-chairman of siBIM (BIM Association Sloveni). Since 2017 he has been collaborating with University of Naples Federico II (Prof. Gianluca Dell'Acqua) where he gave lectures on BIM and supervises PhD students.

Use of procedural modelling for the enrichment of BIM models with pavement material property sets

In the lecture, a BIM based procedural modelling approach for some road pavement use cases was presented using latest IFC 4x2 schema, IfcOpenShell, Pyhton as programming language and a database. The approach focuses on the IFC modelling of an extensive set of custom material properties for the road pavement use cases.

Gabriele Tebaldi
Associate Professor at University of Parma and Joint Professor at University of Florida

Gabriele Tebaldi is Chairman of RILEM TC 264-RAP Asphalt Pavement Recycling, Co-chairman of ISAP TC Asphalt Pavements and Environment, Member of Board of Directors and former President of ISAP, Editor in Chief of Road Materials and Pavement Design and Associate Editor of Materials and Structures.

Asphalt road pavements and adaptation to climatic changes

The lecture talked about how the new climatic conditions and phenomena are forcing to change the pavement design approach and the functions of road pavements. Particularly, impact of heavy rain phenomenon and new temperature scenario on construction techniques, design, materials selection and combination, were thoroughly analysed.

Fernando Moreno Navarro
Associate Professor
University of Granada, Spain

Fernando Moreno Navarro is associate professor in Materials Science and in Construction Engineering Procedures at the University of Granada (Spain). He also is Sub-director of the Laboratory of Construction Engineering of the University of Granada (LabIC.UGR). Prof. Moreno-Navarro has published more than 90 papers, he has acted as main investigator in more than 40 research projects in collaboration with the industry and developed patents and new technologies related to asphalt pavements and bituminous materials. His work has been awarded in several occasions by different international organisms and associations of the road and railway sectors. Last year he received the Robert L'Hermite Medal from RILEM (International Union of Laboratories and Experts in Construction Materials, Systems and Structures).

The use of Crumb Rubber Modified Asphalt Binders in High Traffic Volume Highways

The lecture dealt with the main characterization tests to be used for improving the design of crumb rubber asphalt mixtures as well as with the recommendation of use to avoid worthless experiences. After that, the works carried out during laboratory phase and construction site to use these materials in roads that support high traffic volumes and severe environmental conditions were summarised.

Andrea Albani
Managing director
Misano Word Circuit

Andrea Albani is the managing director of the Marco Simoncelli World Circuit (Misano, Italy). He was coordinator of the project Terra dei Motori "Motor Valley" in 2000. From 2001 to 2008, he worked on strategic marketing project for Ducati Motor Holding, Yamaha Italia, Bimota, Kawasaki and Maserati SpA. As scientific member of the Motor Valley committee, he collaborated with Emilia-Romagna region on motorbike-riding projects. Since 2009, he has been working for Santa Monica S.p.A. as managing director of the Marco Simoncelli World Circuit (Misano, Italy). In 2017 he has become vice president of the board of the Motor Valley Development Association and since 2019 he is vice president in charge of Federturismo committee.

He likes running, skiing and he's fond of reading and art.

Characteristics and activities of the Marco Simoncelli World Circuit

The workshop at the Marco Simoncelli World Circuit began with the history of the circuit, from Santa Monica circuit to Misano World Circuit, and the explanation of the reasons to build the circuit in Misano Adriatico (Romagna, Italy). The lesson described the main characteristics and activities of the circuit with emphasis on development, sustainability and safety projects, shows and events such as MotoGP and Superbike racing.

Ezio Santagata
Full Professor
Politecnico di Torino

Ezio Santagata is full professor of "Roads, Railways and Airports" in the Politecnico di Torino. After obtaining his degree in the University of Ancona, in 1993 and 1995 he was Visiting Scholar at Penn State University (USA). His research is focused on pavement materials and structures, with an emphasis on laboratory testing of bituminous binders and mixtures. He has published more than 200 scientific and technical papers in national and international journals and conference proceedings. He has been Principal Investigator of several research programs sponsored by private partners, by the Italian Ministry of University and Research, and by the European Commission. He is the member of the Editorial Board of four International Journals. Currently he also acts as a Consultant for Companies and Administrations in the area of pavement engineering and asphalt technology in Europe, Asia and in the Middle East.

High-performance mixtures for race track wearing courses

The lecture focused on the design, production and laying of asphalt wearing courses for race tracks. In particular, topics addressed during the presentation included preliminary assessment of paving sites, criteria for materials selection, automated and 3D construction modelling, asphalt volumetric and functional characterization, tyre-pavement interactions, pavement long-term durability and maintenance. Although the principles of asphalt science and technology remain unchanged, it was shown that in the case of race tracks the identification of optimal solutions and their full-scale implementation may require a tailored, non-conventional approach.

Felice A. Santagata
- Rector of the University of Ancona (1976 – 1979)
- Professor Emeritus
- Honorary President of SIIV

Felice A. Santagata graduated in Civil Engineering in 1961 at the Politecnico di Torino, where he began his academic career.

Full professor of "Roads, Railways and Airports" since 1975.

During his career, he has taught in the Politecnico di Torino and in the Universities of Ancona, L'Aquila, Perugia and Modena.

He founded the Institute of Hydraulics and Infrastructures in the University of Ancona in 1977 and led the Institute until 1992.

He was one of the Founder Members of SIIV in 1990.

In the period 1990-2008 he was the National Coordinator of PhD programs in "Roads, Railways and Airports".

In the period 1992-2002 he was the President of the Committee on "Standards on Materials and Pavements" of the Italian National Research Council (CNR).

In 1996 he founded the Italian Interuniversity Road and Airport Research Centre (CIRS).

In 1997 he was the founder of the airline company "Federico II".

He is the first Author and Editor-in-Chief of the textbook "Strade - Teoria e Tecnica delle Costruzioni Stradali", published by Pearson.

Currently, on behalf of the Consiglio Superiore dei Lavori Pubblici, he is the Coordinator of the Task Group for the preparation of the new specifications for road materials.

Members of his School have contributed to the growth of several Italian Universities including Ancona, Potenza, Cosenza, Enna, Genova, L'Aquila, Modena, Napoli, Padova, Parma, Perugia, PoliTorino, PoliMilano, San Marino, Trento and Udine.

In 2016 the Polytechnic University of Marche has dedicated its Laboratory of Roads, Railways and Airports to Prof. Felice A. Santagata.

Donato Carlea
President of the Superior Council of Public Works (Consiglio Superiore dei Lavori Pubblici)

Donato Carlea graduated in Civil Engineering in 1978 at the University of Naples (Italy). He was lecturer in bachelor, master and high-education courses in several Italian Universities such as University of Perugia, University of Rome "La Sapienza", University of Naples "Federico II", telematic University e-campus in the field of legislation of public works, architectural and preservation design, inspection of quality control.

He worked as superintendent of public works for several Italian regions, i.e. Lombardia (1997-1998), Trentino Alto Adige (1998-2001), Umbria (2001-2004), Campania and Molise (2007-2010), Lazio, Abruzzo and Sardegna (2010-2013), Campania and Molise (2013-2014), Sicilia and Calabria (2016-2018).

He was "Commissario Straordinario per le grandi opere strategiche" for Lazio - Abruzzo - Molise (from 17/10/2004 to 30/11/2005) and "Direttore Generale del Servizio di Vigilanza dell'Autorità di Vigilanza dei Contratti Pubblici di lavori, servizi e forniture" (from 01/12/2005 to 30/9/2007)

He is President in charge of the Superior Council of Public Works (Consiglio Superiore dei Lavori Pubblici) since 29th November 2018.

Antonio Montepara
Full professor
University of Parma

Antonio Montepara is full professor of "Roads, Railways and Airports" in the University of Parma (Italy). In the period 2007-2012 he was the Dean of the Faculty of Engineering in the University of Parma. He is president in charge of the course in Civil and Environmental Engineering. His research is focused on performance-based characterization of road materials, modelling of microstructural materials, application of fracture mechanism theory to bituminous materials, pavement reinforcement systems and recycling techniques for road construction and maintenance. He has published more than 150 scientific and technical papers in national and international journals and conference proceedings. He is member of the Permanent Monitoring Panel "Mitigation of Catastrophic Risk" for Ettore Majorana Foundation and Centre for Scientific Culture.

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The use of crumb rubber modified asphalt binders in high traffic volume highways

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Abstract

The objective of the present project consists of evaluating the long-term performance of crumb rubber modified asphalt mixtures used as surface layer in roads with high traffic volumes. For this purpose, a complete study from laboratory phase to road trial sections has been carried out, analysing aspects such as material workability, resistance to ageing, to plastic deformations, and to fatigue and low temperature cracking, among others. The results have demonstrated that crumb rubber modified asphalt mixtures could offer similar or even better mechanical behaviour to that measured for traditional asphalt mixtures.

Keywords

Crumb rubber, warm mix asphalt, mechanical performance

Introduction

The economic and social developments of recent decades have led to the need for more efficient and sustainable road infrastructures. In this regard, efforts have been focused on developing more durable materials that allow for increasing the service life of road pavements [1]. Thus, one of the current challenges in the road pavement industry concerns the implementation of a circular economy in which materials are reused whilst applying more environmentally friendly construction techniques [2, 3].

To meet this goal, the Ministry of Public Works and Housing of Andalucía (Junta de Andalucía) decided to use crumb rubber from end-of-use tyres as bitumen modifier and to manufacture the asphalt mixture at a low temperature (by using additives to obtain warm mix asphalts) [4, 5].

This document presents some of the main findings from the laboratory phase of developing crumb rubber modified bitumen (CRMB), its production in plant, and its application in the rehabilitation of a pavement section in the A-92 Highway located in the province of Granada, Spain. The A-92 withstands more than 18,000 vehicles per day and 2,600 heavy vehicles per day under an extreme climate conditions (1,400 m above sea level, with the presence of snow during winter, and high temperatures and many hours of solar radiation during summer).

Research project

Three different asphalt mixtures BBTM 11 were designed: two hot (CRMB-HMA and PMB-HMA) and one warm-mix asphalt (CRMB-WMA). The design of these mixtures included the water sensitivity test, wheel tracking test, air void content test, TSRST and UGR-FACT [6]. Following the design and evaluation of the mixtures at laboratory level, a series of mixing processes were carried out in a real asphalt plant for each type of mixture to test their reproducibility and finally used in the rehabilitation of a section of pavement on the A-92 highway (Figure 1).

Figure 1. Images from the spreading and compaction of the CRMB-WMA.

Findings

The mixture manufactured with crumb rubber modified bitumen at 30 °C lower than the hot conventional mixtures led to a mechanical performance comparable to that recorded for traditional high-performance hot mixtures. This mixture can be manufactured in a conventional asphalt plant and spread with conventional equipment, achieving a material with a similar mechanical response to that of the reference hot mixtures (even higher in terms of resistance to fatigue and thermal cracking, particle loss, and permanent deformations). In addition, the cost overrun associated with the use of additives for lowering the temperature can be partially compensated by the reduced energy consumption in plant. Taken together, these findings suggest that warm mixtures manufactured with crumb rubber could offer an interesting alternative to conventional hot mixtures for

improving the durability of road pavements whilst reducing the environmental impacts associated with their construction/rehabilitation.

References

[1] Abtahi, S.M.; Sheikhzadeh, M.; Hejazi, S.M. (2010) Fiber-reinforced asphalt-concrete – A review. Construction and Building Materials, 24 (6), 871-877.

[2] Chomicz-Kowalska, A.; Gardziejczyk, W.; Iwa´nski, M. (2016) Moisture resistance and compactibility of asphalt concrete produced in half-warm mix asphalt technology with foamed bitumen. Construction and Building Materials, 126, 108-118.

[3] Sol-Sánchez, M.; Moreno-Navarro, F.; García-Travé, G.; Rubio-Gámez, M.C. (2016) Analysing industrial manufacturing in-plant and in-service performance of asphalt mixtures cleaner technologies. Journal of Cleaner Production. 121, 56-63.

[4] D'Angelo, J.; Harm, E.; Bartoszek, J.; Baumgardner, G.; Corrigan, M.; Cowsert, J.; Harman, T.; Jamshidi, M.; Jones, W.; Newcomb, D.; Prowell, B.D.; Sines, R.; Yeaton, B. (2008) Warm-Mix Asphalt: European Practice. Report No. FHWA-PL-08-007. Alexandria, Estados Unidos.

[5] Rubio, M.C., Martínez, G.; Baena, L.; Moreno, F. (2012) Warm mix asphalt: an over-view. Journal of Clearner Production, 24 (8), 76-84.

[6] Moreno-Navarro, F., Rubio-Gámez, M. C. (2016) A review of fatigue damage in bituminous mixtures: Understanding the phenomenon from a new perspective. Construction and Building Materials, 113, 927-938.

Chemical and rheological analysis of "green" bitumen extenders

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Abstract

This study encourages the use of recycled and by-product materials for the production of bituminous binders. In detail, the paper aims to replace a certain amount of a bitumen Pen 50/70 by means of an extender made of rubber (R) from end-of-life tyres and re-refined engine oil bottom (REOB), i.e. the by-product of refining mineral waste oils. The experimental program was divided into three phases. First, R-REOB chemical interaction was evaluated to maximize the use of both materials. Then, multiple variables of the R-REOB production process affecting the final bituminous blend rheology were investigated. Finally, extended bitumens are prepared and tested.

Keywords

Extended bitumen, rheology, REOB, tyre rubber

Introduction

Thanks to a greater attention to the environment and an increased awareness to the depletion of non-renewable resources, a sustainable approach is required in all production activities and development of new products. The economy is moving from an open-ended system to a circular system, where a relationship between resource use and waste exists. According to the current trend and policy directives pavement engineers are focused on innovative and eco-friendly construction materials.

Today, many researches aim to reduce the amount of bitumen by replacing it with more sustainable materials. Alternative products that could be used in bituminous binders are additives, such as polymers, and waste materials like bio or engine oils [1]. Among polymers, rubber from end-of-life tyres is one of the most used material in asphalt industry. Due to vulcanisation process undergone, the natural rubber gets advantageous elastic properties and turns into a more resilient material [2]. Commonly, it is used in road pavements thanks to the offered benefits in terms of high-temperature performance, or rather rutting resistance, and fatigue life [3]. Nevertheless, its addition leads to an overall increase in binder viscosity, which turns into higher production temperature and greenhouse gas emissions [4]. In contrast, the re-refined engine oil bottom (REOB) has been added to bitumen due to its softening effect, which may allow improvement of low-temperature response and thermal cracking resistance [5]. Conflicting opinions have been collected about rutting resistance of bitumen-REOB blend. Despite some positive results, an high amount of REOB seems to be detrimental for the final performances at high-temperatures [6].

Recent studies have evaluated the addition of both materials as bitumen additives with the aim to compensate the softening effect of REOB with the increased viscosity brought in by the rubber, turning it into a more effective and sustainable production process [4]. Pursuing the possibility of balancing these two effects, the present study aims to define green bitumen extenders made by rubber-REOB blend. Furthermore, the mixing process

variables and base properties of constituent materials have been considered to develop the investigation on the extenders behaviour.

Research project

The final goal of this research is the reduction of petroleum bitumen in road materials maximizing the quantity of the proposed binder extender. The new extended binders underwent rheological and chemical analysis to evaluate their potential performances in asphalt applications.

The reference and base material is a bitumen Pen 50/70 to be mixed with the two recycled materials: powdered rubber (R) and REOB. The R was obtained by recycling processes of end-of-life tyres of cars and trucks by trituration at ambient temperature. The particles dimension varies in the range of 0-0.4 mm. Two REOBs have been compared, which are produced in two Italian oil-refining plants.

The experimental program was divided into three phases. Firstly, R-REOB chemical interaction was evaluated to find a ratio that could maximize their use and advantages. Those quantities were defined as the amount of REOB that R could absorb by using nuclear magnetic resonance and scanning electron microscopy. The second phase covers the investigation on extenders production process for defining which variables affect the binder rheology; type of REOB, R content, mixing temperature and type of mixer are analysed by performing dynamic shear rheometer tests on the binders. This study is on-going. The third phase involves the analysis of extended bitumens based on the collected data and eventually their application to the production of asphalt concretes at the lab scale.

Preliminary results

The first phase of the experimental program was completed and the following conclusions can be drawn. The R-REOB ratio that can optimize the amount of both materials ranges between 1:1 and 1:2. The two REOBs behave in a slightly different way, which can be related to their origins

(plants). Further studies on the rheological behaviour of the extenders are on-going considering both ratios.

References

[1] W. A. W. A. Aziz, Md M.A., Rahman, Md T., Hainin, M.R. and Bakar, 'Alternative binders for flexible pavement', *Constr. Build. Mater.*, vol. 84, pp. 315–319, 2015.

[2] D. Lo Presti, 'Recycled Tyre Rubber Modified Bitumens for road asphalt mixtures: A literature review', *Constr. Build. Mater.*, vol. 49, pp. 863–881, 2013.

[3] X. Ding, T. Ma, W. Zhang, and D. Zhang, 'Experimental study of stable crumb rubber asphalt and asphalt mixture', *Constr. Build. Mater.*, vol. 157, pp. 975–981, 2017.

[4] A. Amini and R. Imaninasab, 'Investigating the effectiveness of Vacuum Tower Bottoms for Asphalt Rubber Binder based on performance properties and statistical analysis', *J. Clean. Prod.*, vol. 171, pp. 1101–1110, 2018.

[5] A. Golalipour and H. Bahia, 'Evaluation of Oil Modification Effect on Asphalt Binder Thermal Cracking and Aging Properties', *Proc. Can. Tech. Asph. Assoc.*, 2014.

[6] Asphalt Institute, State of the knowledge - The use of REOB/VTAE in asphalt - IS-235, First edit. USA, 2016.

Assessment of eco-friendly modified asphalt mixture using PMA methodology

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Abstract

The research program aims to define a new methodological procedure to design eco-friendly modified asphalt using polymer modified asphalt (PMA) methodology in substitution to polymer modification of the bitumen (PmB) technology. In the starting phase two different mixes were optimized using SUPERPAVE methodology, and the Indirect Tensile Strength (ITS) was evaluated. The first mixture is a Traditional Mixture (TM) and another one is a Modified Mixture (MM) with the addition of 5% (by total mass of bitumen) of polymeric compound using PMA technology. From the ITS analysis, the MM shows an ITS value higher about of 20% than traditional TM.

Keywords

Polymer Modified hot mix Asphalt (PMA), Polymeric compound, Hot Mix Asphalt

Introduction

The properties of road bitumens can be improved by means of polymers and fibres. Modification as identified by both rheological and mechanical tests is intended to induce to higher performance. The common way to significantly improve the performance properties of the bitumen and also the properties of related asphalt mixture and corresponding pavement layers (increasing the viscosity at high temperature and elasticity at low temperature) is the polymer modification of the bitumen (PmB). Common production of the pre-blended PmB is connected to the corresponding industrial process and machinery. The transport and storage of the PmB to the asphalt mixing plant requires consequent following of the strict qualitative procedures. The other equivalent way of polymer modification of the bitumen is by adding the polymer modifier in the form of granules already into asphalt mixture (into the asphalt mixer), which significantly simplifies the production process. The research program aims to define an innovative polymeric compound that could be potentially considered as a relevant solution for sustainable long-life pavements that does not deteriorate structurally, needing only timely surface maintenance and allowing reduced base course thickness leading to a cost effective and eco-friendly perpetual pavement design.

Materials

In this starting phase of research program, a hot mix asphalt (HMA) mixture for dense-graded friction courses were designed and prepared to meet the goals listed in the first section. The SUPERPAVE mix design procedures was adopted. A 50/70 penetration grade bitumen was used as binder. The preliminary evaluation of the collected asphalt samples was conducted to assure its intrinsic properties (shear modulus, viscosity, penetration, softening point etc). The design aggregate structure was established by mathematically combining the gradation of the individual materials into a blend of a single gradation. The blend gradation was then compared to the specification requirements as: 1) UNI EN 13108-1; 2)

Technical Specifications on road maintenance of the National Italian Autonomous Roads Corporation; 3) SUPERPAVE graduation requirements; 4) Maximum density gradation obtained using n=0.45 in the equation developed by Fuller and Thompson in 1907.

Method

Starting from the aggregate distribution described above, two different asphalt mixtures were optimized using SUPERPAVE procedure. The first one was a Traditional Mixture (TM) and the other one is a Modified Mixture (MM) with the addition of 5% (by total weight of bitumen) of polymeric compound. During this phase of research program, the ITS (EN 12697-23) was evaluated at 10°C, to establish the basic mechanical properties of the studied mixtures. Three specimens for each mixture were compacted using gyratory compactor at 160 number of gyrations, using a diameter mould of 150 mm. After compaction each specimen has been storage at least for 4 hours using air chamber conditioning to test temperature according to EN 12697-23.

Preliminary results and future goals

From the mix design phase, the both mixtures were optimized at 4.5 % by total mass of aggregates. From the analysis of ITS at 10°C, the MM mixture shows an ITS value (3.82 MPa) about 20% higher than TM mixture (3.19 MPa). During next phases of research program, additional tests will be carried out (ITSR, ITSM, Fatigue) on asphalt concrete modified using PMA technology, by also introducing different waste polymers (i.e. different types of plastics) to improve mechanical properties of final product.

References

[1] Becker, Yvonne, Maryro P. Mendez, and Yajaira Rodríguez. "Polymer modified asphalt." Vision tecnologica. 2001.

[2] Amin, I., Alabasey, R., Azam, A., El-Badawy, S., & Gabr, A. (2015). Evaluation of polymer modified asphalt mixtures in pavement construction. In 8th international engineering conference, 17–22 Novemeber, Faculty of Engineering, Mansoura University, Mansoura.

[3] Montanelli, E. F. (2013). Fiber/polymeric compound for high modulus polymer modified asphalt (PMA). Procedia-Social and Behavioral Sciences, 104, 39-48.

[4] Fuller, William B., and Sanford E. Thompson. "The laws of proportioning concrete." (1907): 67-143.

LCA of recycled bituminous mixtures containing jet grouting waste

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Abstract

The study aimed to compare mechanical and environmental performance of four solutions for base layer of a flexible pavement with hot and cold technology, with and without the reemployment of jet grouting waste obtained from land consolidation work during the construction of underground tunnels. The laboratory investigation provided cold bituminous mixture with optimum performance mechanical compared to hot bituminous mixtures. The environmental evaluation has been focused on life cycle assessment (LCA) taking into account all manufacturing process from cradle to laying of flexible pavement having as base layer the four mixtures investigated.

Keywords

Hot bituminous mixtures, cold bituminous mixtures, life cycle assessment, reclaimed asphalt pavement, jet grouting waste

Introduction

In the field of road construction, it is increasingly focusing on the need for sustainable development. This reflects the growing tendency to reduce the quantity of materials going to landfill and to reuse non-renewable resources in place of raw materials that should be preserved in nature. The mechanical and the environmental effects of non-traditional materials in road bituminous mixtures have been investigating i.e. construction and demolition waste [1], ashes from electricity facilities [2], waste foundry sand [3], waste glass powder [4] as well as RAP [5]. One of main tools to be used for quantifying the potential impacts deriving from the use of traditional and alternative materials in road construction is life cycle assessment LCA (ISO 14040, ISO 4044) defined as an objective procedure for assessing energy and environmental loads related to a process or an activity. It can be carried out through the identification of energy and used materials and waste released into the environment related to a specific process.

The research presented here focused on eco-efficiency evaluations of four several bituminous mixtures studied in order to compare mechanical performance and LCA characterization.

Research project

Experimental research intended to compare mechanical and environmental performance of a base layer of flexible pavement, designed following four criteria: 1. hot mix asphalt (HMA), 2. hot mix asphalt containing jet grouting waste (JTW) in alternative to a part of traditional limestone aggregates as filler and sand, 3. cold reclaimed asphalt (CRA) and 4. cold reclaimed asphalt (CRAJ) containing RAP composed by limestone and basalt aggregates in addition to JTW. Leaching test was carried out to test environmental components of JTW. The laboratory phases consisted of two stages: 1) the first one focuses on the mix design procedure by Superpave method for all two hot bituminous mixtures with and without JTW verifying composition and volumetric properties (i.e. grading curves and air voids)

and mechanical performance (i.e. indirect tensile strength ITS, water sensitivity, stiffness); 2) the second step focused on the mix design of cold bituminous blend analysing the effects of curing time in order to get a final solution that can reflect or even improve the performance of previous mixtures. LCA was conducted on the basis of real data provided by a local producer of bituminous mixtures and data derived from literature study, to assess for each of four mentioned solutions (HMA, HMAJ, CRA CRAJ as a base layer) some key environmental features connected to all activities of unitary manufacturing process from cradle to laying: global warning potential; formation potential of tropospheric ozone; acidification potential of soil and water; eutrophication potential; total suspended particulate; energetic and not-energetic resources both in plant and in site; non-renewable energy resources; water; bitumen; fresh aggregates; secondary raw material (reused of RAP and JTW); waste production.

Findings

The mechanical results showed that CRAJ mixture reaches the ITS values of a traditional HMA in just 14 days of curing time while achieving the highest ITS obtained for an HMAJ in 28 days of curing. Compared with the hot bituminous mixtures, both cold recycled mixtures with and without JTW showed good performance. The LCA highlighted that CRAJ returns an overall value five times lower than HMA; in particular, CRAJ compared with traditional HMA presented a reduction of pollutant emissions, in terms of CO_2, C_2H_4, SO_2 and NO_3, of around 3% and 60% respectively for the activities of aggregates production and in-plant mixing.

References

[1] Ossa, A., García, J. L., & Botero, E. Use of recycled construction and demolition waste (CDW) aggregates: a sustainable alternative for the pavement construction industry. J. Clean. Prod, *135*, 379-386. 2016.

[2] Veropalumbo, R., Viscione, N., Formisano, A.. Hot mix asphalt with fly ashes for dense-graded surface layers of rural roads, WIT Transactions on Ecology and the Environment. 215, 93-105, 2018.

[3] Dyer, P. P., de Lima, M. G., Klinsky, L. M. G., Silva, S. A., & Coppio, G. J. Environmental characterization of Foundry Waste Sand (WFS) in hot mix asphalt (HMA) mixtures. Constr. Build. Mater., *171* 474-484, 2018.

[4] Simone, A., Mazzotta, F., Eskandarsefat, S., Sangiorgi, C., Vignali, V., Lantieri, C., & Dondi, G Experimental application of waste glass powder filler in recycled dense-graded asphalt mixtures. Road Mater. Pavement Des., 20(3), 592-607, 2019.

[5] Blanc, J., Hornych, P., Sotoodeh-Nia, Z., Williams, C., Porot, L., Pouget, S., Boysen, R., Planche, J.-P., Lo Presti, D., Jimenez, A., Chailleux, E. Full-scale validation of bio-recycled asphalt mixtures for road pavements. J. Clean. Prod., 227, 1068-1078, 2019.

Performance optimization of warm recycled mixtures

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Abstract

This paper describes a laboratory investigation aimed at the performance evaluation of warm recycled asphalt mixtures for wearing courses. The mixtures were produced with WMA technology and include relatively high percentages (up to 30%) of RA. Moreover, a HMA containing a lower RA content was selected as control mixture. Strength and stiffness properties, water sensitivity and fatigue resistance were investigated on shear gyratory compacted specimens. The results proved the possibility to produce suitable WMA mixtures with higher RA contents without penalizing their performance compared to the control one.

Keywords

Warm Mix Asphalt; Reclaimed Asphalt; fatigue

Introduction

Compared with conventional Hot Mix Asphalt (HMA), Warm Mix Asphalt (WMA) allows the reduction of the mixing and compaction temperatures by 20 to 40 °C [1]. In Europe, over 80 % of roads are constructed with asphalt mixtures [2]. After being milled from old pavement, the material becomes Reclaimed Asphalt (RA). Plentiful investigations on the combination of WMA mixture and RA were carried out. The results showed that high RA contents (up to 50%) could increase stiffness, improve rutting performance and moisture resistance of WMA mixture [3-6].

The objective of this investigation is to design reliable dense graded recycled asphalt mixtures for wearing course by using WMA technology and relatively high contents of RA (up to 30%). The performance of the asphalt mixtures was studied through laboratory tests aimed at evaluating strength and stiffness properties, water sensitivity and fatigue resistance.

Research project

Three mixtures were prepared in laboratory by using a plain bitumen, different RA contents and a chemical WMA additive (only for WMAs). The WMA mixture with 20% RA content and 4.1% of added binder was referred as M-20-4.1 and the WMA mixture with 30% RA content and 3.4% of added binder was referred as M-30-3.4. As control one, a mixture with 15% RA content was produced with HMA technology and was referred as M0-15. For the WMA mixtures, the mixing and compaction temperatures were 120 °C and 110 °C, respectively, whereas for the HMA, 160 °C and 150 °C were used, respectively. Indirect Tensile Strength (ITS), water sensitivity (Indirect Tensile Strength Ratio – ITSR), Indirect Tensile Stiffness Modulus (ITSM) and fatigue resistance (Indirect Tensile Fatigue Test – ITFT) were evaluated.

Findings

From Figure 1.a, it is possible to observe that increased RA contents provide slightly lower ITS values with respect to the control mixture, while remaining within the local technical specification requirements (> 0.6 MPa). Moreover, the increase of RA content does not significantly affect the strength properties after water conditioning (Figure 1.b), denoting a proper water sensitivity of WMAs.

The results of the indirect tensile stiffness modulus (Fig. 2.a) show that the WMA mixtures with higher RA contents are characterized by a reduced stiffness as compared to the control mixture (HMA), probably due to the reduced production and compaction temperatures.

As far as the ITFT, Figure 2.b shows that WMAs containing higher RA content provide higher fatigue resistance compared to the control one, denoting a promising behaviour of these environmentally friendly materials.

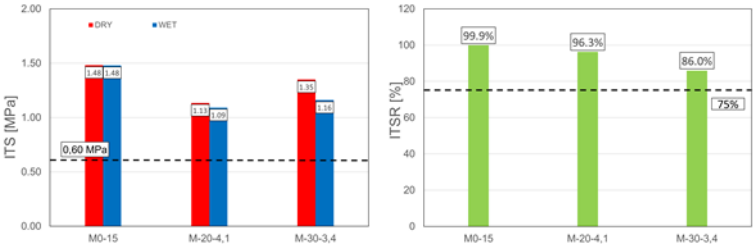

Figure 1. Results: a) ITS; b) ITSR

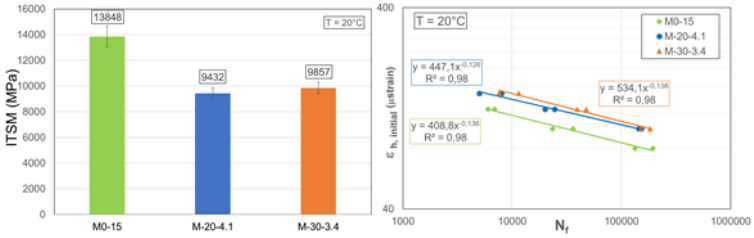

Figure 2. Results: a) ITSM; b) ITFT

References

[1] Rubio, M.C., et al., Warm mix asphalt: an overview. Journal of Cleaner Production, 2012. 24: p. 76-84.
[2] Antunes, V., A.C. Freire, and J. Neves, A review on the effect of RAP recycling on bituminous mixtures properties and the viability of multi-recycling. Construction and Building Materials, 2019. 211: p. 453-469.
[3] Behbahani, H., et al., Laboratory investigation of rutting performance of warm mix asphalt containing high content of reclaimed asphalt pavement. 2017. 35(15): p. 1556-1561.
[4] Moghadas Nejad, F., et al., Rutting performance prediction of warm mix asphalt containing reclaimed asphalt pavements. 2014. 15(1): p. 207-219.
[5] Vargas-Nordcbeck, A., D.H.J.R.M. Timm, and P. Design, Rutting characterization of warm mix asphalt and high RAP mixtures. 2012. 13(sup1): p. 1-20.
[6] Yin, F., et al., Novel Method for Moisture Susceptibility and Rutting Evaluation Using Hamburg Wheel Tracking Test. Transportation Research Record: Journal of the Transportation Research Board, 2014. 2446(1): p. 1-7.

Hot recycling: maximising the use of RAP with no additives

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Abstract

Reclaimed asphalt pavement (RAP) is currently one of the most recycled material in the world and has been studied in several countries due to its economic and environmental benefits. Nevertheless, its application in wearing courses is still limited to low RAP contents.

This paper presents the evaluation of mixtures designed with 0, 10, 20 and 25% RAP to assess its use on wearing and/or binder courses in heavy traffic highways in Brazil. Firstly, indirect tensile strength (ITS), dynamic modulus (DM) and flow number (FN) tests were carried out in order to analyse the mechanical properties of the recycled mixtures with no additive incorporation. Then, the fatigue life of the control mixture and the mixture with 25% RAP before and after the addition of a rejuvenator agent were evaluated.

Keywords

RAP, Asphalt concrete, Hot recycling

Introduction

Although the demand and use of reclaimed asphalt pavement (RAP) has continually increased during the past years, the percentage of RAP in asphalt mixtures for its use in wearing courses seldom increases above 20 to 25% [1]. In Brazil, one of the main reasons for RAP's limited use is the lack of asphalt plant adaptations for addition of RAP in the process of production of recycled mixtures. In addition, the variability of RAP and the concern about the mechanical behaviour and performance of recycled materials is also a deadlock. Many researchers consider it and shoed that mixtures with up to 15% are not significantly affected by RAP heterogeneity [2, 3]. However, higher RAP contents can considerably change the overall performance of the mixture. Thus, this paper addresses both, the volumetric and mechanical properties, of recycled asphalt mixtures with low RAP contents.

Research project

The objectives of the research are to evaluate the effect of RAP content on the dosage and mechanical behaviour of hot recycled asphalt mixtures and to verify the effect of the use of one rejuvenating agent in the mechanical properties of recycled asphalt mixtures.

The experimental project of the research consisted in performing the indirect tensile strength (ITS), dynamic modulus (DM) and flow number tests for mixtures with 0, 10, 20 and 25% RAP. After that, the four-point bending test was performed in mixtures with 0 and 25% RAP, before and after addition of a bio-based rejuvenating agent. Table 1 summarizes the experimental project.

There are several methods of RAP addition in batch and continuous plants. Batch plants generally do not allow as high RAP use as drum plants [2, 4]. Thus, the typical range is up to 25% RAP. In Figure 1 is shown a batch plant adapted up to 25% RAP in Brazil. In order to simulate the asphalt plant production of the recycled mixtures, during the dosage of the mixtures in

laboratory, the RAP was introduced at room temperature and virgin aggregates were superheated at 180°C.

Mixture	RAP [%]	Rejuvenating agent	ITS	DM	FN	Fatigue
M0	0	No	Yes	Yes	Yes	Yes
M10	10	No	Yes	Yes	Yes	No
M20	20	No	Yes	Yes	Yes	No
M25	25	No	Yes	Yes	Yes	Yes
M25RA	25	Yes	Yes	Yes	Yes	Yes

Table 1. Experimental project

Figure 1. Batch plant adapted up to 25% RAP.

Findings

The aim of the research was to evaluate recycled asphalt mixtures with low RAP contents. According to the preliminary results, it was possible to conclude:

- the conditioning of RAP affects the dosage and mechanical properties of recycle mixtures;
- test results for mixture with 25% RAP did not follow an expected trend;

- the 25% RAP content is in a low to high level threshold which must be assessed according to the available conditions at the place of production of the mixture.

References

[1] AL-Qadi, I.L.; Aurangzeb, Q.; Carpenter, S. H.; Pine, W.L.; Trapanier, J. Impact of High RAP Content on Structural and Performance Properties of Asphalt Mixtures. Research Report FHWA-A-ICT-12-002, Illinois Center for Transportation, Rantoul. 2012.

[2] Kandhal, P. S.; Mallick, R. B. Pavement Recycling Guidelines for State and Local Governments. Federal Highway Administration, Report Nº FHWA-SA-98-042. Form DOT F 17007.7 (8-72). 1997.

[3] Huang, B. & Vukosavljevic, D. Laboratory study of fatigue characteristics of HMA surface mixtures containing recycled asphalt pavement (RAP). TRB Annual Meeting (CD-ROM). Transportation Research Board of National Academies, Washington, D.C., 2004.

[4] Shah, A.; Mcdaniel, R. S.; Huber, G. A.; Gallivan, V. L. Investigation of properties of plant-produced reclaimed asphalt pavement mixtures. Transportation Research Record: Journal of the Transportation Research Board Nº. 1998, p. 103-111. Washington, D.C., 2007

Activities of the TC 264-RAP TG1 on cold recycling

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Abstract

As it is well known, cold recycling of reclaimed asphalt (RA) is a favourable technique to build or to maintain road networks.

The current RILEM TC 264-RAP TG1 on cold recycling mainly focuses on the influence of different RA sources on physical and mechanical characteristics of cement-bitumen treated mixtures (CBTM) using foam or emulsified bitumen, considering compaction and curing methods. This paper presents the project and the proposals behind the TG1 and the laboratories involved in the inter-laboratory testing project on RA produced and selected in San Marino.

Keywords

Cold recycling, reclaimed asphalt, inter-laboratory testing, compaction procedure, mechanical characterization

Introduction

Cold recycling is a process that generally allows obtaining reliable structural materials to be involved in construction and maintenance projects. Nevertheless, knowledge and expertise in cold recycling are still rather weak, because of the lack of standardized procedures and recognized know-how. This aspect causes both a wide variety of different practices and the inability to unify laboratories and construction procedures.

Cement-bitumen treated materials (CBTM) are produced with a significant amount of reclaimed asphalt (RA), bitumen emulsion or foamed bitumen, cement and water. CBTM is a hybrid material which inherits properties from both asphalt concrete (AC), since the bituminous component plays a significant role, and cement-treated materials (CTMs), because the cement influences stiffness and curing of the mixture.

The basic idea behind CBTMs was to start from a CTM and, adding a bituminous binder (in form of foam or emulsion), to reduce cracking susceptibility and the overall structural stiffness of the recycled material. This results in a mechanical behaviour closer to that of an AC as thermal dependency and fatigue issues appear. The dosages of residual bitumen and cement control the stiffness and thermal sensitivity of CBTMs: these factors must be addressed both in the design and in the construction control phase [1].

The RILEM TC 237-SIB TG6 on cold recycling worked in 2012-2018 on the characterization of RA to be used for cold recycling. This characterization differs from the RA characterization when used in hot recycling, where the aged bitumen melts and the aggregate gradation combines with the virgin material. In cold recycling the RA behaves as it is and for instance black gradation, fragmentation resistance and geometric properties of particles have a significant influence on the performance of the final product [2, 3]. At the end of the TG6 mandate, the RILEM TC 264-RAP launched a new TG, so-called TG1, on cold recycling with the purposes of sharing mix design and curing procedures to support the selection of the optimum mixture also in relationship with RA characteristics. Therefore, a new inter-laboratory testing program has been proposed to the TG1

members to evaluate the influence of different RA sources, appropriately selected and characterized, on strength and stiffness of cold recycled mixtures [4].

Research project

The inter-laboratory testing project considers two RA sources, so-called RAP1 and RAP2, that were produced in San Marino and Alabama, respectively. The project is based on two curing procedures (free-surface drying, FSD, and partially-surface drying, PSD) and involving different compaction techniques (Marshall, Proctor and gyratory compactors).

Mechanical properties will be investigated through a wide experimental program focused on the following properties:

- Strength, by means of the indirect tensile strength;
- Water sensitivity, by means of indirect tensile ratio;
- Stiffness, by means of indirect tensile stiffness modulus and wave propagation;
- Compactability, by means of air voids analysis [5] and compaction evolution.

The laboratories that have been working at the mentioned project are reported in Table 1.

Laboratories	Country
École de technologie supérieure (ÉTS)	Canada
University of New Hampshire	USA
University of the Republic of San Marino, CBR	San Marino
University of Padua	Italy
University of Antwerp – EMIB	Belgium
University of Technology of Vienna	Austria
University of Parma	Italy
University of Technology of Braunschweig	Germany
NTEC Nottingham	United Kingdom
University of Sao Paulo	Brazil
IFSTTAR	France

Table 1. TG1 participating laboratories

References

[1] Grilli, A., Graziani, A., & Bocci, M., Compactability and thermal sensitivity of cement–bitumen-treated materials. Road Materials and Pavement Design, 13(4), 599-617, 2012.

[2] D. Perraton, G. Tebaldi, E. Dave, F. Bilodeau, G. Giacomello, A. Grilli, A. Graziani, M. Bocci, J. Grenfell, P. Muraya, M. Pasetto, K. Kuna, A. Apeagyei, D. Lo Presti, G. Airey, K. Jenkins, E. Hajj, M. Hugener and P. Marsac, Tests campaign analysis to evaluate the capability of fragmentation test to characterize recycled asphalt pavement (RAP) material. In 8th RILEM international symposium on testing and characterization of sustainable and innovative bituminous materials (pp. 965-976). Springer, Dordrecht, 2016.

[3] Partl, M. N., Porot, L., Di Benedetto, H., Canestrari, F., Marsac, P., & Tebaldi, G. (Eds.), Testing and Characterization of Sustainable Innovative Bituminous Materials and Systems: State-of-the-Art Report of the RILEM Technical Committee 237-SIB (Vol. 24). Springer 2018.

[4] https://www.rilem.net/groupe/264-rap-asphalt-pavement-recycling-335, visited on July 30th,2019.

[5] A. Grilli, A. Graziani, E. Bocci, M. Bocci "Volumetric properties and influence of water content on compactability of recycled mixtures", Materials and Structures, ISSN 1359-5997, Volume 49, Number 10, DOI 10.1617/s11527-016-0792-x, 2016.

Evaluation of reliability of RILEM Fragmentation test for RAP characterization

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Abstract

In this study, the authors show the results of a reliability evaluation of the Fragmentation test, proposed by RILEM TC 237-SIB TG6, inducing an artificial variation in the RAP gradation source to create different RAPs that can be considered just apparently the same. A certain amount of RAP aggregates has been gradually replaced with steel slags to assess the sensitivity of this test. The obtained results are encouraging, as they fit with the initial assumption that RAP sources with different percentages of RAP clusters are differently ranked by the Fragmentation test. Thus, a job site laboratory can provide information on the quality of the recycled material to be used on field applications.

Keywords

Fragmentation Test, RAP, modified Proctor

Introduction

Reclaimed asphalt pavement (RAP) is the result of the milling operations, during the rehabilitation of old pavements. This material is composed by a blend of aggregates of different size, glued together by old bitumen. It is characterized by a great variation in the structural composition of the material, considering the presence of clusters: fine aggregates bounded together by old bitumen.

The correct evaluation of RAP characterization was one of the main purposes of the RILEM Technical Committee 237-SIB TG6 Cold recycling: a quick evaluation of this material is highly interesting in order to assess the RAP directly on a job site with a simplified procedure.

Experimental project

This study was focused on the assessment of RAP properties, evaluated by means of Fragmentation test, proposed by the RILEM Technical Committee 237-SIB TG6 Cold recycling [1, 2, 3] and currently by RLEM TC 264-RAP TG1 Cold recycling. In particular, this test is able to identify the changing in the grading curve, due to mixing and compaction phases. The scope of this study is to test one source of RAP, mixed together with steel slag at different percentages, to evaluate if the fragmentation test can detect different RAP sources.

The selected RAP was mixed at a proportion of 50%, to create an artificial material with similar grading curve, but characterized by a different composition and different percentages of RAP clusters. A total of three different types of material were tested: 100% RAP, 50%RAP and 50% steel slag and finally 100% steel slag. The test was performed at three different temperature: 5, 20 and 40°C.

The RILEM protocol for the fragmentation test requires to sieve the material on four different classes from 5 mm to the maximum size of 30 mm. The samples were tested using the modified Proctor test. After the compaction phase, the material was sieved on a 2 mm control sieve. The

coefficient of fragmentation was calculated as the percentage of passing material on the control sieve by total weight of material before compaction.

The Figure 1 shows the variation of the total %PCS as function of temperature, for both 100% RAP and 50% RAP + 50% Steel Slag. The values are standardized referring to the %PCS (percent passing through the control sieve) at 5°C for each mixture. This can highlight a better understanding of the temperature susceptibility of the two analysed blends, which represent different percentages of bitumen. More details about the results have been reported in the paper [4].

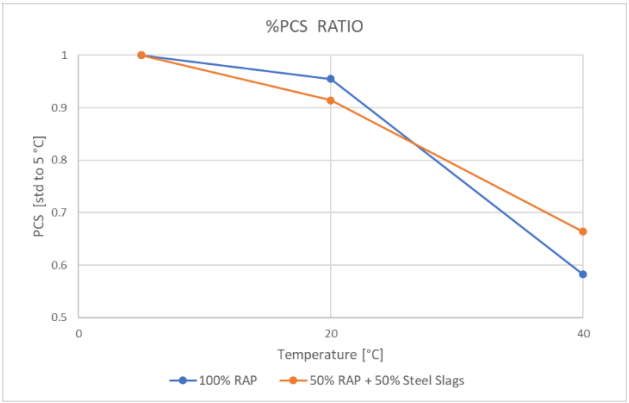

Figure 1. %PCS Ratio at different temperatures [4]

Findings

The authors proposed a method to assess the reliability of the Fragmentation test to characterize RAP materials. The following conclusions can be drawn:

- This test can distinguish different RAP sources, confirming the previous results published by Perraton et al.
- The less number of clusters are in the material, the less changing in the grading curve can be detected.

- The test conducted at 40°C may indicate the important information on the temperature during the mixing and compaction operations.

References

[1] Perraton, D., Tebaldi, G., Dave, E., Bilodeau, F., Giacomello, G., Grilli, A., & Pasetto, M. (2016). Tests campaign analysis to evaluate the capability of fragmentation test to characterize recycled asphalt pavement (RAP) material. In 8th RILEM International Symposium on Testing and Characterization of Sustainable and Innovative Bituminous Materials (pp. 965-976). Springer, Dordrecht.

[2] Tebaldi G., Dave E., Hugener M., Falchetto Cannone A., Perraton D., Grilli A., Lo Presti D., Pasetto M., Loizos A., Jenkins K., Apeagyei A., Grenfell J., Bocci M., Cold Recycling of Reclaimed Asphalt, Chapter 6, Testing and Characterization of sustainable innovative bituminous materials and systems, STAR 237-SIB, RILEM book series, ISBN 978-3-319-71022-8, 2018.

[3] G. Tebaldi, E. V. Dave, A. Cannone Falchetto, M. Hugener, D. Perraton, A. Grilli, D. Lo Presti, M. Pasetto, A. Loizos, K. Jenkins, A. Apeagyei, J. Grenfell, M. Bocci "Recommendation of RILEM TC237-SIB on fragmentation test for recycled asphalt", Materials and Structures, (2019) 52: 82.

[4] Preti F., Noto S., Gouveia B., Tebaldi G., Evaluation of reliability of RILEM Fragmentation Test, M. Pasetto et al. (Eds.): ISAP APE 2019, LNCE 48, pp. 1–8, 2020.

Comparison of stiffness modulus of cold recycled mixtures obtained from indirect tensile and compression tests

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Abstract

Cold recycling of old asphalt pavements is maintenance treatment which is among one of the most effective in reuse of the old road pavement materials. Addition of cement and bituminous emulsion to mineral mixture allows to obtain durable material with high mechanical performance. On the other hand, addition of two binding agents makes the behaviour of the mixture more complicated. This study presents preliminary results of the comparison of stiffness moduli of six cold recycled mixtures determined from two tests: indirect tensile stiffness modulus and asphalt mixture performance test. Test were conducted for two curing periods in the temperatures of +5°C and +25°C.

Keywords

Cold recycling, stiffness modulus, cement, bituminous emulsion

Introduction

Cold recycling of old asphalt pavements is maintenance treatment which is among one of the most effective in reuse of the old road pavement materials. Addition of cement and bituminous emulsion to mineral mixture composed of old and new aggregate allows to obtain durable material with high mechanical performance. On the other hand, addition of two binding agents makes the behaviour of the mixture more complicated, what was described in many studies [1,2,3]. Bituminous emulsion in the mixtures is responsible for viscoelastic behaviour, especially dependence of mechanical and rheological properties on temperature and time of loading, while addition of cement in the mixtures is responsible for dependence of the mechanical properties on time of curing and its further behaviour in the field, where quite often reflective cracks appear. Another question which is still open is which of the binding agents is responsible for relations between different schemes of tests. Are they stable as in cement bound materials or are they condition dependant as in bituminous materials?

Research project and objectives

For the purpose of the study authors have tested six cold recycled mixtures with the same mineral grading curve and different combinations of binding agents. Binding agents changed in the range between 2% and 4% (6% for emulsion), with the step of 2%. Each of the mixture was given a designation to describe the amount of used binding agents – for example designation C2E4 means that in the mixture 2% of cement and 4% of bituminous emulsion were used. Mixtures were tested in two different tests: Indirect Tensile Stiffness Modulus test according to EN 12697-26 methodology and Asphalt Mixture Performance Test (Figure 1 and Figure 2). Test protocols were appropriately adjusted to cold recycled materials. Mixtures were tested in two curing periods - 28 days and 3 years after compaction in the temperature of +5°C and +25°C respectively. Test schemes are presented in figure 1 and summary of the conducted tests are presented in the table 1.

Figure 1. Test scheme for Indirect Tensile Stiffness Modulus

Figure 2. Test scheme for Asphalt Mixture Performance Test

Materials	Test	Temperature [°C]	Repetitions [no.]
C2E2, C2E4 C2E6, C4E2 C4E4, C4E6	ITSM AMPT	+ 5 + 25	3 (ITSM) 3 (AMPT)

Table 1. Summary of the conducted tests

Findings

Performed test confirmed a complex behaviour of cold recycled mixtures. Following preliminary conclusions can be stated:

- For the temperature of +5°C and curing period of 28 days the ITSM/AMPT ratio is in range from 0.87 to 1.16;
- For the temperature of +25°C and curing period of 3 years the ITSM/AMPT ratio is in range from 0.75 to 1.05;
- Findings should be confirmed with the help of other laboratories (round robin test) to avoid accidental errors;
- The relations should be studied also for other schemes of tests and combination of the test conditions.

References

[1] Dołżycki B., Jaczewski M., Author and Szydłowski C. The long-term properties of mineral-cement-emulsion mixtures. Construction and Building Materials, 156, 799-808, 2017.

[2] Graziani A., Godenzoni C., Canestrari F. Experimental characterization of the 3D linear viscoelastic behavior of cold recycled bitumen emulsion mixtures. Journal of Traffic and Transportation Engineering (English Edition), 6(4), 324-336, 2019.

[3] Grilli A., Cardone F., Bocci E. Mechanical behaviour of cement-bitumen treated materials containing different amounts of reclaimed asphalt. European Journal of Environmental and Civil Engineering, 22(7), 836-851, 2018.

Investigation of cold in-place recycled mixtures fracture parameters

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Abstract

The mineral-cement-emulsion (MCE) mixtures are one of the subbase layer used in road reconstruction in Poland. MCE mixtures are one of major types of cold recycling of old asphalt pavements, composed by binding of the old materials reclaimed from the pavement and new mineral aggregate using two different binding agents – cement and asphaltic emulsion. The main objective of this study was to try to rank MCE subbase in terms of crack resistance compared to other road base materials. The additional objective was to check whether the change in the proportion of binding agents (cement and emulsion) influences the fracture resistance of the mixtures.

Keywords

Fracture toughness, cold in-place recycling, road subbase

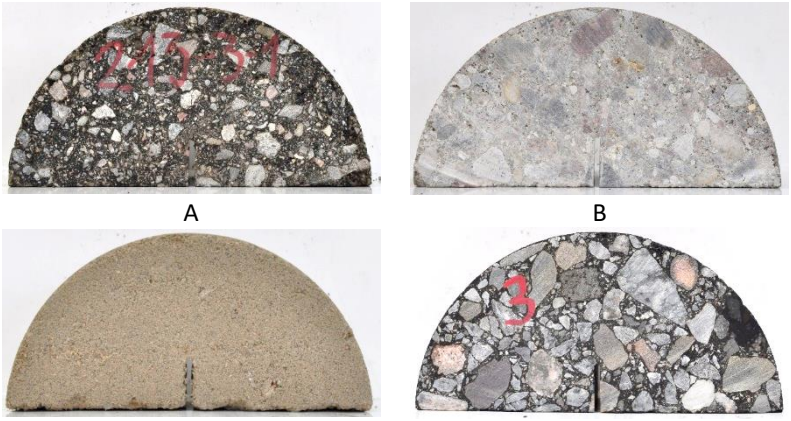
Introduction

Deep cold in-place recycling belongs to the most commonly used types of recycling of existing old flexible pavements, especially when it comes to low-volume roads (local roads) [1]. Different types of binding agents and their combinations are used for cold in-place recycling. In Poland the two most common technologies are miner-al-cement-emulsion mixtures (MCE) and mixtures with combination of foamed bitumen and cement.

The properties of an MCE mixture strongly depend on the proportions and interactions between the two binding agents used [2, 3, 4]. An addition of emulsion results in an increase in viscous behaviour (the pavement acts more similarly to a flexible pavement), an increase in internal integrity, a decrease in the risk of shrinkage cracking, an increase in resistance to water and frost action, as well as an increase in the fatigue life of the pavement.

Research project

To access CIR mixtures fracture parameters MCE mixtures were made with six combinations of binding agents (mixture designations: C = % of cement, E = % of emulsion, ex. C2E2) and compared with materials commonly used in road subbase construction – cement-treated aggregate C1.5/2, cement concrete C8/10 and three type asphalt mixtures AC 22 P. For the evaluation of road materials cracking resistance, the basic parameters of fracture mechanics were determined: fracture toughness K_{IC} and *J*-integral. The tests were performed on semi-circular beams (SCB), at +10°C with deformation speed equal to 1mm/min. Samples with three notch depth were tested: 10mm, 20mm and 30mm. The view of tested materials are show on figure 1.

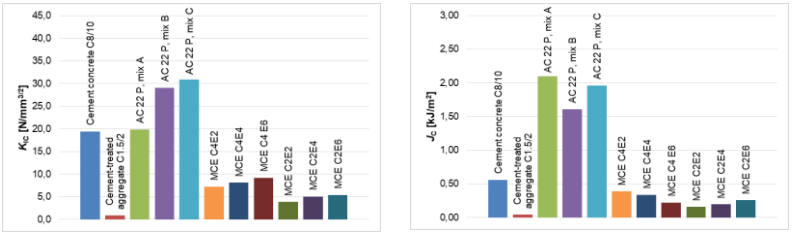


A B C D

Figure 1. View of tested materials for road subbase, A – MCE mixture, B – cement concrete C8/10, C – cement-treated aggregate C1,5/2, D – asphalt concrete AC 22 P

Preliminary results

Based on the results of the studies, it can be concluded that the MCE subbase is more resistant to cracking than cement-treated aggregate and less resistant to cracking than asphalt concrete or cement concrete. Figure 2 presents mean value of fracture toughness for three notch depths and *J*-integral of tested materials.



A B

Figure 2. Results of fracture test, A – K_{IC}, B – J_C

Based on the preliminary test results it could be stated that:

- An increase in the emulsion content at a constant cement content results in an increase in fracture toughness;
- In the case of *J*-integral, there is no constant dependence on binding agents combinations;
- MCE mixes are characterized by lower resistance to cracking than bituminous concrete AC 22 P and cement concrete C8/10 and higher resistance to cracking than the cement-treated aggregate C1.5/2.

References

[1] Dołżycki B., Jaskuła P.: Review and evaluation of cold recycling with bitumen emulsion and cement for rehabilitation of old pavements. Journal of Traffic and Transportation Engineering, Volume 6, Issue 4, 311-323, 2019.

[2] Buczyński P., Iwański M.: Complex modulus change within the linear viscoelastic region of the mineral-cement mixture with foamed bitumen. Construction and Building Materials 172, 52-62, 2018.

[3] Bocci M., Grilli A., Cardone F., Graziani A.: A study on the mechanical behaviour of cement–bitumen treated materials. Construction and Building Materials 25, 773–778, 2011.

[4] Meocci M., Grilli A., La Torre F., Bocci M.: Evaluation of mechanical performance of cement–bitumen-treated materials through laboratory and in-situ testing. Road Materials and Pavement Design 18(2), 376-389, 2017.

[5] Dolzycki B., Jaczewski M., Szydlowski C.: The long-term properties of mineral-cement-emulsion mixtures. Construction and Building Materials 156, 799-808, 2017.

Differences between cold-recycled asphalt base produced in the mixing plant and in situ with the recycling machine

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Abstract

Cold mix asphalt (CMA) manufactured using bitumen emulsion is more and more used to buid base and subbase courses of road pavement. CMA is a promising alternative material for a wide range of paving applications from preventive maintenance and repair to new pavement construction. In these mixes, due to economic and environmental reasons, it is common to use, instead of virgin aggregates, reclaimed asphalt pavement (RAP).

In this research project, the differences between the volumetric and mechanical characteristics of cold-recycled asphalt base (CRAB) produced in the mixing plant and in situ with the recycling machine will be evaluated. The mix curing will also be investigated.

Keywords

Cold-recycled asphalt base, Recycling machine, Reclaimed Asphalt pavement (RAP), Curing, Asphalt Plant

Introduction

Nowadays, due to economic and environmental reasons, the tendency is to use reclaimed asphalt pavement (RAP) as much as possible. The use of RAP is relevant to safeguard natural resources and avoid the impact caused by the extraction of virgin materials, producing economic and energy savings. [1].

Particularly, in the base and subbase courses, the use of cold recycling techniques is very widespread because it allows using 100% of RAP [2]. The bitumen emulsion and foamed bitumen are the most frequently used binders in cold recycling applications. In the CRAB, they are mixed with RAP, water, cement and eventually raw aggregates to correct the gradation curve.

Two ways are available to produce a CRAB mix. The first consist of mixing the materials in the plant as in the case of hot-mix-asphalt, the second deals with the use of a recycling machine to mill, mix and lay down the CRAB directly in situ.

Research project

This research program aims at evaluating the differences of the mechanical performances between CRAB produced in plant and in situ with/without RAP gradation correction.

For this purpose, indirect tensile stiffness modulus (ITSM) tests and indirect tensile strength (ITS) tests were carried on in 4 different kind of cold recycled mixtures (Table 1).

All the specimens (150 mm diameter) have been compacted in situ with gyratory compactor (100 revolutions).

Mix	Type	Raw aggregates
A	recycling machine	coarse aggregates
B	recycling machine	coarse aggregates
C	recycling machine	NO
D	mixing plant	coarse aggregates

Table 1. List of mixes made and tested

The tests were carried out at 4 different curing times (3, 7, 14, 28 days), also highlighting the moisture loss.

Preliminary results and expected outcomes

The following figures show the moisture loss, ITS and ITSM trends of the 4 mixtures tested.

For all the comments and considerations further tests of characterization of the mixture composition are necessary. These tests will be carried out soon.

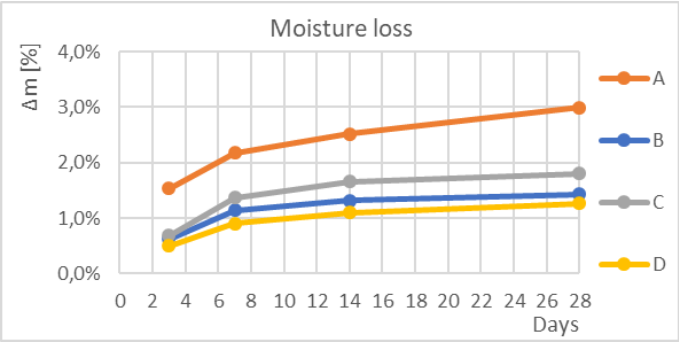

Figure 1. Evolution of moisture loss with curing

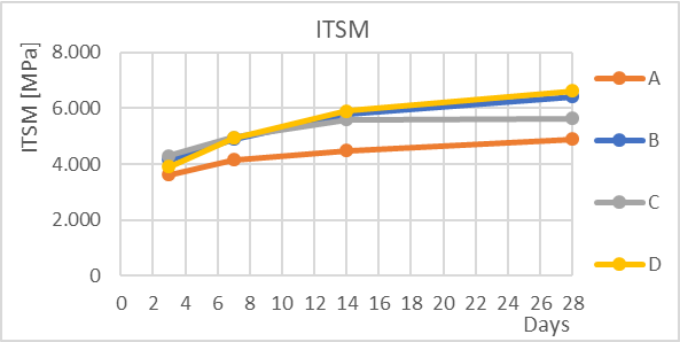

Figure 2. Evolution of ITSM with curing

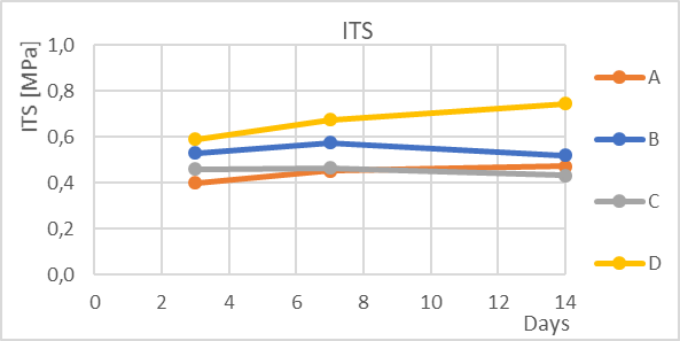

Figure 3. Evolution of ITS with curing

References

[1] G. Flores, J. Gallego, L. Miranda, J. R. Marcobal. Design methodology for in situ cold recycled mixtures with emulsion and 100% RAP. Construction and Building Materials. 2019.

[2] M. Faramarzia, K. W. Leeb, Y. Kimc, S. Kwon. A case study on a cement treated RAP containing asphalt emulsion and acryl polymer. Case Studies in Construction Materials. 2018.

Modified bending beam rheometer test for rheological analysis of asphalt emulsion-cement mastics

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Abstract

This work focused on exploiting the potential of the BBR test for analysing asphalt emulsion-cement mastics tailored for cold in-place recycling applications in the first weeks of curing, i.e. phase which implies the coexistence of viscoelastic and brittle materials. A consistent modified BBR testing protocol, was proposed. The authors suggested to introduce glass microspheres, acting as ‘‘inert solid skeleton”, in the production of AEC mastics for BBR prismatic beams, to study the interaction between asphalt emulsion and cement in thin film and to limit the specimens’ shrinkage and warpage during the curing period. Finally, a feasibility study for validating the new modified experimental setup was presented.

Keywords

Asphalt emulsion, asphalt-cement composites, glass microspheres, BBR, rheometry

Introduction

With the widespread of asphalt emulsion-cement (AEC) composites a number of studies received extensive attention since the 1970s [1]. Today the use of AEC composites in cold-in-place recycling (CIR) is gaining world-wide recognition and popularity. In this application, the primary binder is the asphalt emulsion whereas cement is used as an admixture to significantly improve the early performances of the mix. Although the simultaneous presence of so different binders does not produce a new one [2], the physical and mechanical properties over time of the AEC mixtures depend on the dosages and the relative proportions between the asphalt binder contained in the emulsion and the cement, i.e. on the asphalt to cement ratio (A/C). The performances of AEC mortars and mixtures mainly depend on the rheological properties of their corresponding mastics. In the light of the above the authors suggest to study the behaviour of the AEC mastics tailored for CIR applications in the first weeks of curing, exploiting the potential of the BBR [3]. The flexural creep stiffness, determined from this test, would represent a very interesting parameter to describe the stress–strain–time response of AEC mastics at the test temperature within the linear viscoelastic response range. The main objective of this work was to establish a consistent testing protocol, that outlined in detail all the practical steps for the sample preparation and the test procedure, to analyse AEC mastics characterized by a wide range of consistency using the BBR approach [4].

Experimental project

To study the interaction between asphalt emulsion and cement in thin film, the authors proposed to introduce glass microsphere (with a nominal diameter of 400–600 µm) as “solid skeleton” which represent ideal aggregates: the glass composition, the very low oil and water absorption, the high chemical resistance and the near perfect spherical shape make them excellent for this application. After a preliminary study three parameters were considered: glass microspheres volume concentration

(ϕ_{gm}) equal to 0.5; water volume concentration (ϕ_w) equal to 0.3; volumetric asphalt to cement ratio (A/C) ranging from 0 to 5. A fixed amount of pre-wetting water was added to glass microspheres and stirred until a homogeneous mixture was obtained. Then, the cement was put, and the mixture mixed for one minute, to enhance the workability and avoid the emulsion breaking. Afterwards, asphalt emulsion was added and stirred for one minute. Once a homogeneous mixture was obtained, it was poured into the test moulds. The filled moulds were stored at lab condition for 48 h prior to demoulding. Before demoulding, the moulds were cooled in a cold chamber (T = -10°C) for three minutes to stiffen the test specimens so they can be readily demoulded without distortions. Cement and glass microspheres guarantee a stiffer behaviour of the samples also at higher temperatures. Thus, tests were performed at above-zero temperatures to analyse the mastics behaviour closer to the ordinary conditions and to ignore the contribution of possible residual frozen water entrapped in the samples. A reduced load of 490 ± 20mN was applied for 240 s to maintain the deflection within the linear elasticity limits.

Preliminary results

The results of the feasibility study, performed on a set of mixtures characterized by different A/C volumetric ratios, offered possible interpretation keys about these mixtures. The trend of the flexural creep stiffness and of the m-value by varying the A/C ratio can give significant information about the mastics behaviour, in terms of prevalence of asphalt or cement contribution. These rheometric measurements resulted to be ideal to highlight the time and temperature dependency of several related phenomena which affect these mixtures, also verifying the applicability of the time-temperature superposition principle. In summary, the modified BBR test represents a good approach to analyse the behaviour of AEC mastics as a function of different parameter providing a rigorous and controllable theoretical assumption in the laboratory for optimizing the mix design in full-scale or to evaluate, in back analysis, the reasons for successes and failures.

References

[1] X. Fang, A. Garcia-Hernandez, P. Lura, Overview on cold cement bitumen emulsion asphalt, RILEM Technical Letters. 1 (2016) 116–121. doi:10.21809/rilemtechlett.2016.23.

[2] [F. Giuliani, X-ray diffraction method for studying cement-modified bitumen emulsion mixtures in asphalt pavement cold recycling, in: First International Symposium on Subgrade Stabilization and in Situ Pavement Recycling Using Cement, Salamanca, 2001.

[3] H.U. Bahia, D.A. Anderson, D.W. Christensen, The bending beam rheometer: a simple device for measuring low temperature rheology of asphalt binders, in: Asphalt Paving Technology: Association of Asphalt Paving Technologists-Proceedings of the Technical Sessions, 1992: pp. 117–153.

[4] E. Garilli, F. Autelitano, F. Giuliani, Use of bending beam rheometer test for rheological analysis of asphalt emulsion-cement mastics in cold in-place recycling, Construction and Building Materials. 222 (2019) 484–492. doi:10.1016/j.conbuildmat.2019.06.141.

Effect of freeze-thaw cycles on RAP/natural aggregate unbound mixtures properties

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Abstract

This paper presents an experimental study to evaluate the effect of freeze-thaw cycles on performance properties of reclaimed asphalt pavement (RAP)/natural aggregate mixtures for the construction of unbound base layers. A californian bearing ratio test and repeated load triaxial test were carried out on RAP and crushed limestone mixtures with varying RAP content on standard samples and samples exposed to freeze-thaw cycles. With an increase in RAP content, the sensitivity of the mixtures to freeze-thaw cycling is reduced, but only up to certain RAP content.

Keywords

Repeated load triaxial test, freeze-thaw, bearing capacity, resilient moduli, permanent deformation

Introduction

Unbound granular base layers are commonly used in asphalt pavements as they are the most economical option to ensure adequate strength of the pavement structure. Although these layers are traditionally built with locally sourced natural aggregates, the depletion of natural aggregate resources on one side and increased quantities of construction and demolition (C&D) waste on the other side lead to introduction of recycled materials such as reclaimed asphalt pavement (RAP) into unbound granular layer. The use of RAP in unbound base courses is considered inferior when compared to its use in asphalt courses, but this method of using RAP has nevertheless gained in popularity because it is a material recovery technique, and because of its favourable environmental effects (conservation of natural resources, minimisation of waste), and economic benefits [1].

In Croatia, RAP/natural aggregate mixtures were used as material for unbound layer in several rehabilitation projects, mainly on local roads with thin asphalt layer. Characterisation of RAP natural aggregate mixtures in these projects was done using technical requirements set for natural aggregates. Although all mixtures passed materials characterisation tests, and material was characterised as suitable for construction of the unbound layer, soon after construction (after the winter period) problems in the form of excessive deformations occurred. To gain better insight into performance of RAP/natural aggregate mixtures systematic laboratory research was conducted. Research included investigation on the effect of freeze-thaw cycles on RAP/natural aggregate bearing capacity expressed by Californian Bearing Ratio (CBR), resilient moduli and permanent deformations.

Research project

Laboratory test, e.g. California bearing ratio, resilient moduli and permanent deformation were done on four RAP/natural aggregate mixtures: a mixture with 100% crushed limestone (control mixture), and mixtures with 20, 35, and 50 % RAP.

More on the mixture properties, sample preparation and treatment, as well as California bearing ratio and repeated load triaxial test configurations can be found in [1], [2] and [3].

Findings

Main findings of conducted research indicate that RAP/natural aggregate mixtures exposed to freeze-thaw cycles have lower values of CBR and resilient moduli (Figure 1), and are more prone to accumulation of permanent deformation (Figure 2).

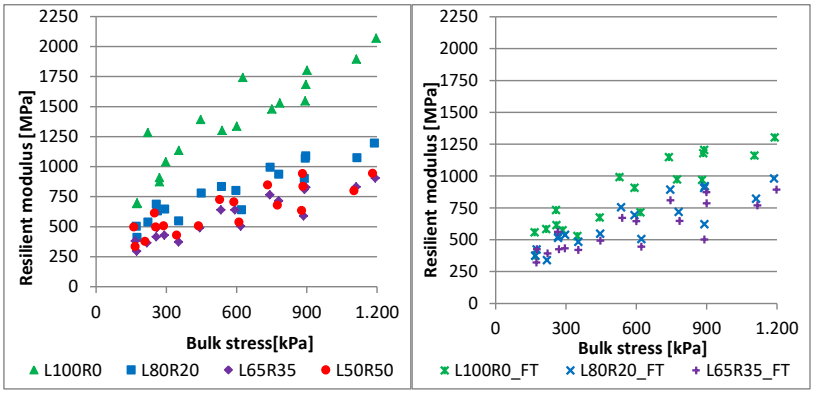

Figure 1. Resilient moduli velues on standard (left) and conditioned (right) samples (left) and samples exposed to freeze-thaw cycles (right) [3]

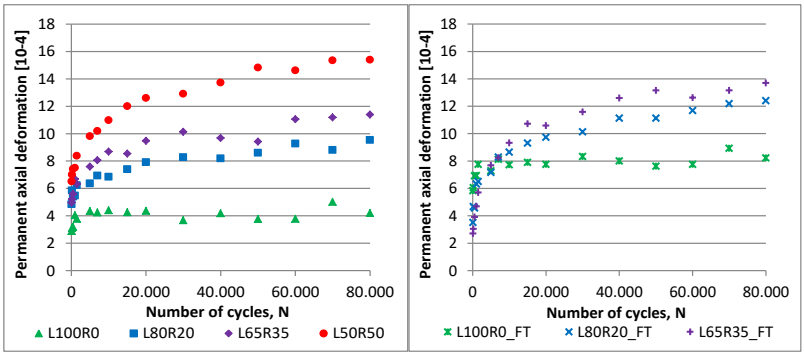

Figure 2. Results of permanent deformation test on standard samples (left) and samples exposed to freeze-thaw cycles (right) [3]

Comparison of standard samples and samples exposed to freeze-thaw cycles indicates that investigated mixtures are less sensitive to freeze-thaw conditioning but only up to certain RAP content (less than 35% of RAP).

References

[1] Domitrović, J. ; Rukavina, T. ; Dimter, S. Properties of unbound base course mixes with recycled asphalt. Građevinar, 68, 269-277, 2016.

[2] Domitrović, J. ; Rukavina, T. ; Dimter, S. Effect of moisture content and freeze-thaw cycles on bearing capacity of RAP/natural aggregate mixtures. 4th International Conference on Road and Rail Infrastructure-CETRA 2016, Šibenik Croatia, 23-25.05.2016.

[3] Domitrović, J., Rukavina, T., Lenart, S. Effect of freeze-thaw cycles on the resilient moduli and permanent deformation of RAP/natural aggregate unbound base mixtures. Transportation Geotechnics, 18, 83-91, 2019

Mastic Creep investigation for predicting HMA creep behaviour

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Abstract

Nowadays, heavy traffic levels and climatic changes combination can lead to a premature pavement failure. This phenomenon is usually due to the damage accumulation. To better understand and predict this HMA behaviour, a mastic creep compliance investigation has been done. This study was conducted by performing a new direct tensile creep test (MDTCT) and using a servo-hydraulic machine. The test has been calibrated by applying three different loads, 100, 150 and 200 N, at 7°C. The preliminary results shown less creep curves accuracy. However, a home-made gravity creep machine has been properly designed to increase the curves fitting.

Keywords

Mastic Creep Compliance, HMA, Permanent damage accumulation, Heavy traffic level, SuperPave

Introduction

Last decades have been labelling from increasing traffic levels and climatic changes. Their combination can lead to a premature pavement failure usually due to the accumulation of deformation. Several studies aimed to establish a new methodology for performance-HMA mechanical characterisation. The SuperPave protocol was defined to satisfy this request. However, three different tests, creep compliance [3], resilient modulus [1] and tensile strength [2], were calibrated. Based on those tensile strength tests a viscoelastic-HMA mechanical framework cracking behaviour has been developed and the fracture energy parameter was introduced [4-6]. Based on that information, the effects of filler on HMAs were studied by introducing a new test configuration [7]. By using it, a relationship between mastics and HMAs mechanical cracking behaviours was carried out and the influence of fillers on the fracture energy parameter was established [8]. This research project aims to study and compare the HMA creep compliance with the mastic creep.

Research project

This research project aims to predict the HMA creep behaviour by calibrating a new MDTCT. To correctly achieve the proposed aim, a servo-hydraulic test machines was used. The test has been calibrated by using three loads, 100, 150 and 200 N, and 60 seconds of load application. The tests were performed at 7°C to respect the material visco-elastic region. The involved materials have been currently represented from a starting combination of SBS modified bitumen, PG 64-22, and limestone filler. The aim will be enhanced by comparing and statistically analysing the results of both mastic and HMA analyses. After the mentioned calibration, the described analysis will be performed by selecting other fillers and bitumen for validating the test.

Preliminary results

Preliminary servo-hydraulic-test-machine-results have been shown in Figure 1. Analysing those outcomes is possible to carry out that the servo-hydraulic machine presents high load noise and the accuracy of the measurement has been affected from it. This result needed to necessarily design a gravity home-made machine. Its load application has not affected from any noise due to the gravity action. The expected results should be better fitted creep curves and test repeatability. Further investigation will involve other test methodologies and their results will be compared with the mastic DTC outcomes.

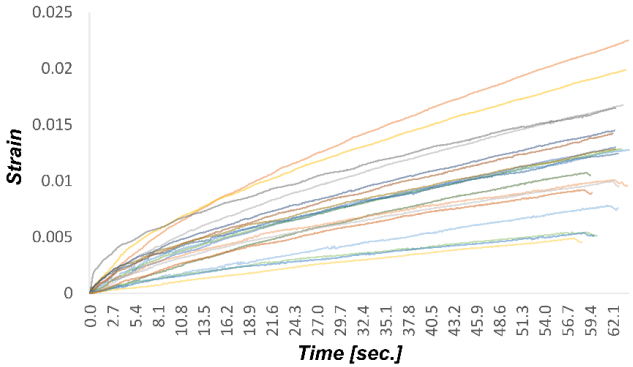

Figure 1. Servo-hydraulic test machine results

References

[1] Buttlar, W. G., & Roque, R. (1994). Development and evaluation of the strategic highway research program measurement and analysis system for indirect tensile testing at low temperatures. Transportation Research Record, 1454, 163–171.

[2] Roque, R., & Buttlar, W. G. (1992). The development of a measurement and analysis system to accurately

determine asphalt concrete properties using the indirect tensile mode. Journal of the Association of Asphalt Paving Technologists, 61, 304–332.

[3] Roque, R., Zhang, Z., & Sankar, B. (1999). Determination of crack growth rate parameters of asphalt mixtures using the Superpave Indirect Tension Test (IDT). Journal of the Association of Asphalt Paving Technologists, 68, 404–433.

[4] Zhang, Z., Roque, R., Birgisson, B., & Sangpetgnam, B. (2001). Identification and verification of a suitable crack growth law. Journal of the Association of Asphalt Paving Technologists, 70, 206–241.

[5] Roque, R., Birgisson, B., Drakos, C., & Dietrich, B. (2004). Development and field evaluation of energybased criteria for top-down cracking performance of hot mix asphalt. Journal of the Association of Asphalt Paving Technologists, 73, 229–260.

[6] Roque, R., Birgisson, B., Sangpetgnam, B., & Zhang, Z. (2002). Hot mix asphalt fracture mechanics: A fundamental crack growth law for asphalt mixtures. Journal of the Association of Asphalt Paving Technologist, 71, 816–827.

[7] Montepara, A., Romeo, E., Isola, M., & Tebaldi, G. (2011). The role of fillers on cracking behaviour of mastics and asphalt mixtures. Journal of the Association of Asphalt Pavement Technologists, 80, 161–191.

[8] Antonio Roberto, Elena Romeo, Antonio Montepara & Riccardo Roncella (2018): Effect of fillers and their fractional voids on fundamental fracture properties of asphalt mixtures and mastics, Road Materials and Pavement Design, DOI:10.1080/14680629.2018.1475297.

Investigation of thermal behaviour of coloured asphalt pavements

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Abstract

Coloured pavement techniques are more and more used in urban areas as traffic calming measures for the pedestrian areas and bike lanes but also as valuable mitigation strategy for the phenomenon of heating concentration through the cities. Along with the mechanical characterization, a consistent knowledge of the thermal behaviour of these materials is needed. The research project on thermal behaviour of coloured pavements undertakes an experimental investigation involving red, yellow, green and blue specimens utilizing mortars and resins for surface treatments, or tinted oxides for the colour modification of the asphalt mixes. The results highlight the contribution of colour in terms of heating processes.

Keywords

Coloured asphalt, thermal behaviour, oxides addition

Introduction

Coloured asphalt pavements could represent an innovative solution to the Urban Heat Island (UHI) phenomenon (i.e. temperature increases in cities) as well as for aesthetic preservation and traffic calming [1, 2]. Important benefits could be obtained with the use of suitable coloured or clear materials in terms of thermic and permeability properties [3]. Coloured or clear road pavements can be built using different materials and techniques such as synthetic transparent binders, modified decoloured bitumens, additives and pigments for mixtures, varnishes and paintings for wearing courses [4].

Experimental project

"Fully-coloured" asphalt concretes were achieved by adding coloured oxides (red or green pellets dosed at 5% by aggregate weight) during the preparation of a dense graded asphalt concrete (AC16) obtained using limestone aggregates and 50/70 penetration-grade bitumen. On the other hand, surface-coloured mixes were obtained by painting the black upper surface of "black" reference AC16 slabs using alternatively mortars or resins for surface treatment.

Thermal performance of studied materials was assessed analysing material responses in terms of simulated in-service temperatures, emissivity and albedo values. Thermic distributions on slabs were recorded by a thermal camera (Figure 1). Experimental setting up was organized to minimize the influence of boundary conditions [5].

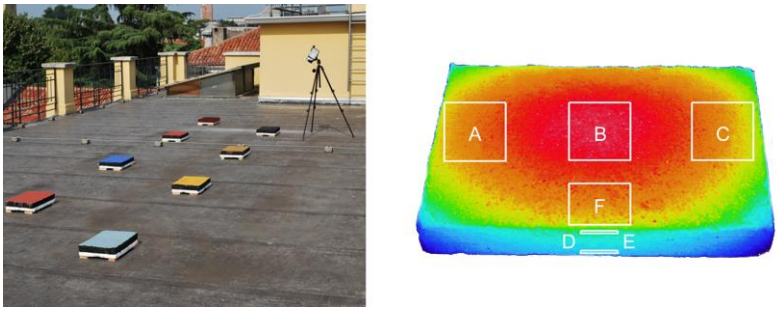

Figure 1. Set up (left), recorded temperature distribution (right) [5]

Findings

Emissivity calibration did not show significant information; inversely, albedo values indicate highest attitude to light rays' reflection for azure mortar slab and yellow resin slab. These findings were in accordance with average thermic trends deduced from in-service monitoring. In this case, highest heat mitigation was reached by azure mortar slab, with lower peak or medium temperatures. In general, results suggested that colour seems more effective with respect to material type in the case of surface treatment, as well as oxide pigments were not strongly able to mitigate heat concentration regardless the colour used (red or green). Thermal analysis suggested that surface colour (rather than material types) provided a sensible contribution to contain in-field surface temperatures. Along with a mechanical characterization, these preliminary findings seem to highlight suitable solutions to achieve thermal-optimized surfaces able to mitigate urban heat island phenomenon.

References

[1] Kyriakodis, G.E., Santamorius, M.: Using Reflective Pavements to Mitigate Urban Heat Island in Warm Climates - Results from a Large Scale Urban Mitigation Project, Urban Climate, In press (2017), pp. 14, doi: 10.1016/j.uclim.2017.02.002.

[2] Bocci, M., Grilli, A., Cardone, F., Virgili, A.: Clear Asphalt Mixture for Wearing Course in Tunnels: Experimental Application in the Province of Bolzano, Procedia - Social and Behavioral Sciences, 53 (2012), pp. 115-124, doi: 10.1016/j.sbspro.2012.09.865.

[3] Li, H., Harvey, J.T., Holland, T.J., Kayhanian, M.: The Use of Reflective and Permeable Pavements as a Potential Practice for Heat Island Mitigation and Storm Water Management, Environmental Research Letters, 8 (2013) 1, pp. 1-14, doi: 10.1088/1748-9326/8/4/049501.

[4] Merusi, F., Giuliani, F.: Chromatic and Rheological Characteristics of Clear Road Binders, Transportation Research Record: Journal of the Transportation Research Board, 2293 (2012), pp. 114-122, doi: 10.3141/2293-14.

M. Pasetto, E. Pasquini, G. Giacomello, A. Baliello, “Preliminary investigation of mechanical and functional properties of coloured asphalt pavement surfaces”, 5th International Conference on Road and Rail Infrastructure CETRA2018, Zara, 2018.

Linking infrastructure IFC models with databases

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Abstract

Recent developments in terms of full standardization of information modelling (BIM) for linear infrastructure projects as proposed by building SMART, finally opened the possibility of accomplishing fully interoperable models. Infrastructure information models become valuable assets when they are harnessed in a project's common data environment and potentially integrated with external databases, resourcing for example to Object Relational Mapping (ORM) techniques. The present paper summarizes the latest standardization progresses and their relevance to the sector, outlining next stage BIM workflows that integrate BIM models and databases.

Keywords

Building Information Modelling (BIM), Industry Foundation Classes (IFC), Database Programming

Introduction

The offered possibilities of Building Information Modelling (BIM) when applied to linear infrastructure projects, such as highways, are being continuously explored, enhanced and researched by the industry and academic communities [1]. Currently, more than mitigating the asset's impact on the surrounding environment, practitioners are becoming aware of the importance of connecting risk vulnerability data of the construction itself. Most tools prepared to deliver Virtual Design Models (VDM) offer the possibility to connect external databases to the model, however, real interoperability between them, i.e. by means of open standards, such as Industry Foundation Classes (IFC), still presents challenges. Furthermore, to take the utmost value of IFC in its latest released versions, the infrastructure design software need to be updated, which in the case of linear infrastructure projects is paramount, as BuildingSMART recent standardisation efforts are focused on delivering robust open standards dedicated to this field, including IFC-Road, IFC-Rail, IFC-Bridge and IFC-Tunnel. Infrastructure projects are known for large volumes of data related among others, to design, maintenance, safety, cost and historical data, overloading sometimes the Common Data Environment (CDE) with an unmanageable large number of BIM-submodels. For instance, overlapping GIS data with BIM, creating a connection between existing spatial databases can go beyond georeferencing, as the importance of connecting risk vulnerability data of the construction itself is becoming fundamental for protection of the surrounding environment as well as the preservation of the full operability of the infrastructures.

Connecting IFC to databases

The latest release of the IFC common data schema for Open BIM data exchange, although being published as a draft version, resulted from the IFC-Bridge project conclusion [2]. Accordingly, the leading software companies are already preparing features to enable smooth import/export capability of the standard. Figure 1, exemplifies the specification of the

components and events (e.g. superelevation and lane widening) of the roadway, presenting a longitudinal and lateral breakdown.

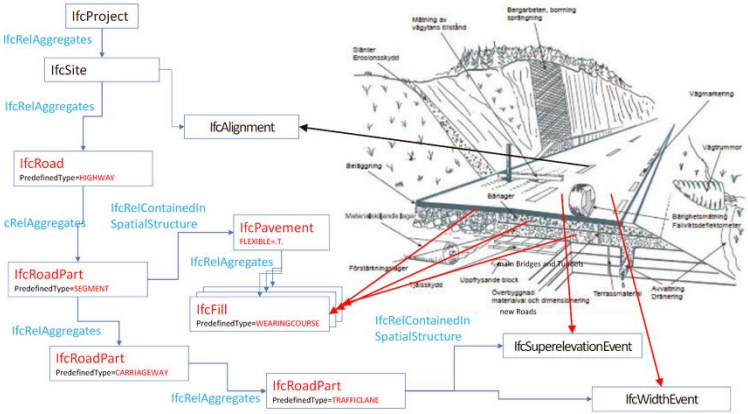

Figure 1. IFC-Road project element proposal, adapted from [3].

Establishing the connection between those elements and required information leads sometimes to the previously mentioned overload of the CDE. BIM workflows are becoming more all-encompassing and databases are needed for storing Master Information Delivery Plans (MIDP), IFC models, normative documents, bill of quantities, spatial data, progress monitoring visual big data [4] etc. Database design is an established technology yet not fully exploited with latest techniques as the Object Relational Mapping (ORM), which enables the conversion of data objects between object-oriented languages, namely Python, Ruby, Java or C++ and a database system [5]. The Entity-Relationship diagram (Figure 2) allows users to design a conceptual map of database tables and their connections. IFC files are stored in the table Document with the fileCategory “IFC”.

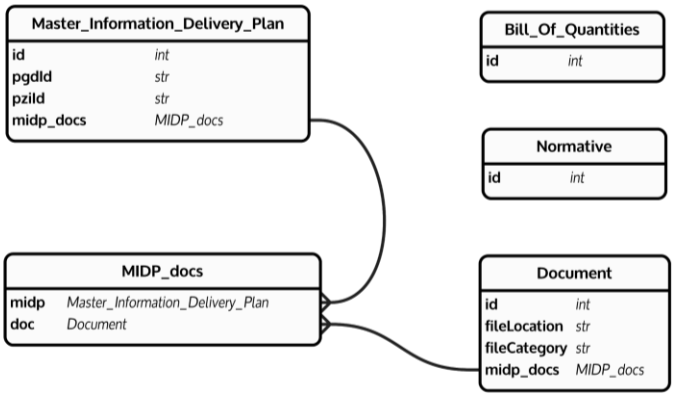

Figure 2. Entity-relationship diagram for a BIM workflow.

The tables are containers that hold data once implemented and populated in a database. The ORM technique creates the database tables from classes in the source code, thus eliminating the need for manual creation at database side. Such application can query a complete project, composed of multiple databases, as if they were stored in memory, streamlining the process of connecting components to their properties. So if a linear infrastructure BIM model is prepared properly resourcing to the latest release IFC 4x2, (even though so far only published as a draft), or following the latest developments from the IFC Road Expert Panel, where the proposal is that all road components are properly defined through specific IFC elements, the task of linking database objects to the model is simplified. Finally, the code below shows classes in Python generated from the entity-relationships diagram on the Figure 3.

```
db = Database()
class Bill_Of_Quantities(db.Entity):
    id = PrimaryKey(int, auto=True)

class Document(db.Entity):
    id = PrimaryKey(int, auto=True)
    fileLocation = Optional(str)
    fileCategory = Optional(str)
    midp_docs = Set('MIDP_docs')
```

```
        class Normative(db.Entity):
            id = PrimaryKey(int, auto=True)

        class Master_Information_Delivery_Plan(db.Entity):
            id = PrimaryKey(int, auto=True)
            pgdId = Optional(str)
            pziId = Optional(str)
            midp_docs = Set('MIDP_docs')

        class MIDP_docs(db.Entity):
            midp                                                =
Required(Master_Information_Delivery_Plan)
            doc = Required(Document)
            PrimaryKey(midp, doc)

        db.generate_mapping()
```

Figure 3. Python generated classes.

The last line of the code directly creates the database tables without any manual intervention. The presented approach is supposed to be less demanding for non-IT engineers, because it abstracts the background coding and manual database SQL operations.

Final remarks

Application of databases to BIM workflows is highly desirable for transportation engineering projects like roads, rails, bridges, tunnels and airports. Advanced object-oriented database design techniques like the ORM shorten the design-to-database-to code path to only the design-to-code path thus eliminating the error-prone manual creation of database tables. With the project database created all projects parts are accessible through one single interface by means of query syntax. This is expected to help the professional teams and researchers providing BIM workflow efficiency, minimizing errors of misplacing important sources of information and preventing incompatibilities between model formats.

References

[1] Dell'Acqua, G., BIM per infrastrutture. Il Building Information Modeling per le grandi opere lineari, EPC Editore, October, 2018.

[2] BuildingSMART, Industry Foundation Classes, Version 4.2 bSI Draft Standard IFC Bridge proposed extension, available at: https://standards.buildingsmart.org/IFC/DEV/IFC4_2/FINAL/HTML/

[3] BuildingSMART, IFC Road Expert Panel WP3: Conceptual Model Report. (2019).

[4] A. Tibaut, D. Zazula, Sustainable management of construction site big visual data, Sustain. Sci. (2018).

[5] Vial, G. (2018). Lessons in persisting object data using object-relational mapping. IEEE Software.

Pavement management system for the road network of the Republic of San Marino

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Abstract

Local road administrations (LRA) manage extended and heterogeneousroad networks with limited budget and human resources. LRA require a tailored pavement management system (PMS) to plan activities and to achieve efficient solution in a multi-year prospective. The adopted PMS in the Republic of San Marino has been based on a tight coordination among the government authority, the national road agency, the geographic information system office, the agency for public services, construction enterprises and mix-plants operating in the territory. This paper shows the pillars of the procedure in use in San Marino considering good practices and potentialities.

Keywords

PMS, local road administration, GIS

Introduction

The pavement management system (PMS) is addressed to identify a rational and cost-effective maintenance planning through a systematic process based on a multi-year assessment [1-5]. Local road administrations (LRA) manage wide and fragmented road network with significant resource constraints. For this reason, infrastructures can appropriately work only through the coordination of all the interested territorial institutions and stakeholders in a specific rational operations plan.

In this context, the University of the Republic of San Marino (UniRSM), the San Marino state-owned enterprise for public works (AASLP), the government authority (SST), the geographic information system office (SIT), the agency for public services (AASS), have been working together since 2016. UniRSM and AASLP play a fundamental role in management, executive and checking actions, working as a central-decision maker and as a bridge among different institutions and stakeholders (Figure 1). UniRSM and AASLP follow the social guideline established by SST and have the mission to satisfy it through the coordination with other agencies (SIT and AASS), mix-plants, construction enterprises and laboratories for quality control [6].

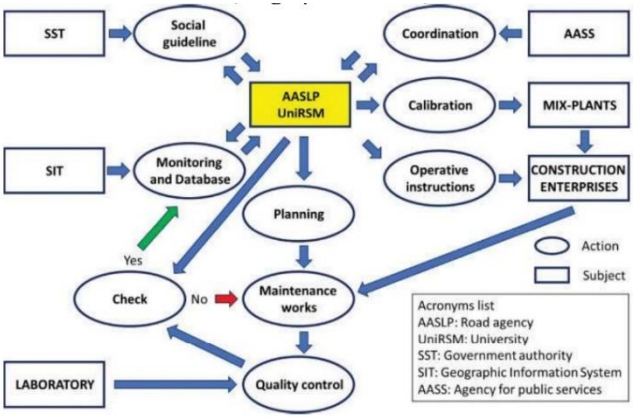


Figure 1. Strategy and coordination for San Marino road management planning

Research project

The research project mainly focuses on the identification of priorities and the prediction of the rideability conditions of existing and new pavements (Figure 2). The ranking of maintenance priority of homogeneous sections of the road network will be determined considering pavement condition (PCI, IRI and TFC), traffic volume, road function and maintenance history. Evolution models implemented in a GIS tool will show the effectiveness of different maintenance methods over time taking into account the economical investments.

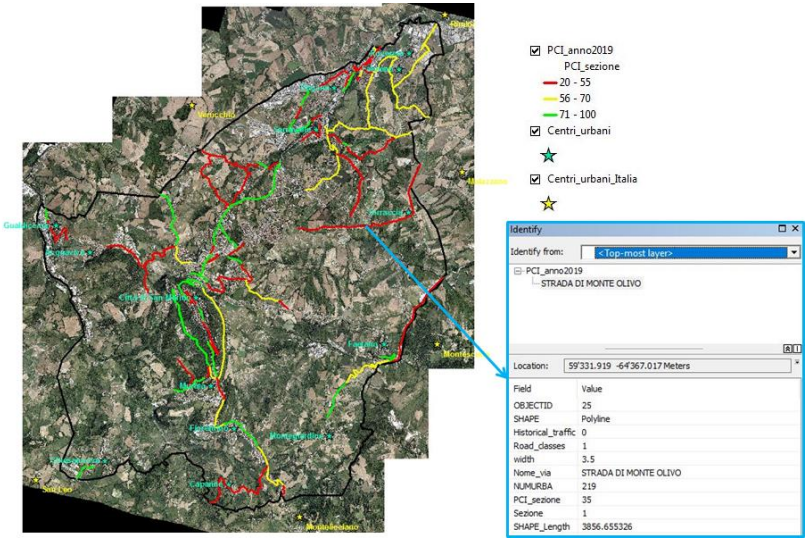


Figure 2: PCI representation on GIS of San Marino main connectors

Expected outcomes

The research project intends to create an overall scheme of actions for an efficient PMS and to develop GIS-supported tools in which implement and share data and to carry out an easy-to-read comparison of design solutions based on a multi-years planning.

References

[1] Wolters A., Zimmerman K., Schattier K., Rietgraf A., Implementing pavement management systems for local agencies, implementation guide. ICT-R27-87, Illinois Center of Transportation, 2011.

[2] Center for Urban Transportation Research, Pavement Management Systems for local Governments. Center for Urban Transportation Research, College of Engineering, University of South Florida, 1995.

[3] Misra A., Roohanirad A., Somboonyanon P., Guidelines for a Roadway Management System (RMS) for Local Governments. Midwest Transportation Consortium, report no. MTC A-01, 2003.

[4] National Cooperative Highway Research Program, Pavement Management Applications Using Geographic Information Systems. NCHRP synthesis 335, Transportation Research Board Washington, D.C. 2004.

[5] Pennsylvania Department of Transportation. Automated pavement condition survey field manual. Bureau of Maintenance and Operations, Asset Management Division, publication 336, Harrisburg, Pennsylvania, 2012.

[6] Grilli A., Casali M., Muratori D., Bascucci F., Pavement Management System for local administrations: Guidelines in the Republic of San Marino. International Journal of Pavement Research and Technology, 12 (2019) 97-100, DOI: https://doi.org/ 10.1007/s42947-019-0012-5.

Sponsors and collaborations

17th SIIV International Summer School 2019
5th SIIV Arena (PhD Symposium)
16-20 September 2019, San Marino, Republic of San Marino

Azienda Autonoma di Stato per i Lavori Pubblici (AASLP)

The first Agreement between the Azienda Autonoma di Stato per i Lavori Pubblici (AASLP) and the University of the Republic of San Marino (Road engineering sector), signed by the Rector of the University, Prof. Corrado Petrocelli, and the President of AASLP, Dr. Federico Bartoletti, dates to 27 September 2016. The relationship between the two national institutions has been continually strengthened so far, in the field of road construction and maintenance as a whole.

Figura 1. Agreement Unirsm-AASLP 2016

The main joined activities are the following:

- tight partnership between the academic teaching on "Road infrastructures" and AASLP technicians allowing open lessons,

specific exercises, training and case studies applied to the San Marino road network;

- identification and application of a rational planning method for road maintenance works including eco-sustainable techniques;
- design and quality control support for innovative and eco-sustainable techniques;
- monitoring of pavement and safety driving conditions;
- coordination for the management of maintenance works on the road network of the Republic of San Marino.

Over the years, the collaboration has led to the organization of numerous meetings and workshops as well as the establishment of relationship with Italian municipalities. From the partnership among University, AASLP and Fano municipality, three technical manuals have been created to help technicians to rank road sections, to identify failures and distresses, to understand road conditions and to determine the specific repair techniques.

Nowadays, Matteo Casali is the Executive Director and manages the agency along with the President, Federico Bartoletti.

Figure 2: Matteo Casali (AASLP director), Federico Bartoletti (AASLP president)

Ecopneus

Ecopneus scpa is the non-profit company for the tracking, collection, processing and final destination of end-of-life tyres (ELTs) created by the major tyre manufacturers operating in Italy (Bridgestone, Continental, Goodyear-Dunlop, Marangoni, Michelin and Pirelli). In the course of time many other companies have joined Ecopneus. Under Art. 228 of Legislative Decree 152/2006, tyre manufacturers and importers are indeed obliged to ensure the management of a quantity of ELTs equal in weight to that which is placed on the replacement market in the preceding calendar year, based on the Extended Producer Responsibility – an organizational model adopted by the majority of the European Countries.

As provided for by Ministerial Decree 82/2011, which implements Art. 228, in addition to providing for all the operations necessary to ensure the correct recovery of all the ELTs under their responsibility, on behalf of its business partners, Ecopneus is also entrusted with the duty of reporting to the Authorities.

Together with the management activities of collection, transportation, treatment and recovery of a yearly average of 210,000 tonnes of ELTs, Ecopneus is also strongly committed to promote the applications for recycled rubber, as well as initiatives of information and awareness raising for the creation of a “recycling culture”.

Each year approximately 350,000 tonnes of tyres reach the end of their life in Italy, equal in weight to over 38 million tyres detached from our cars, two-wheeled vehicles, and trucks, up to large industrial and agricultural vehicles.

A European Union directive has prohibited sending ELTs to landfills since 2006, recognizing the quality and value of recycled rubber for compulsory recovery. This system became operational in Italy in 2011 (DM 82/2011). Ecopneus works within it with the responsibility to track, collect,

and send for recovery an amount of ELTs corresponding to the market share represented by the partner companies, about 70% of the whole national production. This is equivalent to 250,000 tonnes/year as an average.

In order to ensure that the environmental targets are met as well as the best level of service at the minimal cost, Ecopneus has adopted an innovative organizational model (network model) that coordinates a network of qualified companies charged with the collection and transfer of the ELTs to centres specialized in processing and recovery.

Figure 1. Scheme of how Ecopneus works

Marini – Fayat Group

Marini, established in Alfonsine in 1899, is a world leader in the production of asphalt plants.

Activity began with the production of bicycles, motor bikes and 2 stroke diesel engines. Later on, when the road building sector was in great expansion, Marini started the production of asphalt plants, road building machinery and road maintenance equipment.

In 1973 Marini S.p.A. was constituted and in 1988 the majority of shares was acquired by Fayat Holding.

Over the past 10 years, Marini has made important investments in the production sector, emphasizing its distinguishing feature as an industrial complex (Figure 1). This is the result of a precise strategy aimed to guarantee the very best quality by manufacturing the most important asphalt machinery components inside the Marini workshops.

Figure 1: Impianto Marini, Alfonsine (RA - Italy)

In view of this, Marini is able to carry out all main production phases internally: cutting and welding of the sheet-iron, construction of components, assembly, surface treatments like sand-blasting and painting, manufacture and installation of electric and electronic appliances and software development.

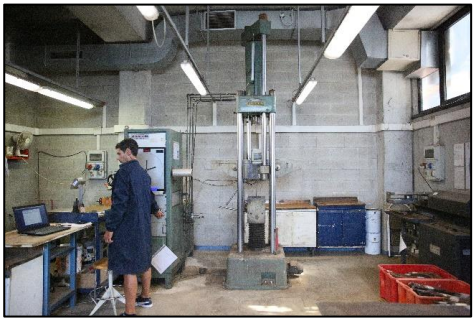
Marini in facts & figures

- 3000 asphalt plants sold worldwide;
- HQ production area exceeding 150,000 m^2;
- 37,000 m^2 under cover;
- a warehouse stock worth more 10 million euros (to guarantee quickest possible spare parts delivery service);
- 400 employees;
- over 1000 voluntary training days each year;
- around 40 young people approach the world of work through Marini's "job experience" programmes thanks to agreements set up with schools, universities and technical colleges;
- a multicultural context consisting of more than 30 different nationalities;
- 3 production branches: China, India and Turkey;
- 3 commercial branches in Russia, Dubai and Poland;
- commercial and after-sales service throughout the world.

Laboratorio TEMA

LABORATORIO SPERIMENTALE
MATERIALI DA COSTRUZIONE

TEMA, founded in 1983, is a laboratory which is active in the field of experimental characterization of construction materials. Its activities are carried out in three main sectors: infrastructures, structures and geotechnics. The laboratory, settled in Fano (PU - Italy), is authorized by the Italian Ministry of Infrastructures and Transportation (Ministero Infrastrutture e Trasporti) to perform certification tests on building materials such as cement concrete, steel, hydraulic binders, aggregates and bricks (as per Law n. 1086/71, art. 20). Furthermore, TEMA operates within the scheme of a quality management system certified according to UNI EN ISO 9001:15.



Universal testing machine

Steel chemical analysis

TEMA has constantly devoted part of its efforts to the support of higher formation activities.

3000 kN Compression machine

One of its Partners has achieved a high degree of specialization in the field of soil mechanics, earning an MS (1993) and a PhD (1998) at the Massachusetts Institute of Technology (MIT), and thereafter reaching the Associate Professor position at Purdue University (2000). Another Partner has focused on topics related to transportation infrastructures, obtaining the Full Professor role in the Politecnico di Torino (2001).

Steel bending test

Marco Simoncelli World Circuit

The Misano motor racing circuit was designed in 1969 (3488 m). and sports activities began after three years. Nowadays, Misano World Circuit is the only circuit in Italy and one of the few in the world hosting the two most prestigious motorcycle world championships. Considering the two new grandstands the capacity of Misano World Circuit (MWC) exceeds 100,000 (figure 1). In 2012, after the death in Sepang of the popular "Sic", who had started his motorcycle career in Misano, the circuit was renamed "Misano World Circuit Marco Simoncelli".

Figure 1: Misano World Circuit Marco Simoncelli

In recent years, MWC has also distinguished itself for its attention to social issues, from road safety to environmental sustainability. A series of initiatives has been promoted to raise public, team and driver awareness of the importance of adopting sustainable behaviour in a social and environmental sense.

Misano World Circuit offers the opportunity to visit the circuit named after the great Marco Simoncelli (Figure 2). The tour is designed in partnership with the AMisano Foundation for fans and tourists that come in Misano Adriatico and on the Rimini Riviera. The tour allows the guests to understand the history of the circuit, facilities and strategic location in a territory, i.e. the Motor Valley and the region of Romagna with a passionate vocation for motorsports.

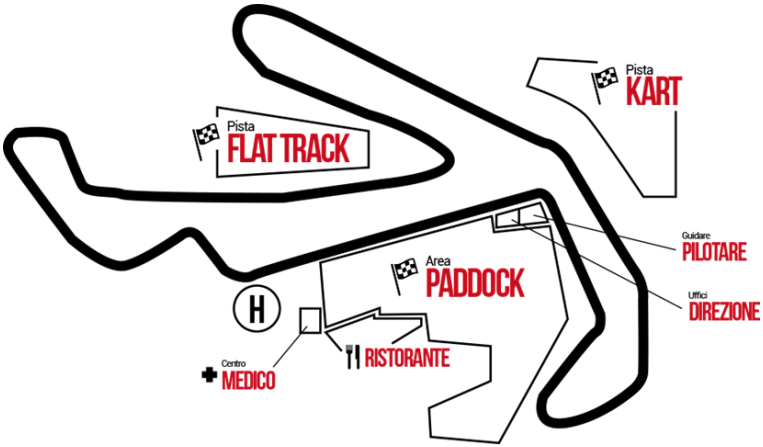


Figure 2. Scheme of the Misano World Circuit Marco Simoncelli

Cooperativa Involo

The social cooperative "*Involo*" is a non-profit organization that deals with services, projects and activities involving disadvantaged people.

The Cooperative was founded in January 2014 and immediately got the approval and support to socio-therapeutic projects from institutions and the San Marino Social Services (ISS).

The Cooperative's mission is to create employment opportunities for disadvantaged groups. The Cooperative focus on the centrality of the human being and human relationships.

The *Involo* Social Cooperative in the last year of activity has involved about 45 people in its activities involving workers into a production process where work is used to stimulate manual skills and relationships.

The Cooperative carries out its main activities in a laboratory located in Galazzano (Republic of San Marino). The activities include packaging, assembling, sorting of postal folders and integration of digital data.

For several years a radio-web-social (involo.org) has been active to give voice to social initiatives.

In addition to the activities that take place within the laboratory there are also external works, such as maintenance of green areas or installation of service machines, which are carried out in small groups supervised by thier instructors.

A pottery (production and sales) in the Acquaviva (San Marino) is in process.

Camerata del Titano

New Music Project: Nicholas Isherwood, Rohan de Saram, Ars Ludi, Lucia Ronchetti, John Kenny, Roberto Fabbriciani, Alvise Vidolin, Magnus Andersson;

String Concert Academy: Ariadne Daskalakis, Leonid Gorokhov, Anthony Spiri, Alessandro Tardino, Luca Sanzò;

International Medieval Music Course: Cristina Alis Raurich, David Fallows, Giovanni Cantarini, Monica Boschetti

Professional Guitar Project: Francesco Biraghi, Piero Bonaguri, Andre De Vitis, Frédéric Zigante;

Accordion Concert Academy: Emanuele Rastelli, Sergio Scappini;

New Music "L'Imaginaire": Andrea Agostini, Ensemble L'Imaginaire, Keiko Murakami, Gilles Grimaitre, Philippe Koerper;

New Film Music: Franco Piersanti;

Courses: Andrea Padova, Daniela Uccello, Enrico Viccardi, Filippo Lattanzi, Marcello Mazzoni, Carlo Alberto Neri, Stefano Malferrari;

Director M° Augusto Ciavatta

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Diana Monaldi – Stiazhkina

Diana is a soprano. She began her studies of choral singing and violin in Russia. In 2011 she received a Bachelor of Science in lyric singing at the State Conservatory in Kazan, Russia. From 2011 to 2019 she was a solo singer at the Mariinsky Theatre in St. Petersburg, directed by Valeriy Gergiev. With the Mariinsky Theatre he has toured many countries such as France, Germany, Italy, Austria, USA, Japan, China and Russia. In 2019 she moved in San Marino where she currently lives.

Emanuele Rastelli

Autodidact at the age of 4, 9 years old he started to study the basic techniques and got clother to the classic style with his teacher, Prof. Massimo Leardini at the Benizzi school in Rimini. In 1996 he won the "Premio internazionale Città di Castelfidardo". At the same event he wins two special awards: "Best Talent" and "Best Bass Player" over 950 musicians from all over the world.

In the last ten years he experimented in various musical styles and performs concerts in the world: Canada, Scotland, Venezuela, Brazil, Argentina, USA, Mexico, Switzerland, Germany, Netherlands Antilles, Norway, Denmark, Uruguay etc.

17th SIIV International Summer School and 5th International SIIV Arena
Resilient road infrastructures:
Climatic changes and perspective of road infrastructures
San Marino, Republic of San Marino
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Antonio Montepara, University of Parma, Italy
Andrea Grilli, University of the Republic of San Marino, San Marino

The SIIV Summer School is a specific event that involves and brings closely into contact the most representative leaders from the academic field, PhD students and research fellows to facilitate exchange of skills and discussion. As a part of the SIIV Summer School, the SIIV Arena (PhD symposium) represents the platform in which PhD students and research fellows show their scientific research, inducing interaction inside the scientific community. The SIIV Arena offers a stage where young researchers paly a leading role promoting ideas and knocking down frontiers in order to exchange knowledge worldwide.

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