EATA2023 program (with abstracts)
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EATA2023

ORGANIZERS:

FRUIT

GDAŃSK UNIVERSITY OF TECHNOLOGY

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Date: Sunday, 11/June/2023

3:00pm - 4:00pm Library Hall (Level 1), Main Building, GdańskTech	**Registration** Location: **Library Hall (Level 1), Main Building, GdańskTech**
4:00pm - 6:30pm Fahrenheit Courtyard (Level 0), Main Building, GdańskTech	**Welcome reception** Location: **Fahrenheit Courtyard (Level 0), Main Building, GdańskTech**

Date: Monday, 12/June/2023

7:30am - 8:30am Library Hall (Level 1), Main Building, GdańskTech	**Registration** Location: **Library Hall (Level 1), Main Building, GdańskTech**
8:30am - 9:00am Aula GdańskTech (Level 3), Main Building, GdańskTech	**Opening** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Gordon Airey**, University of Nottingham, United Kingdom Session Chair: **Prof. Hervé Di Benedetto**, Uni of Lyon / ENTPE, France Session Chair: **Prof. Piotr Jaskuła**, Gdańsk University of Technology, Poland Session Chair: **Prof. Adam Zofka**, Foundation for the Development of Transport Infrastructure Services (FRUIT), Poland
9:00am - 9:30am Aula GdańskTech (Level 3), Main Building, GdańskTech	**Keynote Lecture** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** **Prof. Krzysztof Wilde**, Rector of Gdansk University of Technology Title: **Research on vehicular accidents with road safety equipment and occupant injury analysis**
9:30am - 10:50am Aula GdańskTech (Level 3), Main Building, GdańskTech	**Fatigue performance** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Mª Carmen Rubio Gámez**, University of Granada, Spain Session Chair: **Dr. Dawid Ryś**, Gdansk University of Technology, Poland
10:50am - 11:20am Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech	**Coffee break with posters** Location: **Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech** Chair of poster competition committee: **Prof. Hassan Baaj**, University of Waterloo, Canada
11:20am - 1:00pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Aging and rejuvenation studies** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Michael Wistuba**, Technische Universität Braunschweig, Germany Session Chair: **Dr. Krzysztof Błażejowski**, ORLEN Asfalt, Poland
1:00pm - 2:00pm Fahrenheit and Hevelius Courtyards (Level 0), Main Building, GdańskTech	**Lunch** Location: **Fahrenheit and Hevelius Courtyards (Level 0), Main Building, GdańskTech**
2:00pm - 3:40pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Field validation studies** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Dr. Ann Vanelstraete**, Belgian Road Research Centre, Belgium Session Chair: **Dr. Mieczysław Słowik**, Poznań University of Technology, Poland
3:40pm - 4:10pm Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech	**Coffee break with posters** Location: **Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech**
4:10pm - 5:30pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Cracking resilience** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Cedric Sauzeat**, Uni. of Lyon/ENTPE, France Session Chair: **Dr. Cezary Szydłowski**, Gdańsk University of Technology, Poland
6:30pm - 9:00pm	

Fahrenheit Courtyard (Level 0), Main Building, GdańskTech	**Coctail party** Location: **Fahrenheit Courtyard (Level 0), Main Building, GdańskTech** Co-sponsored by IBEF

Date: Tuesday, 13/June/2023

8:30am - 9:00am Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech	**Coffee break with posters** Location: **Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech**
9:00am - 10:40am Aula GdańskTech (Level 3), Main Building, GdańskTech	**Advanced evaluation of performance-related properties** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Gabriele Tebaldi**, University of Parma, Italy Session Chair: **Oliwia Merska**, West Pomeranian University of Technology, Poland
10:40am - 11:10am Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech	**Coffee break with posters** Location: **Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech**
11:10am - 11:40am Aula GdańskTech (Level 3), Main Building, GdańskTech	**Keynote Lecture** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** **Prof. Eyad Masad**, Ph.D., P.E., F. ASCE Title: **Microstructure Characterization for the Development of Low-Energy Asphalt Binders and Mixtures**
11:40am - 1:00pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Functional pavements** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Fernando Moreno-Navarro**, University of Granada, Spain Session Chair: **Prof. Grzegorz Mazurek**, Kielce University of Technology, Poland
1:00pm - 2:00pm Fahrenheit and Hevelius Courtyards (Level 0), Main Building, GdańskTech	**Lunch** Location: **Fahrenheit and Hevelius Courtyards (Level 0), Main Building, GdańskTech**
2:00pm - 3:40pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Additives and modifications (binders)** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Bernhard Hofko**, TU Wien, Austria Session Chair: **Dr. Aleksander Zborowski**, TPA Sp. z o.o., Poland
3:40pm - 4:10pm Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech	**Coffee break with posters** Location: **Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech**
4:10pm - 5:10pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Resistance to permanent deformations** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Dr. Manfred Norbert Partl**, PaRRC, Switzerland Session Chair: **Dr. Marcin Michał Stienss**, Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Poland
6:30pm - 10:00pm Gdańsk Shakespeare Theater (GTS)	**Gala Dinner** Location: **Gdańsk Shakespeare Theater (GTS)** Gdańsk Shakespeare Theater Address: ul. Wojciecha Bogusławskiego 1 80-818 Gdańsk

Date: Wednesday, 14/June/2023

8:30am - 9:00am Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech	**Coffee break with posters** Location: **Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech**
9:00am - 10:40am Aula GdańskTech (Level 3), Main Building, GdańskTech	**Bio-binders and chemistry-linked performance** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Dr. Aikaterini Varveri**, Delft University of Technology, Netherlands, The Session Chair: **Dr. Agnieszka Woszuk**, Lublin University of Technology, Poland

10:40am - 11:10am Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech	**Coffee break with posters** Location: **Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech**
11:10am - 11:40am Aula GdańskTech (Level 3), Main Building, GdańskTech	**Keynote Lecture** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** **Prof. Jerzy Ejsmont** Title: **Tire Rolling Resistance**
11:40am - 12:40pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Additives and modifications (asphalts)** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Christiane Raab**, Empa, Switzerland Session Chair: **Prof. Marek Pszczola**, Gdansk University of Technology, Poland
12:40pm - 1:00pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**Closing** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Session Chair: **Prof. Gordon Airey**, University of Nottingham, United Kingdom Session Chair: **Prof. Hervé Di Benedetto**, Uni of Lyon / ENTPE, France Session Chair: **Prof. Piotr Jaskuła**, Gdańsk University of Technology, Poland Session Chair: **Prof. Adam Zofka**, Foundation for the Development of Transport Infrastructure Services (FRUIT), Poland
1:00pm - 2:00pm Fahrenheit and Hevelius Courtyards (Level 0), Main Building, GdańskTech	**Lunch** Location: **Fahrenheit and Hevelius Courtyards (Level 0), Main Building, GdańskTech**
2:00pm - 6:00pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**RILEM workshop TC 308-PAR: Performance-based Asphalt Recycling** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Chair: Dr. Gabriele TEBALDI Deputy Chair: Dr. Eshan V. DAVE
Date: Thursday, 15/June/2023	
9:30am - 1:00pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**RILEM workshop TC 279-WMR: Valorisation of Waste and Secondary Materials for Roads** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Chair: Dr. Lily POULIKAKOS Deputy Chair: Dr. Emiliano PASQUINI
1:00pm - 2:00pm Fahrenheit Courtyard (Level 0), Main Building, GdańskTech	**Lunch** Location: **Fahrenheit Courtyard (Level 0), Main Building, GdańskTech**
2:00pm - 5:30pm Aula GdańskTech (Level 3), Main Building, GdańskTech	**RILEM workshop TC 280-CBE: Multiphase characterisation of cold bitumen emulsion materials** Location: **Aula GdańskTech (Level 3), Main Building, GdańskTech** Chair: Dr. Andrea GRAZIANI Deputy Chair: Prof. Alan CARTER

Presentations

S01: Fatigue performance

Time: Monday, 12/June/2023: 9:30am - 10:50am · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Mª Carmen Rubio Gámez, University of Granada, Spain
Session Chair: Dawid Ryś, Gdansk University of Technology, Poland

Rational relationship between the fatigue curves of asphalt mixes obtained from tension/compression and 4-point bending tests

Di Benedetto, Hervé[1]; Perraton, Daniel[2]; Lamothe, Sébastien[2]; Boussabnia, Mohamed Mounir[2]

[1]Univ Lyon, ENTPE, Ecole Centrale de Lyon, CNRS, LTDS, UMR5513, Vaulx en Velin, France; [2]Construction Engineering Department, École de technologie supérieure (ÉTS), Montréal, Canada

The fatigue properties of asphalt mixes are usually established according to a series of laboratory cyclic loading tests at fixed temperature (θ) and frequency (f). Unfortunately, the results are different when considering different types of tests. This paper proposes a rational method to link the 4-point bending (4PB) and tension/compression (TC) fatigue test results. First a theoretical analysis of the 4PB fatigue test is presented. This analysis allows to introduce a link between the fatigue curves (modulus or damage versus number of cycles) of this type of test with the results from uniform TC tests. The 4PB fatigue curve is superimposed with the TC fatigue curve if the reference strain amplitude is correctly chosen. This amplitude must not be the maximum strain at the boundary fibre of the beam (ε0max), as usually considered, but a lower proposed value (ε0h0). Then, the previous approach is extended to the fatigue failure Wöhler's law, which is a line in the Log–Log plot of the number of cycles at failure versus the loading amplitude (stress or strain). An experimental campaign on a Canadian asphalt concrete (HMAC) validates the developped approach. It is an important output from this research as fatigue life from one type of test can be obtained from the other type of test in the case of strain (or displacement) control tests.

External Resource: https://doi.org/10.1080/14680629.2023.2180303

Advanced fatigue and rutting characterization of Polish asphalt mixtures based on the VECD model and viscoplastic shift model

Spadoni, Sara[1]; Ingrassia, Lorenzo Paolo[1]; Jaskuła, Piotr[2]; Canestrari, Francesco[1]

[1]Department of Civil and Building Engineering, and Architecture (DICEA), Università Politecnica delle Marche, Ancona, Italy; [2]Department of Transportation Engineering, Faculty of Civil and Environmental Engineering, Gdańsk University of Technology, Gdańsk, Poland

The advanced asphalt mixture performance-related specifications (AM-PRS) recently developed in USA can allow an optimisation of the design process of asphalt pavements thanks to the possibility to fully take into account the intrinsic material properties. In this study, four typical Polish mixtures, i.e. a Stone Mastic Asphalt (SMA) for wearing course, two mixtures for binder course with neat bitumen or Polymer modified Bitumen (PmB), and a mixture for asphalt base course with neat bitumen, were investigated by applying such advanced framework. The fatigue performance was studied through the simplified viscoelastic continuum damage (S-VECD) approach, whereas the rutting properties were assessed through the viscoplastic theory of the shift model. The findings were consistent with the composition of the studied mixtures, demonstrating the reliability and applicability of the AM-PRS even for typical Polish mixtures. Specifically, the high amount of soft PmB made the SMA mixture tough against fatigue cracking, but also more prone to rutting. The two binder mixtures exhibited good performance against both fatigue and rutting, and the polymer modification improved the toughness and increased the stiffness at high temperatures. The base mixture is expected to suffer fatigue cracking more than rutting, likely due to the low amount of bitumen and coarser aggregate gradation. These results can be used in the future for pavement performance predictions with FlexPAVETM software programme to ultimately optimise the design of Polish pavements.

External Resource: https://doi.org/10.1080/14680629.2023.2180296

Fatigue testing on bitumen binder using different column specimen shapes

Mangalath Shine, Athira[1]; Falla, Gustavo Canon[1]; Kamratowsky, Erik[1]; Wellner, Frohmut[1]; Caro, Silvia[2]; Zeißler, Alexander[1]; Leischner, Sabine[1]

[1]Institute of Urban and Pavement Engineering, Technische Universität Dresden, Dresden, Germany; [2]Department of Civil and Environmental Engineering, Universidad de los Andes, Bogotá, Colombia

The use of cylindrical column specimens to characterise the fatigue degradation of bituminous materials is useful to unify existing fatigue testing methods at different length scales (i.e., asphalt binder, mastic and mortar). However, these specimens commonly fail at the interface between the test material and the steel holders. To overcome this difficulty, this study investigates the fatigue characterisation of four binders using four different notched column geometries. The benefit of these geometries is that they induce failure at the center of the specimen. Finite element simulations were used to determine correction factors to account for the influence of the specimens' shape. Curves of the fatigue life as a function of the applied effective strain were successfully obtained for the different binders. The results show that the use of these notched geometries ensures true cohesive failure within the specimen and is an effective method to characterise fatigue damage in asphalt binders.

External Resource: https://doi.org/10.1080/14680629.2023.2181067

Heterogeneous numerical simulation of fatigue behavior of porous HMA via a multi-scale approach

El Sawda, Christina[1]; Fakhari - Tehrani, Fateh[1]; Absi, Joseph[2]; Petit, Christophe[1]; Reynaud, Philippe[1]

[1]GC2D Laboratory- Génie Civil Diagnostic et Durabilité, Université de Limoges, Egletons, France;b Conservatoire national des arts et métiers, Paris, France; [2]Centre National de la Recherche Scientifique, Institut de Recherche sur les Céramiques, Limoges Cedex, France

Asphalt mixtures mechanical properties often depend on the characteristics of its mastic. The latter includes the bitumen and small particles known as fillers. An analysis of bituminous scales (mastic or mortar) can predict the behaviour of its corresponding asphalt mix. This paper focuses on numerically computing and assessing the mechanical properties of bituminous materials i.e. complex modulus and fatigue. The purpose is to validate a numerical method able to assess fatigue damage via a heterogeneous multiscale approach. The modelling was realized based on finite element method and using the commercial ABAQUS software. The fatigue damage was presented through visual contour graphs as well as the local shear strain distribution. Applying the heterogeneous multiscale approach, it was possible to develop an effective numerical method to define the damage failure. The results showed that the values obtained numerically are similar to the experimental data with an error less than ten percent.

External Resource: https://doi.org/10.1080/14680629.2023.2186134

COF-01: Coffee break with posters

Time: Monday, 12/June/2023: 10:50am - 11:20am · *Location:* Hall in front of Aula GdańskTech (Level 3), Main Building, GdańskTech

Chair of poster competition committee: **Prof. Hassan Baaj**, University of Waterloo, Canada

Quantifying the Influence of Heating and Resting on The Formation of the Bitumen Microstructure

Mirwald, Johannes[1]; Nlszl, Christina[1]; Eberhardsteiner, Lukas[2]; Hofko, Bernahrd[1]

[1]CD Laboratory Bitumen, TU Wien, Austria; [2]Institute of Transportation, TU Wien, Austria

The investigation of the bitumen microstructure can provide an alternative approach to characterize the material. However, various factors prior to its analysis need to be considered, before being able to come to a meaningful conclusion. This involves the identification of factors like heating time and temperature as well as resting time and how it can affect the resulting microstructure. Furthermore, the need for quantifying the microstructure is sought after. Thus, the goal of this study is to address these parameters and quantify their respective influence via a combination of optical inverse dark- and bright field microscopy and subsequent particle analysis of the dark field images. The results show that small binder quantities, typically used for microscopy, can oxidize within one or two minutes of heating or when selecting heating temperatures above 150°C. Therefore, staying below these parameters will ensure that the sample surface has not experienced any ageing. Furthermore, the resting time study revealed that the microstructure becomes stable after 30 minutes of resting, making binder characterization via microscopy much more convenient. For imaging analysis an overall area covered by bee structure enables universal characterization and comparison, while providing good differentiation between binders of different origin. These findings should set the basis for future research, where microscopy can be used to identify and tackle important questions related to changes caused by ageing, modification or rejuvenation.

Impact of the mastic phase and compaction temperature on the sigmoidal gyratory compaction curve

Margaritis, Alexandros; Tanghe, Tine; Vansteenkiste, Stefan; De Visscher, Joëlle; Vanelstraete, Ann

Belgian Road Research Centre (BRRC), Belgium

In this study, the compactability and workability of asphalt mixtures is assessed in retrospect to key mix design factors. To better understand how the compactability and workability of asphalt mixtures evolve, asphalt mixtures compacted at different temperatures and asphalt mixtures with various mastic compositions were considered. The gyratory compaction data were further analysed using a sigmoidal curve model. To account for the changes in the mastic phase, the mastic film thickness, and the mastic stiffness indicator (MSI)were considered to track the mastic phase changes. The sigmoidal curve parameters revealed that the mastic film thickness had a more pronounced effect on the compaction process compared to the effect of compaction temperature. Finally, two space diagrams are proposed for the assessment of compactability and workability, namely the C0 (initial compacity) versus CCIP (compacity at the inflection point), and the plot of β4/β3 versus β3, with β4 and β3 being shape parameters of the sigmoidal curve.

Implementing Temperature-Based Artificial Neural Network (ANN) Modeling in Assessing Pavement Structural Conditions

Bastola, Nitish R.[1]; Acharjee, Prashanta[1]; Souliman, Mena I.[1]; Dessouky, Samer[2]

[1]University of Texas at Tyler, USA; [2]University of Texas at San Antonio, USA

Different non-destructive testing (NDT) technologies are utilized to assess the structural capacity and conditions of the pavement. In most cases, NDT involves pavement deflection measurement to predict pavement performance. Among different NDTs, Falling Weight Deflectometer (FWD) has been utilized widely in the US and offshores for decades. However, utilization of FWD results in traffic disturbances around the test site. Therefore, different options such as simulating the actual FWD test with varying software applications are common. Simulations successfully reduced traffic disturbances, but the computational power and tedious pavement modeling still delay the process of evaluating the pavement performance. Recently, the novel approach of utilizing machine learning tools has been common. Machine learning tools have numerous functions, one of which is effective prediction capabilities. Therefore, this study uses one of the most common approaches for machine learning, referred to as Artificial Neural Network (ANN) method. This approach eliminates the traditional way of collecting FWD data and tedious software simulations; instead, a predictive model with 15,000 data points is developed. The model uses the least number of inputs focusing on the most influencing variables and considers the pavement surface temperature variation during the FWD testing period, which many of the previously developed studies lacked. Moreover, the ANN predicted deflection values are utilized to validate different deflection parameters and assess the pavement conditions correlating with the occurring distresses. Transportation agencies can use the newly developed procedures efficiently to get early information on maintenance and rehabilitation procedures.

Development of a Non-contact Measurement Technique for Asphalt Mixture Uniaxial Fatigue Testing

Vaddy, Poornachandra; Kutay, M. Emin; Abdollahi, Seyed Farhad; Hasnat, Mumtahin

Michigan State University, USA

Methods of material testing of Hot Mix Asphalt (HMA) mixtures have constantly been evolving with time. Many new methods are being developed by researchers to make the testing process easier, inexpensive, and less time-consuming. One such effort was a non-contact measurement of strains in HMA test specimens using image analysis techniques. Several image analysis based algorithms were developed in the past, however their applicability was mostly limited to large strain monotonic tests. The traditional algorithms are based on image correlation methods, and they can only measure movements that are more than one pixel. Therefore, if low strain levels need to be measured during a cyclic test, an extremely high-resolution camera with high frame rate is needed. Such cameras are quite costly, which makes it infeasible to integrate in asphalt testing equipment such as the Asphalt Mixture Performance Tester

(AMPT). The objective of this research was to develop a computationally efficient Optical Flow (OF)algorithm to measure sub-pixel movements. Such algorithm allows to use of relatively inexpensive cameras to measure relatively low strain levels at relatively high loading frequencies employed in uniaxial fatigue testing. The algorithm was evaluated with various patterns placed on the HMA specimen (e.g., no pattern, printed speckle pattern, and painted speckle pattern). The results indicated that the proposed OF algorithm was able to measure the strains with high accuracy (>92%), compared to the LVDT measurements. Among the tested three different patterns, all patterns produced accurate results with an error of only 5-8%. It is envisioned that non-contact strain measurement technique will reduce testing time and enhance efficiency.

Investigations on the Production Temperature of WMA Mixes with CRMB Using Workability Approach

Kumar, Saurabh; Wagh, Vivek Pratap; Gupta, Ankit
IIT (BHU) Varanasi, India

The utilisation of crumb rubber in highway building has gained popularity in last few decades. The use of crumb rubber modified (CRM) asphalt binder demands high production temperature (mixing and compaction temperature) for construction of flexible pavement. This higher production temperature can be reduced by Warm Mix Asphalt (WMA) technology which is a sustainable technology that allows asphalt mixtures to be produced and compacted at lower temperatures than hot mix asphalt (HMA).Several concerns have been raised regarding the determination of the mixing and compaction temperatures of CRM mixtures. This study attempts to explore the mixing and compaction temperatures of CRM mixtures incorporated with WMA additives. Three different types of WMA additives, including Sasobit (S), Rediset (R), and Asphamin (AM), are used for preparation of CRM mixtures (CRMB60+WMA) with varying dosages. One viscosity graded (VG) asphalt binder, VG30, is used in this study as reference binder. Rotational Viscometer (RV) was used to analyse the unmodified (VG30) and CRM modified asphalt binders. A workability-based approach has been used to determine the production temperatures of CRM asphalt mixtures. It was found that production temperatures determined by testing asphalt binders through RV do not yield appropriate results for CRM asphalt binders. Workability analysis showed that CRM mixtures incorporated with WMA technology, regardless of dosage and type, exhibit improved workability at all the test temperatures compared to the CRMB 60 mixture. It was found that the workability approach used in this study was able to quantify the mixing and compaction temperatures for different CRM mixture incorporated with WMA technologies. About 4-13% and 5-22% reduction in mixing and compaction temperatures, respectively, were obtained for different WMA technologies. The application of WMA technologies considerably reduces the mixing and compaction temperatures, depending upon the technology, its type and dosage. The results of the current study also recognise the value of using WMA and CRM asphalt binders for environmental friendly construction of the pavement.

Dynamic Shar Modulus (|Gb*|) and Phase Angle (□b) Prediction Model for Modified Binder Using Artificial Neural Network (ANN)

Acharjee, Prashanta Kumar; Souliman, Mena I.
University of Texas at Tyler, USA

ASTM A-VTS data is widely used to describe the viscosity of asphalt binders. But it only accounts for the effect of temperature on asphalt binder. But Asphalt Binder is a visco-elastic material. Therefore ,its physical and rheological properties depend on both temperature and frequency. To account for the effect of temperature and frequency on asphalt binder, dynamic shear modulus (|Gb*|) and Phase Angle(□b) are incorporated into the Performance Grading (PG) system. |Gb*| or □b are two critical binder properties in the Mechanistic-Empirical Design Guide (MEPDG). In this study, multiple |Gb*| or □b prediction models for modified binders are developed using Artificial Neural Network (ANN). 3203data points from 9 modified binders were used in the model training, validation, and testing process. The ANN-based prediction model showed a better prediction performance than the previous two regression-based models. Two equations are also extracted from the corresponding |Gb*| or □b models. For simplicity, models with four neurons were chosen for the equation extraction. The extracted equation showed better prediction performance than the two previous models in every statistical parameter. Unlike the previous models, the new |Gb*| and □b are two single simple equations without any interdependency. These two models with equations can convert the large A-VTS database for modified binder into |Gb*| or □b format and the models can be incorporated into the MEPDG in the future.

Novel low temperature binders for warm asphalt mixes. Comparison with standard hot mixes

Gonzalez, Maria Gonzalez[1]; Victoria, Maria del Mar Colas[1]; Mena, Vicente Perez[1]; Rubio Gamez, Maria del Carmen[2]; Navarro, Fernando Moreno[2]
[1]CEPSA Commercial & Clean Energies, Spain; [2]Universidad de Granada, Spain

In this work warm mixes with a range of bituminous binders, comprising conventional bitumen, polymer modified bitumen and bitumen with crumb rubber from end-of-life tyres, were studied. The binders used for warm mixes were specifically designed for manufacturing at temperatures in the range of 140ºC and its performance was compared with homologous reference binders for hot mixes. Two types of common paving asphalt mixes (AC 22 and BBTM 11B) were manufactured and the influence of temperature, binder content in the asphalt mix and the mineral skeleton in the properties of the mixes were assessed.

Stiffness modulus prediction against basic physical and mechanical characteristics of recycled base course with foamed bitumen and emulsified bitumen

Mazurek, Grzegorz; Buczyński, Przemysław; Iwański, Marek
Kielce University of Technology, Poland

The paper's objective was to present the results of predicting the stiffness modulus of a recycled mix containing a blended road binder with foamed bitumen and emulsified bitumen. The Sm(acc. to IT-CY) indirect tensile test was used at temperatures of -10 oC, +5 oC, +13 oC and +25 oC. Prediction of the stiffness modulus accounted for the effect of temperature, the type of road binders, the sampling

location and the type of technology selected. All effects, except temperature, were included in the model by entangling their effects through recycled base course physical and mechanical characteristics, such as indirect tensile strength, compressive strength, creep rate, air void content and moisture resistance. As a result, it was possible to determine a regression model based on multiple regression with a coefficient of determination R2=0.78. Temperature and compressive strength were found to have the strongest effect on the variability of stiffness modulus. However, indirect tensile strength also significantly affected the Sm characteristic. In addition, FB-RCM (foamed bitumen)recycled mixtures proved to be more favourable than EB-RCM (emulsified bitumen) mixtures as they exhibited a lower deformation rate while retaining limited stiffness.

Effect of crack sealing treatment on skid resistance of pavement

Tušar, Marjan; Kokot, Darko; Ržek, Lidija
ZAG Ljubljana, SLOVENIA

The goal of study was to evaluate effect of crack sealing treatment on skid resistance of pavement. Measurements were performed with Skid Resistance Tester (British pendulum) and with SCIMTEX, equipment that measures side-way force acting perpendicular to measuring wheel, set at 20 degrees angle to travelling direction. Results of SRT measurements on surface of bituminous sealing compound after sealing treatment showed considerable loss of skid resistance compared to non-sealed surface. The lowest measured value was 23 SRT units, what is substantially below the requirement for highways in Slovenia(50 SRT units). Such results were obtained only on narrow region within the limits of treated crack. Width of treated fissure is normally around 3 cm, so such treatment has a considerable impact on safety of bikers and motorcyclists, due to the fact that contact width between pavement and the wheels of bikes and motorcycles in bends is less than 3 cm. We tried to improve skid resistance of pavements after treatment by using specially produced expanded clay with grain size 2/4 mm. Measurements with SRT and SCRIMTEX equipment showed some improvement in skid resistance.

Characterization of cold recycled asphalt mixtures including reinforcing fibres

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In the recent years, cold recycling techniques have been widely used all over the world thanks to their huge environmental advantages. However, their performances are lower than the traditional hot-mix asphalt, both for the longer time to develop the final mechanical properties, which leads to delays in the reopening to road traffic, and for the lower fatigue resistance. The present paper deals with the characterization of cold recycled asphalt mixtures (CRAM), made with 100% of reclaimed asphalt pavement, where synthetic fibres were included to improve the fatigue performance. The investigation involved the analysis of the curing time, volumetric properties, stiffness, strength, rheological behaviour and resistance to cyclic loading. The results showed that the use of synthetic fibre, with the optimum dosage, determined a higher CRAM performance, especially in terms of fatigue resistance.

Quality Control of Asphalt Binders in the Full In-Service Temperature Range using Dynamic Shear Rheometer Plate-Plate Geometry

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A quality control for choosing suitable asphalt binders for specific purposes is a helpful way to check the compatibility with additives like waxes or rubber. In this study, 14 different 70/100 asphalt binders originating from eight different manufacturers and 14 different refineries from Germany, Austria, Poland, and the Czech Republic are analyzed. All asphalt binders are tested in fresh and laboratory aged condition. The methodology includes determination of viscoelastic properties at elevated and intermediate service temperatures, as well as the relaxation capability at low service temperature. The results indicate that asphalt binders can sufficiently be differentiated in terms of their hardness and viscoelastic behavior in the elevated and intermediate service temperature range. For a comprehensive quality control, not only the virgin binder but also the short term and long-term aged binder should be analyzed. The relaxation tests show promising results to differentiate and characterize asphalt binders in terms of their resistance to low temperature cracking therefore relaxation tests should be included for any quality control of asphalt binders.

Comparative Laboratory Performance Analysis of Different Cementitious Admixtures Used for Stabilized Aggregate Base

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Aggregate base stabilization has been widely employed for composite pavement applications with different cementitious admixtures. These mineral inorganic materials are of different types, like commercial chemical admixture (CCA) or supplementary cementitious materials (SCMs). The present study presents a comparative analytical study to evaluate the performance of these admixtures for cementitious stabilized aggregates (CSA). Four admixtures, such as two CCA (Ac-I and Ac-II), andt wo SCMs (fly ash and slag) were chosen along with cement to evaluate mechanical strength via Unconfined Compressive Strength (UCS), and Modulus of Rupture (MoR), microstructural properties via ICP-AES, SEM and TGA for these admixtures, impact on the composite flexible pavement design and costs. Statistical One-way ANOVA test was conducted to determine differences in their strength development at 7 and 28 days. The addition of admixtures showed an increased degree of hydration reaction in the case of CCA and SCMs, and increased strength development in the case of SCMs, while it reduced CCA at 28 days. Composite pavement design for these admixtures revealed a slight benefit of using CCA, while the minimum thickness of the bituminous layer increased for SCMs by 5 mm. Admixtures resist

tensile stresses due to early construction traffic plying after seven days on a short cured CSA layer in line with cement. Application of SCMs resulted in savings of up to 16% in the cost of the CSA layer, while the cost increased by up to 30% on the application of CCA.

Investigation of the Bonding Properties of Bitumen Using a Novel Modified BBS Test

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The binder bond strength (BBS) test is a standard test that can quantify the bitumen-aggregate adhesive bond and the internal bitumen cohesive strength as described in AASHTO TP-91. Numerous studies have reported that the BBS test can offer direct and quick bond strength measurement at the bitumen-aggregate interface. However, the index "bond strength" used in this method cannot provide a clear distinction when evaluating the performance of different base bitumens of the same grade. Even when comparing base bitumen and modified bitumen, some results do not correspond to the practical field experience associated with the performance of these binders. In this study, a novel modified BBS test using the universal testing machine (UTM) is introduced and "bond energy" is proposed to be the critical indicator rather than "bond strength". The results of the standard BBS test and the BBS-UTM test on six base bitumens and a styrene butadiene-styrene modified bitumen (SBSMB) are compared, with the Cantabro loss test used to validate the accuracy of the BBS-UTM test. The results show that the BBS-UTM test is a reliable and accurate method to characterise the bonding of bitumen (especially modified bitumen). In addition, the "bond energy" can be considered the critical indicator for evaluating the bonding performance of different binders. In the paper, the different stages of the loading force-displacement curve in the BBS-UTM test are analysed in detail. The bond energy is divided into adhesion and tenacity, which provides a mechanistic explanation for the mechanical response of the base bitumens and SBSMB when subjected to external tensile forces. Significant differences are observed in the bonding properties (including adhesion and tenacity) between the base bitumens and SBSMB, and even among the base bitumens with the same penetration grade. To link bitumen chemical compositional to the bonding performance, the bitumen four component test (SARA analysis) was conducted on the base bitumens. The correlation between bitumen components and bonding indicates that excessive amounts of resins in the base bitumens may result in lower bond energy while higher saturates content shows a higher contribution of tenacity in the total bond energy.

Chemo-rheological equivalence of bitumen between different lab ageing procedures: from binder to mixture

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In an attempt to mimic in-situ ageing of asphalt pavements, the exploration of appropriate laboratory ageing simulations has led to multiple standards on bituminous binder level. On asphalt mixture level, however, less consensus exists regarding ageing simulation protocols. This study aims to compare the chemo-rheological performance of bitumen between lab ageing protocols for binders, compacted and loose asphalt mixtures. The same binder was used in a series of bitumen ageing protocols, while it was also used to produce an AC10 mixture that was conditioned as a loose mixture and for compacted cylinders and slabs. Oven ageing of the mixtures was conducted for up to 9 days at 85 °C. The binder testing results, derived from empirical, rheological and chemical tests, indicate that 20 hours of PAV ageing yields approximately similar results as 1 to 2 days of loose mixture oven ageing. Furthermore, in compacted samples, only the outer edge was influenced significantly by oxidative ageing.

The use of the semi-circular bending method to assess the fracture toughness of asphalt concrete mixes with reclaimed asphalt shingles

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The article presents the results of crack-resistance tests of bituminous mixtures with the addition of RAS performed using the SCB method. A mixture of AC 16 asphalt concrete for the bonding course with 50/70 paving bitumen was used for the test as reference mix. The tests were conducted at a temperature of 20°C and a piston speed of 1.25 mm/minute for three cutting depths (10 mm, 22 mm and 34 mm) and two aging conditions of the asphalt mixtures: short-term and long-term. Additionally, for one of the mixtures, the influence of the order of RAS dosing on the obtained SCB results was investigated. Analyses of the results indicates that the JC parameter seems to be more useful for the evaluation of fracture toughness than KIC, differentiating the mixtures with and without RAS, although here, the influence of aging on the obtained results is also atypical. In terms of fracture toughness, the mixes are well diversified by energy parameters such as strain energy to peak load (U), total strain energy (Wf) and fracture energy (Gf), but they do not correctly describe the effect of long-term aging. The parameters FI and TI and, to a slightly lesser extent, CRI, turned out to be the most sensitive to the fracture toughness of asphalt mixtures subjected to various aging conditions. With regard to the mixes with RAS, it was observed that dosing new bitumen first and then adding RAS after it has been mixed with the aggregate allows the mixture to be less sensitive to cracking, especially after long-term aging.

An alternative method for determination of compaction level for the granular layers

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The performance and bearing capacity of the flexible pavement structure is ensured by providing necessary foundation comprised of unbound granular material (UGM) layers and subgrade. Whin this paper the compaction level parameters and deformation modulus relations determined for UGM layers and subgrade in construction site. The experimental data were tested applied standardized and improved test methods, such as an alternative falling weight deflectometer (FWD) test method with repetitive load, the plate load

tester, lightweight deflectometer, dynamic cone penetrometer, and density Proctor tests. The data were analyzed based on statistical comparison of the compaction parameters, pairwise multiple comparison of test methods, clustering procedure for setting a level of compaction evidence and variance determination. Results proved capabilities of the alternative FWD test method under repetitive load to assess the relative compactness rate and the resilient responses, and provided the regression models of the dynamic modulus of the UGM layers and subgrade.

Analysis of the compactibility of bituminous mixtures for reflective crack relief interlayers (RCRI)

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The physical properties determining the strength parameters of bituminous mixtures are strongly influenced by the processes of placement and compaction. The purpose of the latter is to reduce the air void content and rearrange the particles to ensure that the layer achieves the specified design parameters. The effectiveness of this process depends on the compactive effort and is directly related to the mixture temperature. This research focused on the assessment of compactibility of mixtures designed for reflective crack relief interlayers (RCRI) which, in most cases, are applied in thin layers. The bottom asphalt mixtures designed to improve the fatigue behaviour that feature a high content of bitumen and low content of air voids (ca. 1-2%) can also serve this purpose. The materials analysed for compactibility in this research included both asphalt concrete mixtures (AC S, AC AF) and stone mastic asphalt mixtures (SMA, SMA-MA). The gyratory compactor method was used to determine the compaction slope K, the locking point LP and the compaction densification index CDI. All the tested mixtures were fine-graded, i.e. contained grains up to 8 mm in diameter, each mixed with a different type of bituminous binder. The values of CDI show a substantially greater input of energy required for compaction of high polymer modified mixtures (a.k.a. high modified asphalts or HiMA in short), as compared to mixtures of the same design, yet containing the 50/70 bitumen. This is due to the level of modification of the binder to change its parameters, including higher viscosity within the working temperature range of the process of compaction. Locking point analysis showed that SMA and SMA-MA mixtures attain 98%relative compaction before reaching the locking point at which the aggregate skeleton starts to resist further compaction. This is quite the opposite as with the AC S and AC AF mixtures. Among the tested mixtures the best compaction behaviour was observed in the case of SMA-MA 8 50/70, and this over awide range of working temperature (100-160°C) and pressures (150kPa, 600kPa). The design of the innovative mixture SMA-MA assumes an increase in the content of filler and binder, as compared to conventional SMA. This composition is bound to reduce the resistance to compaction, i.e. provide a better compaction behaviour as compared to a conventional SMA mixture.

Evaluation of complex modulus and fatigue properties of cold recycled material mixtures using small-scale specimens

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Cold recycling of bituminous pavements is becoming increasingly important since it allows waste reduction and preservation of natural resources. The stress-strain behaviour of the pavement structure cannot disregard the stiffness and fatigue characterization of cold recycled material (CRM) mixtures, especially if the aim is developing and implementing mechanistic-empirical design methods. The present paper describes a laboratory experiment for evaluating the effects of specimen geometry on the mechanical behaviour of cement bitumen treated materials (CBTM) manufactured with bitumen emulsion and cement. In particular, the focus was on cylindrical specimens with diameter of 38 mm, adopted to improve the efficiency of laboratory specimen fabrication. After a long-term curing, specimens with three different diameters (100 mm, 75 mm and 38 mm) were obtained by coring of gyratory samples. Their complex modulus was measured by means of cyclic compression tests and then rheological modelling was applied. Fatigue tests were also carried out in direct-tension mode of loading. Results and statistical analysis showed that small (diameter of 38 mm) and large (diameter of 75/100 mm) specimens cannot be considered identical.

Performance Evaluation of Recycled Asphalt Mixes Composed of Waste Wood Bio-Oil

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The sustainability in construction activities is in prime focus of present-day infrastructure development. The sustainability involves reuse of existing materials and optimum utilization of resources. In this direction, the present study evaluated the performance of control mix (0% RAP) and 40% recycled asphalt mix with waste wood bio-oil (WBO) as rejuvenator (40% RAP). Superpave based mix design was carried out for both the mixes and optimum binder content (OBC) for control and 40%RAP mix was found to be 5.2% and 5.49%, respectively by weight of total mix. Further, the mixes were subjected for rutting, fatigue and moisture damage resistance evaluation using Indirect Tensile Asphalt Rutting Test (IDEAL-RT), Indirect Tensile Cracking Test (IDEAL-CT), and Tensile Strength Ratio (TSR) test, respectively. The detailed analysis revealed that the addition of WBO affected the rutting resistance of40%RAP mix, however, statistically no significant difference was observed. The cracking resistance of40%RAP mix was found to be higher than control mix at intermediate temperature. The moisture damage resistance of both the mixes satisfied the Asphalt Institute's (MS-2) minimum criteria (>80%).The quadrant plot indicated that the both the mixes fall under "stiff mix" category. Overall, it can be concluded that the RAP mixes composed of WBO improves the cracking performance without significant adverse effects on the rutting and moisture damage resistance.

Innovative testing of whole asphalt layers package for rutting resistance in triaxial apparatus

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The triaxial test with the cyclic axial pressure and the constant confining pressure was applied for investigation of rutting resistance of specimens drilled from five laboratory prepared asphalt blocks with the different arrangement of asphalt mixtures in the wearing and binder layer and the same asphalt mixture in the base layer. The results derived from the test showed the similar slope of the creep curve for the combinations of asphalt mixtures with the polymer modified binder45/80-75 in the wearing and binder layer. No inflection point was identified on the creep curve for these combinations, even after 5 h of loading. The combinations containing the polymer modified asphalt mixture showed the steeper slope of the linear part of the curve resulting in the much higher total vertical deformation of specimens. In addition, the inflexion point on the creep curve was reached within testing period.

A Finite Element-Deep Neural Network Approach for the Prediction of the Rheological Properties of Bitumen

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The rheological properties of bitumen are essential for determining the sensitivity of asphalt binders to rutting and fatigue cracking during the pavement service life. The Dynamic Shear Rheometer test (DSR) is usually utilized to characterize these properties at different temperatures and loading conditions. The current work proposes a finite element-deep neural network approach on the basis of data collected from previous experimental tests and literature for predicting the complex shear modulus ($G*$) and phase angle (δ) at different conditions. We first propose a 3D finite element (FE) model to capture the viscoelastic behavior of bitumen at different loading rates and aging conditions. The Prony series parameters are used to describe the viscoelastic behavior of the proposed FE model. We then develop a deep neural network (DNN) that uses data collected from previous experimental tests and literature. The DNN incorporates 11 input parameters including the SARA fractions (i.e., Saturates, Asphaltenes, Resins, Aromatics) to represent the chemical composition, penetration, and softening point for the physical properties, and the DSR testing frequency and temperature. Additionally, the relative influence of the various model inputs on the rheological parameters is evaluated and ranked using the developed DNN. The proposed models show promising results in terms of predicting $G*$ and δ and indicating the possibility of using the FE models as inputs to the neural networks in the case of data scarcity. The results can guide decision-makers in road authorities and industry on the most important aspects that affect the rheological properties of bitumen, allowing them to prioritize their data collection efforts to enhance pavement performance.

Evaluation of thermal cracking probability for asphalt concretes with high percentage of RAP

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The paper presents determination of the probability of thermal cracking of asphalt mixtures with different reclaimed asphalt pavement (RAP) content on the basis of laboratory tests and analytical evaluation using thermal stress development method. Thermal cracking probability was evaluated taking into consideration: the type and gradation of the mixture (for wearing, binding and base courses), the RAP content in the asphalt mixture (0, 20, 40 and 60%) and the quality of RAP (uniform and nonuniform properties). Bending beam creep and strength tests were applied in the research. Thermal stresses were determined using two different models – for elastic and viscoelastic materials. It was observed that addition of reclaimed asphalt pavement decreases the low temperature properties of all the tested asphalt mixtures. In the case of wearing and binder courses, even an addition of 20% of RAP increases the thermal cracking temperature by around 5-6°C. Moreover, in the case of high amount of RAP or low quality of RAP, the aged bitumen starts to have significant influence on low-temperature properties. The calculated increase in cracking temperature is greater than 5°C.

Design and exploitation of the Perpetual Pavements in Poland

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Using the example of the first intentionally designed and executed perpetual pavement in Poland, in the present paper the idea, design principles and material selection for modern pavements with flexible and strain-resistant anti-fatigue layer is presented. The pavement was built in 2015 on a 12.4 km section of the S8 expressway in Poland. Experience, monitoring results and an analysis of changes in bearing capacity parameters over time from the 7-year exploitation of the long-life pavement are described. After seven years of operation, despite significantly increased traffic loads, the pavement has a very high bearing capacity and good surface condition. All assumed requirements are met. No structural damage has been observed along the entire length of the constructed pavement. The present article also presents examples of further use of perpetual pavement technology, successfully implemented on Poland and Europe's most demanding road sections.

Laboratory Evaluation of Rheological, Chemical and Compositional Properties of Bitumen Recovered from RAP Mixtures Treated with Seven Different Recycling Additives (RA) with Aging

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The use of recycling additives (RAs) in asphalt mixtures with higher contents of recycled asphalt material (RAM) has been gaining increased attention. However, some early studies have indicated that the positive effect that RAs have on initial material properties may not be maintained as the materials age. This paper presents the results of laboratory rheological and chemical characterization of mixtures containing seven different RA products and three control mixtures. The mixtures were produced as part of a National Road Research Alliance (NRRA) field research study with a 40% RAP mixture. RA suppliers determined the amount of their RA additive that needed to be added to the base binder (PG 58S-28) to result in PG XX-34 binder that would then be mixed with a 40% RAP and

placed on the test sections. Samples of the virgin PG58S-28, the RA blended binders, and samples of the 40% RAP mixtures produced with each RA additive and the controls were obtained during production. Binder rheological, chemical, and compositional characteristics of the as blended binders and mixtures followed by PAV aging of blended binders and of binders recovered from the ten mixture test sections was conducted. FTIR, Iatroscan, tests were performed on all binders at all aging conditions. The evolution of properties of the various RA products are compared with the respective control materials.

Effect of Hot-Mix Asphalt Volumetric Properties and RAP Content on CT-Index

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Fatigue cracking is common distress in asphalt pavements that is influenced by several factors, especially those related to the asphalt mix designs. A quick and reliable test that can estimate the cracking potential of asphalt mixes, especially for mix design and QC/QA purposes, is of interest to highway agencies. IDEAL-CT, a newly developed cracking performance test, has shown promise in differentiating the cracking resistance between different asphalt mixtures and is sensitive to binder type, air void, percent binder, and RAP content. However, all the previous work on the IDEAL-CT was accomplished using laboratory specimens. This work used field extracted cores and evaluated the IDEAL-CT performance. The test can differentiate different asphalt mix types but with higher variability than lab-prepared specimens. Comparing the results of different cracking resistance indexes shows that the cracking tolerance index (CTIndex) based on IDEAL-CT and the flexibility index are similar in discriminating cracking performance among different asphalt mixes. The CTIndex is found to have a strong positive relationship with the percent binder and air void contents; a negative one with the RAP content. The multivariate regression model presented is capable of crack performance (in terms of the CTIndex values) prediction of the asphalt mixes using key mix design volumetrics. The model can be used to quantify the input variables' effect on CTIndex associated with a unit change in air voids, percent binder, and RAP contents.

Influence of curing regime and compaction type on performance characteristics of BSM-emulsion

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A practical, unbound base layer can be constructed using the pavement rehabilitation technology known as central cold in-plant recycling (CCPR), which can also eliminate substantial structural distresses. Even though different research groups have studied CCPR, most studies have used the marshall compaction method with standard curing regimes. This study aims to investigate the influence of varying curing regimes (1 day to 28 days) and compaction types employed for the mix design of bitumen stabilized material-emulsion (BSM-emulsion) using the Superpave gyratory compactor (SGC) method. When compared, the findings indicate that the five days of curing and specimens casted using SGC at 100 gyrations have much potential for determining the indirect tensile strength (ITS) values of BSM-emulsion mixes. It was found from the current laboratory investigation that 85% reclaimed asphalt pavement material (RAPM) and 15% fresh aggregate quantities can be used for the preparation of BSM-emulsion mixes. It is also intriguing to note that the BSM-emulsion mixes' performance is improved by adding 1% cement as an active filler. The present study strongly suggests using the SGC method over the Marshall compaction method.

Effects of water-foaming on the ageing of asphalt binders

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This study investigated the effects of water-foaming of asphalt binders and the persistence of these effects on the properties of asphalt binders in scope of laboratory binder short-term ageing. Two paving grade bitumen (35/50 and 50/70 penetration grade) were subjected to water-foaming using a WLB10S laboratory foamer with 2% foaming water content. The study involved rolling thin film oven (RTFOT) procedure on the foamed and non-foamed binders to assess the effects of water-foaming after short-term ageing. The study included standard classification tests, evaluation of high temperature stiffness and multiple stress creep recovery tests, as well as evaluation of changes in chemical composition of the binders using Fourier transform infrared spectroscopy. Regarding the classification tests, it was found that foaming had significant effects on their basic properties, increasing the penetration at 25°C (by 3·0.1 mm) and decreasing the softening point (by 2°C), while the changes in Fraass breaking point were not significant. It was found that the small changes (softening) in asphalt binder rheology caused by water-foaming were reverted in the course of laboratory short-term ageing, which resulted in slightly increased high-temperature stiffness and lowered non-recoverable compliance. The water-foaming of the asphalt binders resulted in small changes in the chemical composition of the binders. Measurable increases in the absorption bands associated to carbonyl and sulfoxide compounds were recorded (characteristic to ageing of asphalt binders) after foaming, but these differences significantly decreased after RTFOT ageing. It was concluded that water-foaming had only temporary effects on the properties of asphalt binders, which were negated by the laboratory conducted short-term ageing process.

Influence of the type of reclaimed asphalt on the properties of the stone mastic mixture SMA JENA 16

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The SMA JENA (Stone Mastic Asphalt for single layer asphalt pavement) mixes have been used in Poland first in 2010 and in the case of single-layer asphalt concretes in 2013. Though the many advantages, including enabling rapid paving and lower construction costs compared to traditional mineral-asphalt mixtures, these technologies are not very popular in Poland. The subject of the paper concerns a single-layer stone mastic asphalt mixture SMA JENA 16 with the addition of granulated reclaimed asphalt pavement material (RAP). Two different RAPs were obtained, one from wearing and binding layers and the second from binding layer and basecourse were used in the tests. Both reclaimed materials significantly differed in the aggregate composition and the type asphalt

binder. The test plan assumed dosing of RAP in the amounts of 10%, 25% and 50% in the composition of the mineral mixture, in a way to preserve the grading curve of the reference mixture. The basic characterization of both RAP materials and the stone mastic asphalt mixture SMA JENA 16 were assessed. In terms of the properties of the produced SMA JENA mixtures, the resistance of the mixture to moisture damage was not significantly affected by the addition of the RAP materials, while a positive effect of the reclaimed material was found in improving the resistance to rutting.

Colloidal Stability of Bituminous Binders: Insights from Investigating the Effects of Aging Process and Bitumen Production Technology through Various Turbidimetric Methods

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Bitumen is a complex system wherein the interactions between its individual components contribute to its compatibility, and the ability to maintain its durability is known as colloidal stability. The loss of this stability can be one of the causes of asphalt pavement deterioration. To gain a better understanding and explore possible solutions to the problem of dispersion stability of petroleum products, various research methods have been developed, with optical methods being the most widely used. This study aimed to investigate the impact of the ageing process during long-term bitumen storage and the type of bitumen production technology on dispersion stability, using turbidimetric methods. The tests were conducted on five samples of 50/70 paving-grade bitumen of various origins. Studies have been performed using turbidity titration and Octel test. The first method allowed to determine the onset of asphaltene flocculation and determine the colloidal stability parameter so-called “Heithaus Parameter”. The Octel test was performed according to ASTM D7061-06 standard, enabling the determination of the Stability Index. These designated parameters were employed to evaluate the influence of selected factors on the dispersion stability of bitumen. Significant variations in the results were observed depending on the test method applied. This is also confirmed by the insufficient correlations between the Heithaus Parameter and the Stability Index. It seems that each method provides valuable insights into the structure and dispersion stability of bituminous binders. However, relying solely on the final parameters seems to be insufficient for unambiguous evaluation of the bitumen dispersion stability.

Influence of Aging Method on Mechanical Properties of SBS Polymers

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Polymer modified bitumen constitute a significant part of the binders for the construction of the asphalt pavements. The durability of the pavements with these binders depends also on the way in which the polymer in the bitumen is destroyed. Degradation (ageing) of polymers is a process leading to the division of macromolecules into fragments of lower molecular weight. The degradation phenomenon can be caused by the impact of various physical, chemical or biological factors. Negative environmental factors causing changes in the properties of polymeric materials include: high temperature, electromagnetic radiation (light and UV radiation), atmospheric oxygen and ozone, humidity, dust and pollution, precipitation, acid rain, gases, micro-organisms and tension. In order to determine the magnitude of changes in the mechanical properties of polymeric materials after ageing with different agents, SBS polymer samples were subjected to accelerated degradation in climate, solar, ozone and thermal shock chambers. The study showed that the degradation process mainly occurs in the polybutadiene structures of the tested elastomers. 1,4-polybutadiene has been found to degrade more readily than 1,2-polybutadiene. Assessing the mechanical properties of the tested SBS polymers, it was found that UV radiation and high ozone concentrations had the most destructive effect on the mechanical properties of the SBS elastomers.

Effects of binder temperature and foaming water content on foamability of asphalt binders

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The aim of the research was to evaluate the properties of 50/70 paving grade bitumen and polymer modified bitumens: 45/80-55, 45/80-80, intended for producing warm mix asphalt. These binders were evaluated using classification tests before and after foaming. Foamability of these binders was evaluated in terms of amount of foaming water and the temperature of the bitumen binder. The important role of the binder temperature in the foaming process comes from the strong relationship between the temperature and viscosity of asphalt binders, as well as from the need to evaporate the foaming water by transferring thermal energy. Therefore, the experimental plans for the foaming tests of the analyzed bitumen binders were implemented, taking into account the assessment of the influence of the binder temperature and the amount of foaming water on the maximum expansion ratio ERm and half-life T1/2 values. The analyzed amounts of foaming water ranged from 1% to 3% with 1% step, while the temperature range of the binder during foaming was from 140°C to 170°C for 50/70 road bitumen and 155°C to 185°C for polymer modified binders (45/80-55,45/80-80) with 15°C step. Optimization was performed to determine the optimal foaming water content for each type of bitumen binder. The analysis of the results showed that the optimal foaming water content was in the range of 1.6%-2.0% for the 50/70 asphalt binder, while for polymer modified bitumens it was found to be in the 1.8% to 2.4% range.

S02: Aging and rejuvenation studies

Time: Monday, 12/June/2023: 11:20am - 1:00pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Michael Wistuba, Technische Universität Braunschweig, Germany
Session Chair: Krzysztof Błażejowski, ORLEN Asfalt, Poland

Rheological Characterisation of Rejuvenator Blending Lines

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Three different rejuvenators are blended with a differently-aged penetration graded asphalt binder 50/70 and investigated using different rheological test methods. Characteristic temperatures T(G* = 15 kPa) and T(G* = 5 MPa) as well as corresponding phase angles δ(G* = 15 kPa) and δ(G* = 5 MPa) are used to evaluate the efficiency of the rejuvenators, to obtain blending lines and to determine required rejuvenator dosage. Each rejuvenator acts slightly different depending on the dosage and linear blending laws can erroneously affect dosage calculation, especially for high dosages. Moreover, the required rejuvenator dosage is different in the high-temperature range according to temperatures T(G* = 15 kPa) compared to intermediate temperature range according to T(G* = 5 MPa). The blending lines of different rejuvenators are of great use for evaluating rejuvenator effectiveness in the high-temperature range. In addition, relaxation tests seem to be suitable for low-temperature evaluation.

External Resource: https://doi.org/10.1080/14680629.2023.2180994

Aging Characteristics of Polyethylene-Modified Asphalt Binders Blended with Different Compatibilizers

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In this study, virgin low-density polyethylene (LDPE) and recycled polyethylene (RPE) were blended with an asphalt binder in combination with compatibilizers such as styrene-butadiene-styrene (SBS), Elvaloy, sulfur,and polyphosphoric acid (PPA): LDPE, LDPE+SBS+Sulfur, LDPE+Elvaloy,LDPE+Elvaloy+PPA, LDPE+sulfur, RPE, RPE+sulfur, and RPE+PPA. This study aimed to investigate (1) the distribution of PE in asphalt binder, (2)chemical changes in the binder due to the addition of compatibilizers, and(3) the ageing characteristics and their effects on the rheological and performance properties. Micrographs revealed that the LDPE dispersity improved with the addition of Elvaloy. The PE blends with sulfur met the target performance grade of PG76V-10. The PE blends with sulfur exhibited the highest fatigue life at low strain levels and degraded rapidly with an increase in strain level. The LDPE blends with Elvaloy experienced the least degradation in fatigue life with an increased strain level; this low ageing susceptibility was due to the lowest carbonyl (Ic=o) and sulfoxide (Is=o) index values.

External Resource: https://doi.org/10.1080/14680629.2023.2181123

Evaluation of long-term oven aging protocols on field cracking performance of asphalt binders containing reclaimed asphaltic materials (RAP/RAS)

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[1]National Center for Asphalt Technology, Auburn, AL, USA; [2]Binder and Mix Laboratory, Turner-Fairbank Highway Research Center, SES Group & Associates, LLC, McLean, VA, USA; [3]Asphalt Materials Research Program Manager, Federal Highway Administration, Turner-Fairbank Highway Research Center, McLean, VA, USA

This study compared two loose mixes' long-term oven aging (LTOA) protocols (i.e., 5-day at 95°C and 8-hour at 135°C) based on asphalt binder rheological and chemical properties. The protocols were then correlated with field aging conditions. Extracted and recovered asphalt binders from four asphalt mixtures were tested in the Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR), Double-Edge-Notched-Tension (DENT) Test, and Fourier Transform Infrared Spectroscopy by Attenuated Total Reflectance (FTIR-ATR). Based on the research results, the loose mix aging protocol of 5-day at 95°C replicates the effects of 2- and 3-year field oxidative aging on the rheological and chemical properties of the binders. The laboratory protocol of 8-hour at 135°C yielded a higher level of aging to the binders compared to the 5-day at 95°C protocol. Additional testing is planned to determine if these loose mix LTOA protocols can simulate 4–5-year field aging in Alabama.

External Resource: https://doi.org/10.1080/14680629.2023.2181004

Ageing behaviour of naturally and artificially aged bitumen samples after the addition of rejuvenators

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Reusing bitumen and asphalt is an approved practice, but the efficiency highly depends on adding virgin bitumen. Rejuvenators have gained increased importance in reaching independence from crude oil and exploring possibilities of multiple reuses. However, rejuvenators are often tested and evaluated exclusively on artificially aged bitumen samples. Therefore, the main objective of this publication is to investigate the rejuvenation of Reclaimed Asphalt Pavement (RAP) binders using three RAP samples and three rejuvenators. Rheological material properties, chemical effects of rejuvenation processes and the ageing behaviour after rejuvenation are examined. The results are further compared to rejuvenated artificially aged bitumen. It has been found that the rejuvenators reveal varying degrees of impact on RAP binders and artificially aged bitumen samples, as artificially aged bitumen samples tend to show fewer ageing changes than the RAP binders. Moreover, also the ageing behaviour of the pure rejuvenator influences the success of reuse.

External Resource: https://doi.org/10.1080/14680629.2023.2181006

Evaluating the Ageing Degrees of Bitumen by Rheological and Chemical Indices

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The ageing of bitumen is an inevitable phenomenon which is still challenging to be characterised. This paper aims at evaluating the ageing degrees of bitumen comprehensively. There were six types of bitumen being aged to five levels for comparing purposes and multiple rheological tests by a DSR as well as chemical test for the SARA (saturates, aromatics, resins and asphaltenes) properties of bitumen were carried out. The critical temperatures, G-R parameter and nonrecoverable-compliance-based ageing indices were proposed to evaluate the ageing degrees of bitumen in terms of low-, intermediate- and high-temperature performance of bitumen, respectively. Also, a novel ageing evaluation index based on the integration of modulus of master curves was employed and modified, which can evaluate the ageing degrees of bitumen accurately in terms of the whole range of temperature. Finally, the chemical ageing index were analysed and was confirmed to have strong linear relationship with rheological indices of bitumen.

External Resource: https://doi.org/10.1080/14680629.2023.2180289

S03: Field validation studies

Time: Monday, 12/June/2023: 2:00pm - 3:40pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Ann Vanelstraete, Belgian Road Research Centre, Belgium
Session Chair: Mieczysław Słowik, Poznań University of Technology, Poland

Chemical and mechanical analysis of field and laboratory aged bitumen

Hofer, Kristina[1]; Werkovits, Stefan[1]; Schönauer, Paul[2]; Mirwald, Johannes[1]; Grothe, Hinrich[1]; Hofko, Bernhard[1]
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To predict the performance of bituminous products during their service life, an accurate simulation of the aging behaviour is required. Several laboratory methods are available, yet the correlation to field aging is mostly missing. In this study, an unmodified bitumen was exposed to laboratory aging with the Pressure Aging Vessel (PAV) using one to five aging cycles and the Viennese Binder Aging (VBA) method, followed by a comparison to a field sample of the same base binder. Measurements with the dynamic shear rheometer (DSR) and Fourier-transform-infrared (FTIR) spectroscopy showed that the field aging level could not be reached neither with VBA nor with multiple PAV cycles, but a better approximation compared to the standard aging procedure was achieved. The FTIR spectra displayed a high degree of correlation between the VBA and field aged sample, especially regarding carbonyl formation in the aromatic fraction and the intensity of the sulphoxide band in the resin and asphaltene fractions. Additionally, the VBA sample showed more similarities to the field sample regarding fluorescence excitation–emission maps. Although both laboratory aging methods are an improvement to the standard procedure, the VBA method allowed for a better qualitative simulation of the chemical properties of the investigated field sample.

External Resource: https://doi.org/10.1080/14680629.2023.2180297

A new tire-sensor-pavement coupling chain for investigating asphalt mixture responses under rolling tire loads

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Understanding the mechanisms for road surface degradation requires an examination of asphalt layer responses under realistic rolling tire loads. In this study, we proposed a novel tire-sensor-pavement coupling chain for integrating the realistic distribution of tire contact stress into the mechanical modelling of the asphalt layer. The tire contact stress distributions under different tire loading conditions including tire loads and tire inflation pressures are obtained by using a sensor measuring system. The temperature- and frequency-dependent material behaviour of asphalt mixes is described through the VENoL (NOnLinear Viscoelastic) model. The model reliability is validated by numerical/experimental confrontation via a series of complex modulus tests. A new algorithm is developed to achieve the coupling simulation of the tire–pavement interaction system. Finally, the dynamic responses of the asphalt mixture including external force, displacement fields and surface deflection were investigated depending on rolling tire loads. The proposed method provides a fundamental requirement for understanding the structural behaviour of asphalt pavement loaded by rolling tires, which can be used to get insights into asphalt pavement surface design.

External Resource: https://doi.org/10.1080/14680629.2023.2180833

A comparative study on the performance of field-sampled asphalt mixtures for heavy-duty pavements using laboratory testing and mechanistic-empirical simulations

Hernando, David[1]; Couscheir, Karolien[1]; Jacobs, Geert[1]; Almalehy, Hosam[1]; Omranian, Seyed Reza[1]; Vuye, Cedric[1]; Braspenninckx, Johan[2]; Van den bergh, Wim[1]
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The demand for durability and resilience in asphalt pavements has led to the progressive implementation of performance-enhancing technologies like bitumen modification using polymers or fibers. This is particularly important in a port environment, where roads are subjected to heavy traffic. The main objective of this study is to contribute to the current state of knowledge on the performance of asphalt mixtures, including polymers and fibers, by conducting a comprehensive laboratory investigation of eight field mixtures, followed by an evaluation of their expected performance in five test sections using the AASHTOWare Pavement ME Design software. The eight mixtures included two lean asphalt mixes to be used as a replacement for granular layers, three base mixtures, and three surface mixtures. Laboratory testing showed that the addition of a blend of 91% polypropylene and 9% glass fibers increased stiffness and resistance to moisture damage. Also, this fiber blend improved cracking resistance when used in a relatively flexible mixture. It was found that top-down cracking predictions followed the trend observed in semicircular bending tests. Conversely, the predicted rutting performance did not align with the rut depth trend in the laboratory. Furthermore, the use of SMA instead of a dense-graded surface layer appeared to increase fatigue cracking in pavement sections with granular bases unless a high-modulus base asphalt layer was used. This study was a first attempt to use advanced pavement performance predictions in Belgium. The data gathered during the future monitoring of the test sections built as part of this study will provide valuable primary data for the local calibration of pavement distress models.

External Resource: https://doi.org/10.1080/14680629.2023.2181011

MASAI: Sustainable, Automated and Intelligent Asphalt Materials. The way to the next generation of asphalt pavements

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Despite the efforts made during decades, pavement construction still uses essentially the same traditional model as that employed one hundred years ago. This makes road construction actions less efficient, thereby affecting the productivity and the possibilities of economic growth of the sector. To help establish a model based on the circular economy, but also to promote the implantation of the new technologies, the Laboratory of Construction Engineering of the University of Granada has created the conception of sustainable and smart asphalt materials named MASAI, which enable the combination of the most important sustainable techniques developed in last decades in a single material. This paper describes the main characteristics of MASAI and presents several of the experiences carried out in Spain that demonstrate their viability and great potential regarding the minimisation of the environmental impact of asphalt pavements and their adaptation to the future needs of users and administrators.

External Resource: https://doi.org/10.1080/14680629.2023.2181007

Experience with overlays containing highly SBS modified binders (HiMA)

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ORLEN Asfalt, Research, Development and Innovation Department, Poland

The first sections of asphalt layers with HiMA (highly polymer-modified binder) in Poland were built in 2013. From the very beginning, the properties of asphalt mixtures with HiMA were very promising, especially in terms of simultaneous resistance to rutting while retaining a high flexibility and tensile resistance (including fatigue). In Poland, there are three types of HiMA binders, differing in hardness (25/55-80, 45/80-80 and 65/105-80) which made it possible to carry out a series of experiments in which these binders were tested in different configurations in all asphalt layers (wearing, binder and base course), in many types of mixes (AC, SMA, BBTM, anti-fatigue), in different types of construction: classical, perpetual, and in different variants of pavement construction and operation - in new construction, reinforcement and maintenance. The presentation includes examples of the use of overlays with HiMA on old, cracked and degraded roads. The selected repair technology and evidence of its performance over time are presented. Both ultra-thin overlays and thicker pavement designs such as "full HiMA" pavement were presented. After observing these sections for almost 10 years, it can be concluded that HiMA binder overlays behave very well, making them a great, environmentally friendly, alternative to paving grade bitumen or classic PMBs.

External Resource: https://www.orbiton.pl/

S04: Cracking resilience

Time: Monday, 12/June/2023: 4:10pm - 5:30pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Cedric Sauzeat, Uni. of Lyon/ENTPE, France
Session Chair: Cezary Szydłowski, Gdańsk University of Technology, Poland

Effects of temperature and age on stress relaxation in straight and modified asphalt binders from a northern Ontario pavement trial

McCloskey, Kalena[1]; Nivitha, M. R.[2]; Ma, Jianmin[1,3]; Hesp, Simon A. M.[1]; Krishnan, J. Murali[4]

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The effects of temperature and age on stress relaxation were investigated for a set of seven asphalt binders from a northern Ontario pavement trial. It was found that between binders, there were rather wide variations for different modes of relaxation. The first peak in the relaxation spectrum, originating from the rapid relaxation within the mobile saturates domains, was relatively insensitive to ageing. The second and third peaks at higher relaxation times changed more with both laboratory ageing and temperature changes. The straight-run Cold Lake asphalt binder showed the least amount of change, and this can likely explain its superior field performance. High styrene–butadiene (SB and SBS) polymer loadings, the presence of polyphosphoric acid (PPA), or re-refined engine oil bottoms (REOB) all resulted in solid-like behaviour, delayed stress relaxation, and associated reduced lifecycles.

External Resource: https://doi.org/10.1080/14680629.2023.2180995

Evaluation of Physical Hardening and Oxidative Aging Effects on Delta Tc of Asphalt Binders

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The Delta Tc (ΔTc) is a rheological parameter for asphalt binders, which has been adopted in the past years by many highway agencies in North America for asphalt binder selection. In this study, the effects of the low-temperature physical hardening and oxidative aging on ΔTc are experimentally investigated and analysed. The experimental study is performed on both plain and polymer-modified binders. The results show that both physical hardening and oxidative aging have strong effects on decreasing ΔTc . An approximate linear relationship is identified between ΔTc and rheological parameters, such as the creep stiffness (S) and the m-value. The linear relationship is theoretically explained by analytical derivation. Based on the linear relationship, a graphical method is proposed for interpreting ΔTc using the log(S)-m diagram. By this method, it is found that polymer modification increases the susceptibility of ΔTc to oxidative aging, while it does not significantly affect the susceptibility of ΔTc to physical hardening.

External Resource: https://doi.org/10.1080/14680629.2023.2181015

Assessment of the low-temperature performance of asphalt mixtures for bridge pavement

Budziński, Bartosz[1]; Mieczkowski, Paweł[1]; Słowik, Mieczysław[2]; Mielczarek, Marta[2]; Bilski, Marcin[2]; Fornalczyk, Sylwia[2]

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The alternative Stone Mastic Asphalt containing an increased amount of bituminous mastic bituminous mixtures (SMA-MA) have been successfully used for additional protective layers on steel and concrete deck bridges. In this application, the mixtures must feature the desired behaviour at both high and low (i.e. below freezing) temperatures. The SMA-MA mixtures owe their improved low-temperature resistance to the bituminous binder used in them, softer than the binders used in mastic asphalts (MA). This article reports a study comparing the selected low-temperature parameters of the SMA-MA and MA mixtures to the parameters of the bituminous binders used in them. The performance of HMA was evaluated by subjecting the specimens to UTST (Uniaxial Tension Stress Test) and TSRST (Thermal Stress Restrained Specimen Test) tests at the test temperatures from −25°C to −10°C. The low-temperature performance of bituminous binders was, in turn, assessed with the BBR test.

External Resource: https://doi.org/10.1080/14680629.2023.2181002

Atomic insight into the nano-cracking behavior of bitumen: considering oxidative aging effects

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Experimental understanding of the nanoscale cracking mechanism in bitumen is challenging. This paper adopts molecular dynamics simulation to study the loading-induced cracking behaviour from four aspects: (1) stress-displacement states; (2) morphology evolution; (3) energy contribution; and (4) the relationship with chemical compositions. Simulation results indicated that the nano-cracking process can be divided into the following stages: increase of free volume (stage I), formation of nanovoids, (stage II), nucleation and propagation (stage III), filamentation (stage IV) and separation (stage V). The density drop was observed in the area where saturates agglomerated, which potentially caused the formation of nanovoids. Energy analysis indicated that the cracking behaviour was related to the non-bond interaction, especially van der Waals interaction. Oxidative aging increased the intermolecular bonding and reduced the molecular mobility, which resulted in larger tensile strength but lower ductility. In addition, the effects of temperature on the nano-cracking behaviour were also presented.

External Resource: https://doi.org/10.1080/14680629.2023.2180292

S05: Advanced evaluation of performance-related properties

Time: Tuesday, 13/June/2023: 9:00am - 10:40am · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Gabriele Tebaldi, University of Parma, Italy
Session Chair: Oliwia Merska, West Pomeranian University of Technology, Poland

Linear and nonlinear thermomechanical behaviour of interface between bituminous mixtures layers: results from 2T3C apparatus and modelling

Tran, Thien Nhan[1]; Mangiafico, Salvatore[1]; Attia, Thomas[2]; Sauzéat, Cédric[1]; Di Benedetto, Hervé[1]
[1]Univ Lyon, ENTPE, Ecole Centrale de Lyon, CNRS, LTDS, UMR5513, Vaulx en Velin, France; [2]Research & Innovation Department, Eiffage Infrastructures, Corbas, France

Thermomechanical behaviour of interface of pavement structures was experimentally characterized using the 2T3C (French acronym for “Torsion-Tension-Compression on Hollow Cylinder”) apparatus developed at ENTPE, combined with 3D Digital Image Correlation (3D-DIC). Tested samples are double-layered hollow cylinders with an interface composed of bitumen emulsion and two layers made of different materials. In this study, cyclic torsion is applied on tested samples at combinations of five temperatures (from 0°C to 40°C) and five frequencies (from 0.01 to 1 Hz). Two different levels of global strain amplitudes are applied on samples (50 and 200 µm/m). The experimental results show that Time-Temperature Superposition Principle holds for all tested conditions. The linear viscoelastic model 2S2P1D perfectly simulates the behaviour of interfaces for the lower global strain amplitude, but not for the higher global strain amplitude because of an underestimation of phase angle. Successful simulation of phase angle values were obtained using the DBNPDSC model.

External Resource: https://doi.org/10.1080/14680629.2023.2181009

Evaluation of the State of Practice Asphalt Binder and Mixture Tests for Assessing the Compatibility of Complex Asphalt Materials

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The present study aims to evaluate binder and mixture testing methods for capturing the compatibility of complex asphalt materials consisting of different virgin binder sources, reclaimed asphalt pavement (RAP) materials and recycling agents (RA). Binder evaluation methods include the saturate, aromatic, resin and asphaltene (SARA) fractionation, advanced polymer chromatography (APC) analysis, differential scanning calorimeter (DSC) and rheological measurements. Mixture performance tests include the complex modulus (E*), direct tension cyclic fatigue (DTCF), disk-shaped compact tension (DCT) and semi-circular bending (SCB) fracture tests. The results from the testing and analysis indicate that the rheological characterisation of asphalt binder or mixture may not capture the incompatibility between virgin binder, RAP and RA. Binder DSC analysis as well as mixture fracture tests have shown promise to evaluate the compatibility of complex asphalt materials with different virgin binders, RAP and RA, as well as the effect of incompatibility on mixture performance.

External Resource: https://doi.org/10.1080/14680629.2023.2181005

Wetting kinetics of a bitumen droplet on a glass substrate

Thiriet, Amelie; Tigier, Léa; Gaudefroy, Vincent; Terrier, Jean-Philippe; Cantot, Justine; Piau, Jean-Michel; Chailleux, Emmanuel
Université Gustave Eiffel, Campus de Nantes, Bouguenais, France

In order to understand how interfacial forces may act in cold mix asphalt just after emulsion breaking, a new experimental procedure has been developed. It tends to mimic what happens when, just after the emulsion breaking, a bitumen droplet is in contact with an aggregate particle. The spreading is monitored by measuring the contact angle of the bitumen droplet on a glass slide over time. As expected, wetting kinetics strongly depends on temperature but equilibrium wetting state (final contact angle) appears to be temperature independent. The main output is the huge effect of the temperature. Indeed, total time for wetting at 35°C is close to 8 h while wetting time at 10°C approaches eight years. The relationship between viscosity at 0 Hz and wetting half-life time was found to be linear. This relationship is intrinsic to the system bitumen/glass/air studied here and derived from the interfacial properties of the three mediums.

External Resource: https://doi.org/10.1080/14680629.2023.2181003

Experimental and Numerical Modelling of Shear Bonding between Asphalt Layers

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Interlayers in asphalt pavements are potential structural damage initiators. In order to better understand the quantitative role of interlayer parameters, such as surface roughness, binder type, binder content and loading type on interlayer shear strength, this paper focuses on the effects of particle interlock and contact conditions on interlayer strength through experimental and numerical modelling. Experimentally, interlayer shear box strength tests on a model material consisting of stiff binder blended with steel balls are performed with and without normal force confinement. A Discrete Element method model of the test is developed using measurements of the model material for calibrating the contact law and for validating the model. It is shown that this model captures adequately the

measured force-displacement response of the specimens. It is thus a feasible starting point for numerically and experimentally studying the role of binder and tack coat regarding interlayer shear strength of real asphalt layers.

External Resource: https://doi.org/10.1080/14680629.2023.2180298

Self-healing master curves of bituminous binders: a non-linear viscoelastic continuum damage framework

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In this paper the viscoelastic continuum damage theory was used to investigate the damage and self-healing potential of bituminous binders, considering the effects of rest temperature, thixotropy, and non-linearity. Experimental testing was carried out by using a procedure in which continuous oscillatory shear loading was imparted to the specimens with the inclusion of a single rest period under multiple temperature conditions. Quantification of self-healing included the determination of material integrity gained and damage parameter recovered after the rest period. Such parameters were calculated by excluding time-dependent and non-linear biasing effects, which were directly evaluated by means of a distinct set of experiments. Results were modelled by using the so-called self-healing master curves, constructed by applying the linear viscoelastic time-temperature shift factors. These self-healing master curves are intended to be used as straightforward tools for the prediction of the self-healing response of neat and polymer modified binders in various time-temperature combinations.

External Resource: https://doi.org/10.1080/14680629.2023.2180295

S06: Functional pavements

Time: Tuesday, 13/June/2023: 11:40am - 1:00pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Fernando Moreno-Navarro, University of Granada, Spain
Session Chair: Grzegorz Mazurek, Kielce University of Technology, Poland

Impact of air voids and environmental temperature of asphalt concrete on black ice

Phan, Tam Minh[1]; Jang, Min-Seok[1]; Seo, Jung-Woo[1]; Yoon, Jae-Hyeong[1]; Park, Dae-Wook[1]; Minh Le, Tri Ho[2]
[1]Department of Civil and Environmental Engineering, Kunsan National University, Gunsan, Republic of Korea; [2]Faculty of Civil Engineering, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam

This study investigates two methods for detecting black ice, a hazardous thin layer of ice on road surfaces. The rain sensor and deep learning methods were explored, while considering the influence of environmental conditions, such as temperature, humidity, and air voids in asphalt concrete, on black ice formation. Results from the rain sensor method showed that the electrical resistance involved cooling time and reached a constant value when black ice was formed. Lower air voids in asphalt concrete led to a higher chance of black ice formation, while humidity had a negligible effect. A vehicle module for detecting black ice was successfully developed using deep learning with 90% accuracy. Furthermore, experiments using infrared heating confirmed that environmental temperature affects the melting time and melting area of black ice. These findings can improve safety for drivers and help with route planning when travelling on black ice roads.

External Resource: https://doi.org/10.1080/14680629.2023.2180293

Optimized Durable Pavement Rolling Resistance

Pettinari, Matteo[1]; Al-Qadi, Imad L.[2]; Ozer, Hasan[3]; Nielsen, Erik[1]
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The road-transport sector has a significant impact on energy consumption. A relevant component of this energy usage is associated with rolling resistance (RR) between tires and pavement. In Denmark, CO2 emissions from road transport alone have been quantified as 4.6 Mt/yr. Replacing standard stone asphalt with durable low-RR pavements is expected to reduce CO2 emissions up to 1%. The Danish Road Directorate started, back in 2012, optimising a surface layer for reducing RR. The low-RR mixture was designed to provide a durable texture capable to meet all safety requirements. In 2016, two low-RR mixtures and reference asphalt concrete were paved on a test section. To evaluate the texture durability these mixtures were sampled at the construction site and tested with a circular road tester. The results show that the durability of low-RR pavements can be enhanced by using premodified binder, which reduces changes in texture properties and increases rutting resistance.

External Resource: https://doi.org/10.1080/14680629.2023.2180991

Urban Mining for Low noise Urban Roads-Towards More Sustainability in the Urban Environment

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The urban environment faces two challenges: waste and noise. The work presented here shows that the use of certain waste and marginal materials for semi-dense asphalt low-noise pavements is a sustainable option. To this end, mechanical, acoustic and life-cycle assessment evaluations were performed, comparing different scenarios. The results show that these alternative materials can, for the most part, reach the mechanical and acoustic performance required for low-noise pavements both at the binder scale and the mixture scale. Depending on the waste material, mix design adjustments might be necessary such as increasing binder content and the selection of substitution fraction. The results showed that the mechanical performance reached 80% of that of all virgin materials in most cases and the acoustic performance was similar. However, the Technical Readiness Level (TRL) for their use varies and depends strongly on the geographic region. To determine if using alternative materials makes sense in addition to mechanical performance, environmental and economic performance should be considered.

External Resource: https://doi.org/10.1080/14680629.2023.2180993

Asphalt mixtures degradation induced by water, frost, and road salt in the 4-PB bending test evaluated by stiffness variability

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Water, frost, and road salt are important environmental factors that affect the durability of the entire pavement structure e.g. during the winter season or in regions located above sea zones. A proprietary experimental method was used to investigate the influence of these factors on mineral asphalt mixtures. Four road mix types of asphalt concrete (AC22) were analysed in the experiment. They differed in production technology, type, and content of the binder used. Based on the experimental approach and test data, changes in the value of the initial stiffness modulus (4-PB-PR test) were analysed. Based on the obtained results, it was established that both interactions caused a significant decrease in the module's value, which reached over a dozen percent. The article also evidenced that lower binder content in mixtures increases the negative environmental impact on the material, whereas its type may accelerate or reduce material degradation.

External Resource: https://doi.org/10.1080/14680629.2023.2181001

S07: Additives and modifications (binders)

Time: Tuesday, 13/June/2023: 2:00pm - 3:40pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Bernhard Hofko, TU Wien, Austria
Session Chair: Aleksander Zborowski, TPA Sp. z o.o., Poland

Laboratory Investigation of Graphene Modified Asphalt Efficacy to Pavement Performance

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[1]Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN, USA; [2]Proton Power, Inc., Lenoir City, TN, USA

The pavement industry is in constant search of new asphalt binder modifiers. Modifying the asphalt binder allows for a wider temperature range, which provides better performance and longer pavement service life. This study aims to evaluate the efficacies of graphene-modified asphalt on pavement performance through the laboratory test on asphalt binder and asphalt mixtures prepared with unmodified and graphene-modified binders. Four different graphene types (varied in particle size and purity), two types of asphalt binder (neat and SBS-modified) and two types of asphalt mixture (surface and base) were used in this study. Three binder types were chosen to perform the asphalt mixture performance tests IDEAL CT and Flow Number. Based on the results of this work, it was concluded that graphene could effectively increase the rutting resistance of asphalt mixture; however, the cracking resistance is strongly correlated to the quality of the graphene (particle size and purity).

External Resource: https://doi.org/10.1080/14680629.2023.2181013

Comparing the performance of SBS and thermoplastics modified asphalt binders and asphalt mixes

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[1]Department of Polymer and Process Engineering, Indian Institute of Technology Roorkee, Roorkee, India; [2]Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, India

This study comprehensively compares the conventional, rheological, morphological, and asphalt mix performance among SBS and several thermoplastics (TPs) modified binders. TPs modified binders (TP-MBs) may have modulus values similar to SBS modified binders (SBS-MBs), but several other critical properties were far inferior. Percent elastic recovery of ungrafted TP-MBs was < 10 percent, phase angle values were close to 80°, and the softening point was 15–20°C lesser than SBS-MBs. At intermediate and low temperatures, TP-MBs exhibited higher complex modulus values and increased the PG intermediate and low temperature. The presence of TP polymer even reduces the ductility compared to the base binder. Similarly, TP-MBs enhance the Marshall stability and rut resistance in mixes by 20–40 percent, but the improvement was not observed in moisture susceptibility, indirect tensile strength, and fatigue crack performance. Hence, analysis limited to the modulus of the MBs, Marshall stability, and rutting in mixes can falsely indicate that TPs can increase the overall performance of asphalt binders and mixes.

External Resource: https://doi.org/10.1080/14680629.2023.2180999

Performance of crumb rubber bitumen and asphalt modified in wet process alone and in combination with SBS polymer

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Road Research Institute, Vilnius Gediminas Technical University, Vilnius, Lithuania

Crumb rubber can be used as a bitumen or asphalt mixture modifier. Many investigations showed promising properties of crumb rubber-modified bitumen. However, the performance of crumb rubber-modified bitumen depends on crumb rubber properties, modification conditions and neat bitumen properties. The goal of this study is to determine the effect of the amount of crumb rubber and crumb rubber and SBS polymer combination on modified bitumen properties and also to evaluate the resistance to rutting of the asphalt mixture with crumb rubber-modified bitumen. The experimental research results showed that 2% crumb rubber can reduce the required amount of SBS polymer by half and ensure the main properties are equal to those of polymer-modified bitumen. It was also found that crumb rubber-modified bitumen (4% of the crumb rubber) and crumb rubber and SBS polymer-modified bitumen (2% of crumb rubber and 2% of SBS polymer) are equal in rutting resistance.

External Resource: https://doi.org/10.1080/14680629.2023.2180294

Performance of modified bituminous binders for mastic asphalt applications: risk assessment by thermal and rheological indices

Vansteenkiste, Stefan; Gail, Annette; Glorie, Lieve; Peaureaux, Philippe; Vanelstraete, Ann
Belgian Road Research Centre (BRRC), Woluwedal, Brussels

To increase the resistance to permanent deformation of mastic asphalt mixtures while maintaining workability, the use of additives has become common practice. Latter include both plastomeric polymers as well as Fisher–Tropsch (FT) waxes, giving rise to morphologically complex binders. However, field experiences indicate that such mastic asphalt mixtures are prone to failure due to cracking shortly after its use on site. Hence, the impact of such additives on the binder performance was investigated. The research approach included an analysis by both thermal as well as rheological indices, aiming for the assessment of binders' performance and identifying possible risks related to cracking. Findings from modulated DSC and DSR measurements are presented and discussed for both a paving grade bitumen 35/50 as well as blends, following modification with plastomer and/or FT-wax at different ageing stages. M-DSC results indicated that additives studied were incompatible with the bitumen matrix, therefore negatively affecting binder performance. Moreover, the determination of rheological indices identified risks of cracking failure associated with the combined use of plastomer and FT-wax.

External Resource: https://doi.org/10.1080/14680629.2023.2181012

Asphalt binders modified with chemically-crosslinked chitosan

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[1]Department of Construction Materials Engineering and Geoengineering, Faculty of Civil Engineering and Architecture, Lublin University of Technology, Lublin, Poland; [2]Road Survey Technology, Ramboll Finland Oy, Espoo, Finland; [3]Foundation for the Development of Transport Infrastructure Services (FRUIT)

Nowadays, the observed trend in road materials technology covers the study of environmentally-friendly modifiers. Therefore, the possibility of modifying bitumen with chitosan and its mixtures with epichlorohydrin was evaluated. The studies were carried out for four different percentages of biopolymer (1.0%, 2.5%, 4.0% and 5.5%) and two percentages (1% and 2%) of crosslinking agents and included the assessment of their influence on the basic binder properties, surface free energy parameters and chemical structure. The results indicate that the appropriately selected quantitative chitosan/epichlorohydrin ratio leads to their crosslinking inside the bitumen causing a softening effect. The study also shows the possible benefits of using biopolymer-modified binders in the production of asphalt mixtures by the enhancement of surface-free energy parameters and reduction of the dynamic viscosity. Chitosan is an environmentally-friendly biodegradable biopolymer, and its chemical crosslinking has a positive effect on the properties of modified bitumen.

External Resource: https://doi.org/10.1080/14680629.2023.2174357

S08: Resistance to permanent deformations

Time: Tuesday, 13/June/2023: 4:10pm - 5:10pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Manfred Norbert Partl, PaRRC, Switzerland
Session Chair: Marcin Michał Stienss, Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Poland

Development of a generalised creep-recovery test and a back-calculation method for determining the permanent deformation of asphalt mixtures in the time domain

Tran, Vu-Tu[1]; Phan, Thanh-Nhan[1]; Tran, Van-Tieng[1]; Do, Tien-Tho[1]; Nguyen, H.T. Tai[1]; Nguyen, Mai Lan[2]

[1]Faculty of Civil Engineering, Ho Chi Minh City University of Technology and Education, Ho Chi Minh City, Vietnam; [2]Department of Materials and Structures, Gustave Eiffel University, Bouguenais, France

The measured strain during a creep-recovery (CR) test comprises both reversible and irreversible strains; therefore, adequate treatment is required to accurately separate them. In this paper, a generalised version of the CR test was proposed to investigate the permanent deformation behaviour of asphalt mixtures exerted by a variety of loading patterns in the time domain. The companion back-calculation algorithm was also proposed to separate with improved accuracy and repeatability the pure viscoelastic (VE) and viscoplastic (VP) strains. First, the creep compliance (CC) was back-calculated based only on the recovery data by using an approximate analytical creep compliance function of the Huet-Sayegh model as the solution function in the optimisation process. Then, the pure VE and VP strains were determined. The results show that the proposed method attains a good level of reliability although relatively short durations of the recovery period have been used.

External Resource: https://doi.org/10.1080/14680629.2023.2180291

Intermediate- and high-temperature damage of bitumen modified by HDPE from various sources

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This research investigated the effect of high-density polyethylene (HDPE) from various sources on the damage-related behaviour of bitumen in the intermediate- and high-temperature domains. For this purpose, base bitumen was modified by the mass fraction of 1.5% of HDPE from post-industrial recycled pellets and from post-consumer recycled flakes. The experimental programme consisted of the multiple stress creep and recovery from 40 to 70°C and of the linear shear strain amplitude sweep at 10, 20, and 30°C. The HDPE significantly reduced the non-recoverable creep compliance but increased the elastic recovery. The post-industrial HDPE-modified bitumen exhibited superior resistance to permanent deformation, with its crystallinity recognised as the most important factor. This reduced the susceptibility of its behaviour to shear stress and temperature. The HDPE-modified bitumen had a considerably longer fatigue life, but its sensitivity to premature failure at low temperatures and the conspicuously high brittleness represented the main issue for further improvements.

External Resource: https://doi.org/10.1080/14680629.2023.2181017

Multiple Stress Creep and Recovery test for bituminous binders – influence of several key experimental parameters

Wang, Di[1]; Zhu, Jiqing[2]; Porot, Laurent[3]; Falchetto, Augusto Cannone[1]; Damen, Sjaak[3]

[1]Department of Civil Engineering, Aalto University, Espoo, Finland; [2]Swedish National Road and Transport Research Institute (VTI), Linköping, Sweden; [3]Kraton Polymers B.V., Almere, Netherlands

The Multiple Stress Creep and Recovery test is recognised to better characterise the high-temperature property of bituminous binders than the traditional methods, especially for polymer modified bitumen (PmB). However, some experimental parameters may affect the test results, such as the preloading, measurement location, stress level. In this study, the effects of these parameters were evaluated through an interlaboratory experiment. Four bituminous binders were short-term aged and analysed by five different laboratories. The variability in most results met the requirements of the European standard, while some failed to pass the American precision criteria. The preloading at 0.1 kPa with ten cycles was found to have a recordable impact on PmB samples, but a less significant effect was observed for the unmodified ones. With the measurement locations, the influence is limited compared to other parameters. As for stress sensitivity, higher stresses lead to remarkable differences.

External Resource: https://doi.org/10.1080/14680629.2023.2180992

S09: Bio-binders and chemistry-linked performance

Time: Wednesday, 14/June/2023: 9:00am - 10:40am · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Aikaterini Varveri, Delft University of Technology, Netherlands, The
Session Chair: Agnieszka Woszuk, Lublin University of Technology, Poland

Physicochemical and aging characterization of bio-binders from pine wood resin for paving applications

Castro-Alonso, Maria Jose[1]; Espinosa, Leidy[2]; Marcelino, Paulo Ricardo Franco[1]; Vasconcelos Savasini, Kamilla[2]; Dos Santos, Julio Cesar[1]; Moraes, Raquel[3]; da Silva, Silvio Silvério[1]; Bernucci, Liedi L.B.[2]

[1]Department of Biotechnology, Engineering School of Lorena of the University of São Paulo, Lorena, Brazil; [2]Department of Transportation Engineering, Polytechnic School of the University of São Paulo, São Paulo, Brazil; [3]National Center for Asphalt Technology (NCAT) at Auburn University, Auburn, Alabama, USA

This study characterised two bio-binders (named Bio A and Bio B) derived from pine wood resins and designed for full replacement of asphalt binder. Bio A and Bio B were compared to a petroleum-based asphalt binder (AC 30/45). Elemental analysis, Fourier-Transform Infrared Spectroscopy, Gas Chromatography-Mass Spectrometry, Thermogravimetric analysis, and Linear Viscoelastic characterisation were applied to evaluate the materials studied. The susceptibility to aging was evaluated by comparing unaged and short-term aged samples of the three binders. Bio A showed a penetration grade of 29 (0.1 mm) and softening point of 55.2°C, while Bio B showed 21 (0.1 mm) and 57°C, respectively. AC 30/45 showed a penetration grade of 30 (0.1 mm) and softening point of 55°C. Bio B was found as more prone to aging than Bio A and AC30/45. This result might be related to the higher presence of saturated fatty acid methyl esters in Bio B.

External Resource: https://doi.org/10.1080/14680629.2023.2180306

Feasibility of using bio-oil from biodiesel production for bio-bitumen creation

Pais, Jorge[1]; Santos, Caio Rubens[2]; Cabette, Marina[1]; Hilliou, Loic[1]; Ribeiro, Jorge[3]; Wang, Hainian[4]; Hasan, Mohd Rosli Mohd[5]

[1]University of Minho, Guimarães, Portugal; [2]Mauá Institute of Technology, São Caetano do Sul, Brasil; [3]Petrogal, Matosinhos, Portugal; [4]Chang'an University, Xi'an, People's Republic of China; [5]School of Civil Engineering, Universiti Sains Malaysia, Penang, Malaysia

Bio-oil resulting from biodiesel production, currently used for energetic valorisation, can be added to the bitumen, producing a bio-bitumen and acting as a bitumen extender by reducing its viscosity. Thus, this paper analyzes the feasibility of using bio-oil to create bio-bitumen. Two base bitumen were used, namely, 0/10 and 35/50 pen bitumen, combined with bio-oil from biodiesel production content of up to 10%. Bio-bitumen characterisation evaluated the chemical, physical and mechanical properties of the bio-bitumen and asphalt mixtures with bio-bitumen. Models for the prediction of bio-bitumen properties were developed. The results obtained in this work confirm that bio-oil from biodiesel production can be added to bitumen, obtaining a sustainable destination for this residue from biodiesel production, proven by the physical and mechanical behaviour obtained for the bio-bitumens and asphalt mixtures with bio-bitumen compatible with base bitumen and asphalt mixtures with conventional binders.

External Resource: https://doi.org/10.1080/14680629.2023.2180305

Investigating the link between the chemical composition of bitumen and the kinetics of the styrene-butadiene-styrene swelling process

Naderi, Koorosh; Jonas, Celine; Carbonneau, Xavier

CORE Center, COLAS, Magny-les-Hameaux, France

Changes in bitumen production processes and crude sources can affect the chemical composition of the bitumen and the quality of the final polymer-modified binder products. As the rheological properties of the final products are of great importance, this study utilises systemic rheology along with functional indices determined from Fourier transform infrared spectroscopy and bitumen fractions to find a link between the chemical composition of bitumen and the kinetics of the polymer swelling process. The results show that the substitution mode of aromatic rings and the colloidal index significantly correlate with swelling parameters. The presence of weakly condensed aromatic rings reduced the swelling rate and elongated the swelling extent. Furthermore, a lower colloidal index resulted in a lower modification degree. It is possible to conclude that the outcomes of chemical studies conducted on the base bitumen are related to the swelling kinetics of styrene–butadiene-styrene-modified binders.

External Resource: https://doi.org/10.1080/14680629.2023.2180990

Rheological investigation on the ageing performance of bio-recycled asphalt binders and mixtures

Jiménez del Barco Carrión, Ana[1]; Presti, Davide Lo[2]; Chailleux, Emmanuel[3]; Airey, Gordon D.[4]

[1]LabIC.ugr, Department of Construction Engineering and Engineering Projects, University of Granada, Granada, Spain; [2]Department of Engineering, University of Palermo, Italy; [3]University Gustave Eiffel, Nantes, France; [4]NTEC, Department of Civil Engineering, University of Nottingham, UK

The current need to move towards more sustainable technologies in the construction sector has promoted the investigation of using alternative materials in asphalt mixtures for pavements. Biomaterials, used as biobinders, have shown their potential as partial replacement of bitumen in asphalt mixtures as solution to decreasing the demand for fossil-fuel-based binders as well as CO2 emissions. However, more research is needed to increase the replacement of bitumen in asphalt mixtures. In this investigation,biobinders are used as full replacement of virgin bitumen and as recycling agent within asphalt mixtures with high Reclaimed Asphalt (RA) content. Blends of biobinders and RA binders, and bio-recycled asphalt mixtures, were produced, subjected to ageing and rheologically characterised. The results show that the rheological properties of binders' blends seem adequate for their

use, while the bio-recycled asphalt mixtures seem to have a faster ageing than conventional ones, hence their full-scale application still remains a concern.

External Resource: https://doi.org/10.1080/14680629.2023.2181010

Chemical characterization of bitumen type and ageing state based on FTIR spectroscopy and discriminant analysis integrated with variable selection methods

Ma, Lili; Varveri, Aikaterini; Jing, Ruxin; Erkens, Sandra

Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, Netherlands

The chemical characterization of bitumen type and ageing state are fundamental in determining structural and mechanical properties of bitumen. This work aims to classify various bitumen types at different ageing states and to identify the primary chemical differences relevant to the classification. Fourier transform infrared (FTIR) spectral data of eight bitumen types at five ageing states were analyzed using a chemometric procedure that incorporates principal component analysis (PCA), linear discriminant analysis (LDA) models, variable selection methods. The models presented results of high accuracy in differentiating bitumen type and ageing state. The results show that the spectral regions that describe the aliphatic and aromatic bonds are critical to the identification of bitumen types. The chemical changes due to bitumen ageing are mainly revealed at the region of 1800 – 900 cm-1. This chemometric method is instructive for the characterization of chemical bitumen properties.

External Resource: https://doi.org/10.1080/14680629.2023.2181008

S10: Additives and modifications (asphalts)

Time: Wednesday, 14/June/2023: 11:40am - 12:40pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech
Session Chair: Christiane Raab, Empa, Switzerland
Session Chair: Marek Pszczola, Gdansk University of Technology, Poland

The effect of multiaxial geocomposite reinforcement on fatigue performance and crack propagation delay in double-layered asphalt beams

Jaskula, Piotr[1]; Rys, Dawid[1]; Stienss, Marcin[1]; Szydlowski, Cezary[1]; Golos, Michal[2]; Kornacka, Kamila[3]; Zoltko, Joanna[3]; Kawalec, Jacek[4,5]

[1]Faculty of Civil and Environmental Engineering, Gdansk University of Technology, Gdansk, Poland; [2]Tensar International Limited, Blackburn, UK; [3]Tensar Polska Sp. z o.o., Gdansk, Poland; [4]Faculty of Civil Engineering, Silesian University of Technology, Gliwice, Poland; [5]Tensar International s.r.o., Cesky Tesin, Czech Republic

The presented study investigates the effect of a recently developed multiaxial geocomposite made of polypropylene geogrid and non-woven fabric on the delay of crack propagation, based on four-point bending tests of large asphalt concrete beams – both for reinforced and non-reinforced specimens. Several approaches are described in this study, including analysis of stiffness modulus decrease and analysis of crack propagation using dissipated energy. The study also includes investigation of the impact of reinforcement on shear resistance of the inter-layer bond. The reinforced system displays reduced decrease in stiffness during cyclic loading; it is able to bear loads over a longer period, in contrast to the unreinforced system. An increase in fatigue life by a factor of 10–22 is possible, as compared to the unreinforced system. The factor of relative increase in the number of cycles to the first initiation of crack in lower asphalt layer when reinforcement is introduced ranges from 5 to 10.

External Resource: https://doi.org/10.1080/14680629.2023.2180998

Laboratory and field characterizations of fibre reinforced porous asphalt: a Dutch case study

Qiu, Jian[1]; Huurman, Rien[1]; Frunt, Mark[1]; Vreugdenhil, Bram[2]; Lucas, Jos[2]; Lastra-González, Pedro[3]; Indacochea-Vega, Irune[3]; Castro-Fresno, Daniel[3]

[1]AsfaltNu C.V., Culemborg, The Netherlands; [2]Rijkswaterstaat, Utrecht, The Netherlands; [3]GITECO Research Group, University of Cantabria, Santander, Spain

A European research project named FIBRA (2017-2021) has been conducted under the Conference of European Directors of Roads (CEDR) on fostering the implementation of fibre-reinforced asphalt mixtures by ensuring its safe, optimised and cost-efficient use. This paper presents a Dutch case study on demonstration of a fibre-reinforced PA 8, top layers of two layer porous asphalt, on Dutch motorway A73. The results indicate that PA 8 can be reinforced using both polyacrylonitrile and aramid fibres instead of polymer modification through evaluation of lab performance, production process and initial pavement performance. The addition of fibres may contribute positively to the strength of the mixture, the stiffness and possibly aging resistance of the mortar. The workability of fibre-reinforced PA 8 is better than that with polymer modification. The accelerated load testing results indicate that the PA 8 with fibre reinforcement has an expected service life similar to that with polymer modification.

External Resource: https://doi.org/10.1080/14680629.2023.2181014

The role of fine aggregate matrix in the linear viscoelastic behaviour of cement-bitumen treated materials

Mignini, Chiara; Cardone, Fabrizio; Graziani, Andrea

Dipartimento di Ingegneria Civile Edile e Architettura, Università Politecnica delle Marche, Ancona, Italy

The use of cold recycling technologies, including cement-bitumen treated materials (CBTM), is rising to address the environmental and economic challenges required for implementing sustainable road pavements. However, to obtain performances comparable to those of hot bituminous mixtures, the advanced study of these relatively new materials is essential, also considering the analysis of the linear viscoelastic (LVE) behaviour. This research studies the complex modulus of fine aggregate matrix (FAM) mortars, representative of the binding matrix of CBTM mixtures, characterised by several compositions. The experimental results were modelled considering both viscous and time- and temperature-independent dissipation components. Findings showed that the LVE behaviour of FAM mortars strongly depends on their composition, especially in terms of bituminous components, i.e. fresh and aged bitumen, and cement. Besides, the aged bitumen coating the reclaimed asphalt aggregate plays a role in the LVE response of CBTM mortars and mixtures.

External Resource: https://doi.org/10.1080/14680629.2023.2180290

RIL-01: RILEM workshop TC 308-PAR: Performance-based Asphalt Recycling

Time: Wednesday, 14/June/2023: 2:00pm - 6:00pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech

Chair: Dr. Gabriele TEBALDI
Deputy Chair: Dr. Eshan V. DAVE

"New needs and open problems on industrial applications of recycling of asphalt pavements": this workshop will be focused on the different aspects of the recycling of asphalt pavements from the point of view of industries and agencies. Its main objective is to explore the main problems found by industry in order to identify where future research should be focused on in the upcoming years. Technical and technological aspects of different asphalt recycling techniques will be covered, as well as life-cycle assessments and the environmental impacts of these recycling technologies. The workshop is set to be a meeting point for discussion among academia, industries and agencies, in order to provide an exchange of ideas and a transfer of knowledge and expertise.

Welcome and Introductions

Tebaldi, Gabriele
University of Parma, Italy

TG-1 Performance based Evaluation of Cold Recycled Asphalt Mixtures

Carter, Alan[1]; Diekmann, Martin[2]; Jenkins, Kim[3]; Carbonneau, Xavier[4]
[1]ETS Montreal; [2]WIRTGEN; [3]Stellenbosch University; [4]Colas

TG-2 Long Term Performance Evaluation of Warm Mixes with Recycling

Rubio, Mayca[1]; Moreno, Fernando[1]; Van Rompu, Julien[2]; Bargenda, Łukasz[3]; Haghshenas, Hamzeh[4]
[1]University of Grenada; [2]Eiffage; [3]Budimex; [4]U.S. Federal Highway Administration

TG-3 Degree of Binder Availability

Presti, Davide[1]; Vasconcelos, Kamilla[2]; Król, Jan[3]
[1]University of Palermo; [2]University of Sao Paulo; [3]Warsaw University of Technology

TG-4 Mixture Performance-based Dosage Optimization of Asphalt Recycling Agents

Hugener, Martin[1]; Cannone-Falchetto, Augusto[2]; Machura, Magdalena[3]; Tabatabaee, Hassan[3]; Staudinger, Angela[4]; Madan, Deepak[4]; Srinivasan, Krishna[4]
[1]EMPA; [2]Aalto University; [3]Cargill Bioindustrial; [4]Sripath Technologies

TG-5 EPD and PCR for Asphalt Mixtures with RA and Recycling Agents

Mukherjee, Amlan[1]; Keijzer, Elisabeth[1]; Gómez Meijide, Breixo[2]
[1]TNO; [2]European Asphalt Pavement Association

Summary and Next steps

Tebaldi, Gabriele[1]; Dave, Eshan[2]
[1]University of Parma; [2]University of New Hampshire

RIL-02: RILEM workshop TC 279-WMR: Valorisation of Waste and Secondary Materials for Roads

Time: Thursday, 15/June/2023: 9:30am - 1:00pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech

Chair: Dr. Lily POULIKAKOS
Deputy Chair: Dr. Emiliano PASQUINI

It is well established that currently a considerable amount of waste is produced and a major part of the resources are wasted through the mainly linear process of material use in our economies. Various types of waste materials such as crumb rubber, plastics and construction & demolition waste have been successfully used in road pavements. RILEM TC 279-WMR aims to develop and broadly demonstrate such solutions in order to promote widespread market uptake. This workshop will bring together several stakeholders including those working within the TC in order to address various aspects pertaining to the use of waste and marginal materials in roads. This can span from choice of waste and marginal materials, laboratory characterization, in situ performance and standardization.

Overview of RILEM TC-279 WMR

Poulikakos, Lily[1]; Pasquini, Emiliano[2]
[1]EMPA, Switzerland; [2]University of Padova, Italy

TG1 Waste plastic modified asphalt binders

Tusar, Marjan
Slovenian National Building and Civil Engineering Institute, Slovenia

TG2 Crumb rubber modified asphalt binders

Pais, Jorge
University of Minho, Portugal

Upscaling Wastes for the Asphalt Market through Chemical Reengineering

Planche, Jean-Pascal
Western Research Institute, USA

TG3 Waste Aggregates in Asphalt Mixtures

Pasquini, Emiliano[1]; Falchetto, Augusto Cannone[2]; Moreno-Navarro, Fernando[3]
[1]University of Padova, Italy; [2]Aalto University, Finland; [3]University of Granada, Spain

TG5 Life Cycle Assessment

Presti, Davide Lo[1]; del Barco Carrion, Ana Jimenez[2]
[1]University of Palermo, Italy; [2]University of Granada, Spain

Evolution and Real-Scale Applications of a Recycled Plastic Based Asphalt Modifier

Eskandarsefat, Shahin
Iterchimica, Italy

Discussion and final thoughts

Poulikakos, Lily[1]; Pasquini, Emiliano[2]
[1]EMPA, Switzerland; [2]University of Padova, Italy

RIL-03: RILEM workshop TC 280-CBE: Multiphase characterisation of cold bitumen emulsion materials

Time: Thursday, 15/June/2023: 2:00pm - 5:30pm · *Location:* Aula GdańskTech (Level 3), Main Building, GdańskTech

Chair: Dr. Andrea GRAZIANI
Deputy Chair: Prof. Alan CARTER

Cold bitumen emulsion technologies play a key role in the development of sustainable bituminous pavements because they allow energy savings and reduction of atmospheric pollution. However, their application range is frequently limited due to the lack of fundamental knowledge concerning the mechanical behaviour and the long-term performance of CBE mixtures. RILEM TC 280-CBE aims to foster the use of CBE technologies as a sustainable alternative to traditional hot technologies.
This workshop will summarise the research findings of the TC members, focusing on the fundamental knowledge related to chemical and physical mechanisms that control the long-term performance of CBE materials and on the mix design and performance of slurry surfacings.

Overview of TC CBE, significance, goals and organization

Graziani, Andrea[1]; **Carter, Alan**[2]
[1]University of Ancona, Italy; [2]ETS, Canada

Results of TG1 - EMULSIONS AND EMULSION-BASED COMPOSITES

Miljkovic, Miomir
University of Nis, Serbia

Industry presentation: Bituminous emulsion industry

Sturm, Dawid
Bitunova, Germany

Results of TG2 - COLD BITUMEN EMULSION MIXTURES

Sangiorgi, Cesare
University of Bologna, Italy

Polish experience in cold recycling with emulsion

Dołżycki, Bohdan
Gdansk University of Technology, Poland

Rheological characterization of cement-bitumen treated mixtures

Graziani, Andrea
University of Ancona, Italy

Discussion and final thoughts

Carter, Alan[1]; **Graziani, Andrea**[2]
[1]ETS, Canada; [2]University of Ancona, Italy