Asphalt Innovation Symposium 2022

Research meets industry

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Book of abstracts

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Preface

Dear attendee and reader,

Welcome. For the fifth time, we can look back on a very interesting year of research and collaboration in asphalt, bitumen, and pavements in general.

Before you, the book of abstracts of the Asphalt Innovation Symposium 2022 is presented.

We are proud of it, not only for the content, but also for bringing together research and industry.

Innovation in pavement construction is crucial, with different actors supporting it. It doesn't matter if the innovation is started by a contractor, supplier, research institute, or agency. The way it is placed into the market, the mutual benefit, and the social and environmental impact: that is why innovations will become common practice.

This symposium takes this responsibility to discuss the various creative ideas and questions, to give them a platform, to give you a platform to present new ideas and to have a reflection panel: the industry.

In this edition, many researchers will present their research output or ongoing research; research, by the way, never ends.

Building information modeling, new materials used in asphalt to increase sustainability, latest insights in mixture design, new methods to discover complex mechanisms, and the use of LCA tools to select appropriate solutions are among the topics covered. Furthermore, one session is dedicated this year to the PhD defense of Georgios Pipintakos: Towards an enhanced understanding of the oxidative ageing mechanisms in bitumen.

With this symposium, we especially want to support the asphalt sector to further innovate in a sustainable manner. Innovation ensures higher social development, with more conscious choices and more efficient methods. The phrases "innovative test methods, smart and sustainability, data analysis and management" will be used more than once during this symposium. The University of Antwerp and all other presenters in this symposium are suitable partners for this.

We look forward to more collaboration in the coming years to face the challenges of climate change, reduction of environmental impact and maybe the best material to pave Mars.

Hence, "research meets industry". This book is compiled by all abstracts of the presentations of AIS2022. Have an exciting reading!

Sincerely,

Prof. Wim Van den bergh, chair

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Session 1:
Introducing research at RERS

Enhancing and strengthening pavement performance at the port of Antwerp using adhesive layer (tack coat) and fiber-reinforced mixtures

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ABSTRACT

It is known that increased traffic and heavy loading as well as climate change have severe ramifications that destructively influence pavement durability. In order to construct resilient pavements, the possibilities to incorporate innovative methods and technologies including the application of new materials such as Lean asphalt, utilization of information technologies referred to as ROAD-IT and smart sensors named Fiber Bragg Grating (FBG), as well as various mixtures and structural designs were evaluated through a collaboration project with the Port of Antwerp (PoA).

Aside from the abovementioned parameters, interlayer bonding between layers which can provide resistance toward pavement layers slippage particularly during summer and under heavy traffic loads was also studied in the PoA project. Accordingly and to diminish shear failure between pavement layers, potential applications of different tack coats (adhesive agents) including conventional and polymer-modified bitumen (PMB) emulsions were examined. The possible beneficial impacts of lime milk (slurry) and glass fiber as interface bonding reinforcement were also investigated in this project.

Moreover, climate change has resulted in changes in sea level, floods, humidity, and precipitation events which in turn influenced the performance, integrity, resilience, and durability of asphaltic pavement around the globe. Hence, in the course of PoA project, the possible mixture reinforcement in terms of both tensile strength and moisture susceptibility was explored using different fibers.

The tack coat study results showed that incorporating PMB emulsion considerably enhanced bonding between layers and outperformed conventional tack coats. The interface shear resistance varies when the application rate of the tack coat changes. Although no considerable influence of slurry on shear resistance was found, less tack coat removal by paver during road execution was detected due to the presence of the slurry. The glass-fiber reinforcement slightly improved shear resistance. However, the concurrent application of tack coat, slurry, and fibers was not satisfactory.

Furthermore, the fiber study results showed that although temperature fluctuations exhibited the highest influence on the all investigated properties, enhancement in the load bearing capacity, indirect tensile strength, and proportion of broken aggregate was observed when a combination of glass and polypropylene fibers up to approximately 0.2% by weight of aggregates was used. It was also observed that fibers slightly reduced the fragility index by obstructing crack propagation and moderated the destructive effects of freeze and thaw cycles by improving mixtures' moisture resistance.

Keywords: pavement resilient, sustainability, moisture susceptibility, tack coat, fiber reinforcements.

Bitumen research on a micro scale

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ABSTRACT

Several domains, mainly connected to the study of binders, more specifically bitumen, cement, bio binders and geopolymers are explored in the micro lab.

Looking for answers to the behavior of bitumen in the material's microscale structure and composition is a key research topic.

Microstructural changes in bitumen could have an impact on the material's mechanical properties. The investigation is performed using new measuring devices like a Confocal Laser Scanning Microscope (CLSM) and multispectral image cameras.

On the one hand, the influence on bitumen of oxidation, UV, and water is like a grey zone, which still needs to be fully explored. On the other hand, additives, rejuvenators, and recycling (bitumen, rubber) will affect the bitumen. From this perspective, we are also looking at the environmental effects, more specifically toxic fumes "VOC".

The affinity of bitumen on asphalt stonese, is a fundamental key to developing a more durable asphalt. New optical detection methods, based on digital image processing (DIP), are currently being developed.

Finally, the optimal use of RAP, recycled asphalt pavement, can be improved by improving the identification of size, shape, and coverage.

It can be concluded that microstructures need to be observed to come up with better macrostructure solutions.

Keywords: micro structures, bitumen, bio binders, geopolymers, identification.

Added functionalities to asphalt pavements

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ABSTRACT

In this presentation, a short overview is given about three ongoing PhD projects at EMIB, all investigating additional functionalities for asphalt pavements. The first topic deals with the thermal and structural analysis of a Heat-Exchanging Asphalt Layer (HEAL), investigated by Taher Ghalandari. The thermal performance and influence of design and operational parameters are studied using both finite element simulations and a fully controllable medium-scale prototype available at Groenenborger campus. The structural analysis is performed by combining lab experiments with calculations in dedicated software for visco-elastic analyses (e.g. Rubicon or Kenpave). The main goals of this research are to determine the actual heat gain and impact on service life of the pavement structure. Results from a feasibility study will be shortly discussed.

A second PhD project investigates different aspects of road traffic noise. Ablenya Barros has already investigated the influence of noise-reducing measures on annoyance and quality of life and studied the reliability of mechanical impedance measurements. Currently, the focus is on psychoacoustics and soundscape perception in collaboration with prof. Freitas from UMinho (Portugal). The following methodology is used for this research. Actual CPX-measurements captured from different pavement types and degradation levels are analyzed using objective psycho-acoustical indicators. Next, audio stimuli are synthesized and combined with visual stimuli in a virtual reality (VR) environment. Finally, the subjective and physiological responses of test subjects in this VR environment are compared with the objective indicators. This should lead to a better understanding and prediction of road traffic annoyance.

Ali Zain Ul Abadeen will start his PhD project in January 2023, studying how to successfully implement TiO_2 in/on asphalt pavements to reduce NO_x emissions or degrade soot depositions by photocatalysis. A multi-disciplinary approach at different scales is used: from the nano- and microscale (binder) to the macroscale (asphalt). The possible interaction between (doped) TiO_2 and bitumen components and the potential impact of TiO_2 on rheological performance or ageing susceptibility will be studied at the binder level. The photocatalytic efficiency and traffic resistance of the applied TiO_2 will be studied at the asphalt level. The main goal is to develop an application method that will keep its photocatalytic efficiency for at least one year under real-life circumstances (weather conditions and traffic exposure).

Keywords: asphalt solar collector, road traffic noise, titanium dioxide, photocatalysis.

Optical measurement systems for bituminous material testing

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ABSTRACT

In this presentation, different optical measurement systems used at the University of Antwerp to characterize the mechanical properties of bituminous materials are briefly introduced. These systems include cameras, scanning laser Doppler vibrometers, and a confocal laser scanning microscope.

Furthermore, the aims and objectives of the ongoing FWO junior postdoctoral project "BITuminous Mortars: an Accelerated testing APproach (BITMA²P)" are discussed. In the BITMA²P project, we investigate the viscoelastic properties of bituminous mortars that can lead to a better understanding of the mechanical behavior of asphalt mixtures and therefore, the design and construction of cost-effective and sustainable road structures.

Even though bituminous mortar is considered as the missing link between binder and asphalt mixtures and is gaining increased worldwide attention, there are still no effective tests to quantify its viscoelastic behavior. The state-of-the-art methods to determine the properties of these materials are cyclic-loading tests, which are time-consuming and use classical measurement instruments that only provide a global view of the mechanical performance of the whole sample.

In this research, novel accelerated testing procedures are proposed that use the full-field vibration response of the samples to estimate the complex modulus and fatigue properties of bituminous mortars. Different optical measurement techniques are used and combined to design and validate these novel methods. These methods will be a big step forward in the road engineering community since the testing time is reduced from hours/days to a few minutes. This offers the possibility to conduct research on more samples and improve the mixture designs. Furthermore, the full-field measurements with the combined optical systems can shed light on some of the highly investigated aspects of asphalt mixtures, such as blending efficiency, self-heating, and the location of microcracks.

Keywords: bituminous mortar, ultrasonic, vibrometry.

Session 2A:
Innovation in mix design

(Theoretical) Mix design of durable asphalt: a glimpse on the new BRRC manual.

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ABSTRACT

The importance of good mix design cannot be overemphasized. BRRC published recently its new guide to the design of bituminous mixtures. With this guide, the BRRC aims to disseminate its knowledge to correctly select the components of bituminous mixtures and their proportional composition, according to the type of mix and the intended mix performance. Together with the production and processing of the asphalt, mix design is a crucial stage in the creation of a sustainable asphalt pavement.

BRRC recommends a method by which the designer can carry out mix design in a rational and efficient manner. The basic principle of the method is that the mix is composed in volumetric fractions. Only afterwards the composition is converted to mass parts, for use in the laboratory and production. This manual therefore provides comprehensive insight into the volumetrics of bituminous mixtures and its impact on performance.

The method starts from theoretical calculations, supported by experimental findings, and implemented in a user-friendly digital application, PradoWeb. This manual explains the calculations so that the designer can correctly interpret the results, and subsequently optimise the design. Examples are illustrated using PradoWeb. Thanks to this first stage of theoretical mix design, the number of laboratory tests needed on the mix is reduced to a minimum, saving considerable time and resources.

The method is not only appropriate for the design of new mixtures, it is also very useful for assessing the impact of changes in certain constituent characteristics or composition, changes that may occur in practice due to variations in material characteristics or variations in production. In this way, one can detect possible risks in terms of e.g. workability or deformation, and quickly make appropriate adjustments.

The method is also applicable in the context of research and innovation, independently of specifications, or in function of special or foreign specifications.

In the presentation, we show you a glimpse on this new guide.

Keywords: mix design, volumetric, VMA, MSI, PradoWeb.

The Dominant Aggregate Size Range-Interstitial Component (DASR-IC) Model: A tool to evaluate the gradation characteristics of asphalt mixtures

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ABSTRACT

Although asphalt mixtures approved by road owners meet the existing specifications, it is known that field performance varies from mixture to mixture, even for similar traffic and environmental conditions. Thus, it follows that there must be mixture characteristics or properties beyond those sanctioned by specifications that play a key role in performance. The objective of this presentation is to introduce the Dominant Aggregate Size Range-Interstitial Component (DASR-IC) Model developed at the University of Florida to link gradation characteristics to aggregate structure and mixture field performance. The DASR-IC model conceptually divides the aggregate structure of an asphalt mixture into two components: the dominant aggregate size range (DASR) and the interstitial component (IC). The DASR consists of the range of large (≥1 mm) interactive particles that forms the primary aggregate structural network (i.e., primary load-carrying structure) and provides resistance to shear. The IC contains the fine aggregate (<1 mm), effective binder, and air voids that fill the interstices within the DASR and provides fracture resistance and durability. In order for large aggregate to be interactive, the relative proportion of particles from two sieves with a size ratio of two must be within 70/30. Furthermore, the range of interactive particles must have a porosity between 38% and 48% to ensure interparticle contact for adequate resistance to deformation. In addition to DASR porosity, the DASR-IC model defines three additional criteria: disruption factor (0.6≤DF≤0.9), effective film thickness in microns (12.5≤EFT≤25), and fine aggregate ratio (0.28≤FAR≤0.36). DF was introduced to make sure that the IC does not disrupt the DASR network; that is, there is a balance between the void volume in the DASR and the volume of potentially disruptive IC particles. EFT was developed to capture the stiffening effect of the IC on the response of the mixture. Finally, FAR reflects the effect of particle interaction within the IC and is believed to be an indicator of the time-dependent response. Although the DASR-IC model may resemble the Bailey method, the latter links gradation to mixture volumetrics, while the former was developed to link gradation characteristics to mixture performance from numerous field sections. The range of acceptable values for the four DASR-IC parameters was derived from Superpave field monitoring sections In Florida and further validated at NCAT and WesTrack. To conclude, it is obvious that many factors dictate field performance, but the DASR-IC model seems to be a promising tool for effective performance-based mix design and to ensure that a road infrastructure project starts off with a sound mix design.

Keywords: asphalt mix design, gradation, dominant aggregate size range, interstitial component, particle interaction.

Stepping forward with asphalt balanced mixture design

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ABSTRACT

It has been 30 years since the inception of the Superpave™ asphalt mixture and binder design system was introduced in the United States. However, over the last three decades, many attributes of the material sources and types have changed, along with testing technology advancements and the desire for incorporation of sustainable approaches to highway construction. Many practitioners in the asphalt pavement community acknowledge that all mixes behave differently and current design procedures may not be optimizing performance using volumetrics alone. Asphalt balanced mixture design (or BMD) encourages the use of performance tests on appropriately-conditioned specimens to address multiple modes of asphalt pavement distress. This process takes into consideration impactful factors such as the mixture aging, traffic speed and loading spectra, climate, and location of the asphalt layer within the pavement structure. BMD is not only about designing optimum asphalt binder content for asphalt mixtures, but also explores the long-term mixture durability and those characteristics improving durability. In many ways, BMD encourages sustainable practices in asphalt mixture design and usage through consideration of the triple bottom line (societal, environmental, and performance characteristics). Specifically, the implementation of BMD may result in measurable benefits to the triple bottom line. There are alternate approaches to incorporating BMD including: (a) Volumetric Design with Performance Verification; (b) Volumetric Design with Performance Optimization; (c) Performance-Modified Volumetric Design; and, (d) Performance Design. Implementation of BMD starts with agencies taking some key steps in being able to continually assess relationships between specification items and field performance to facilitate this measurement. These steps include: (1) setting goals for asphalt performance, design and acceptance; (2) collaborating with stakeholders; (3) setting a timeline for major outcomes and overall effort; and, (4) developing relationship to performance and validation of test criteria. Finally, it is important that agencies consider identifying their specific goals for implementation of BMD, recognizing that it is not a one-size-fits-all approach and will be implemented differently for different agencies based upon their individual goals.

Keywords: balanced mixture design, asphalt, implementation steps

Session 2B:
Newest developments in bitumen research for industry

Fingerprinting of bituminous binders by rheological and thermal indices

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ABSTRACT

The transformation of Europe's economy into a more sustainable one constitutes a key part of the current strategy of the European Commission. Within the paving sector, the re-use of Reclaimed Asphalt (RA) offers a perfect case to fulfill this goal. At present, the additional focus to both environmental as well as economic advantages of re-use demands further optimization in terms of higher percentages of re-use and/or in enabling multiple recycling in the future. A major obstacle to the durable re-use of RA is the advanced ageing state of the binder. Therefore, road contractors increasingly use additives called rejuvenators, which desired effects include a regeneration of the aged RA binder properties and an improvement of the asphalt mixture performance containing a high RA content. However, it is generally accepted that the use of rejuvenators, among other factors adds up to the overall complexity of bituminous binders and hence their performance in asphalt mixtures over time.

At present, no standardized methodology applicable to a bituminous binder exists to fingerprint and map the performance characteristics of binders and/or to evaluate the impact of different commercially available additives such as rejuvenators. Therefore, within the framework of the Re-RACE (Rejuvenation of Reclaimed Asphalt in a Circular Economy) project, the Belgian Road Research Centre (BRRC) aimed to develop a screening procedure in order to evaluate the effectiveness of additives to rejuvenate bituminous binders. Latter procedure included indices derived from rheological measurements both by Dynamic Shear Rheometer (DSR, EN 14770) as well as by Bending Beam Rheometer (BBR, EN 14771) and thermal indices derived from Modulated Differential Scanning Calorimetry (M-DSC) analysis according to protocol optimized at BRRC.

Indices investigated were classified into different categories according to the temperature range (low, intermediate and high) at which the binder performance is studied. To establish a selection of suitable indices, each index was evaluated on its discriminating power based on precision data (repeatability), on its sensitivity to ageing and on its ease to measure. In particular, in this study measurements were performed on a 50/70 grade bitumen at different ageing stages and bituminous blends of fresh and long-term aged bitumen with or without rejuvenator originating from various sources. Following the identification of appropriate indices, results were illustrated using spider graphs allowing for a direct visual assessment of binder characteristics and/or effect of a rejuvenator.

Keywords: Reclaimed Asphalt (RA), rejuvenator, screening method, rheological indices, calorimetry.

"Dark Matter" - Advanced ageing simulation and analysis of bituminous binders

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ABSTRACT

We live in a complex world, and road engineers especially. Not only do they work with complex loading (cyclic-dynamic) and design (based on fatigue and not an ultimate limit state), the most common material (asphalt) also exhibits a complex, time- and temperature-dependent behaviour that evolves over time. This is due changes in bitumen, a complex, organic binding material that interacts in the field with atmospheric conditions in various ways, which we commonly call ageing.

The current standardized method for simulating long-term ageing of bitumen in the lab, the pressure ageing vessel (PAV), achieves a certain amount of oxidative ageing in a short amount of time. However, recent findings show that standard PAV cannot to simulate even one year of field ageing on the top of the surface layer, and thus, multiple times PAV is being introduced to overcome this problem. Due to the high pressure and temperature in PAV, it is doubtful that PAV realistically simulates field ageing. Relevant field parameters like reactive oxygen species (ROS - ozone, nitrogen oxides, etc.), which drive oxidation at ambient conditions, moisture and light, are missing in PAV. Thus, our team at TU Wien is developing a more realistic ageing simulation – the Viennese Binder Ageing (VBA). This method is flexible, with options to incorporate different ROS, varying temperature, humidity and light at ambient pressure.

In ongoing studies, we observe and analyze the impact of single ROS to understand which gas species are driving ageing in the field. ROS are formed in combustion processes and can thus be found in relatively high concentrations close to the road surface. It was found that nitrogen monoxide (NO) and ozone (O_3) have no to limited capability to start oxidative ageing. Nitrogen dioxide (NO_2) acts as a can opener, initiating oxidation and leaving the field open for other ROS to interact with the material and drive further oxidation.

By comparing 5-year-old field-aged samples from an asphalt mix test field with 5-times PAV-aged samples and 5-days VBA-aged samples of the same binder material, we could show that VBA can simulate field ageing more closely. However, open questions remain, and the next steps will include the incorporation of multiple ROS, humidity and light to get even closer to field ageing. Finally, the goal is to create a simple yet realistic ageing simulation that can be adapted to various applications (roads, roofs, surface dam sealings) in various climates. This way, we can take a peak into the future of bitumen before application and pave the way for effective antioxidants and regeneration agents.

Keywords: bitumen, ageing, oxidation, DSR, FTIR

Uncovering the physico-chemical degradation mechanisms in bituminous binders

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ABSTRACT

Road infrastructure networks are currently under pressure due to material ageing, structural degradation and lack of maintenance budget. Road authorities and pavement industry face numerous challenges related to the need for increasing recycling rates (circular economy), the high variability and uncertainties in performance due to the changing composition of bituminous binders, the introduction of emerging binding materials (recycled bitumen, bio-binders, polyurethane, epoxy, rubber-modified binders), the demand for rejuvenators and performance-enhancers, and climate change.

However, there is lack of technology for efficient and reliable prediction of long-term material performance under multiple, complex and interacting environmental conditions considering the changing material characteristics due to variable bitumen composition, inclusion of recycled materials and non-traditional binders. An improved understanding of the link between material compositional characteristics and performance (and its temporal evolution due to environmental factors) and the tools to model it will enable an a-priori design approach wherein material systems can be engineered via chemical interventions to develop circular, durable, climate-resilient, and high-performance paving materials.

To this end, this presentation will focus on an array of studies that combine both experimental and numerical methods at various scales aiming to uncover, model and optimize the relationship between chemistry, rheology and mechanical response of paving materials considering physico-chemical degradation processes. Molecular dynamics simulations, thermodynamic and kinetic modelling come together to study water-bitumen systems and uncover the microscale mechanisms of moisture-induced damage in paving mixtures. Moreover, FTIR spectroscopy and chemometric analysis are utilized to provide insights on the ageing degradation of binders and identify chemical parameters that are critical to the identification of binder ageing state. Finally, a finite element-deep neural network approach is explored to enable the prediction of rheological properties based on physico-chemical properties.

Keywords: bituminous binders, durability, chemomechanics, prediction modelling

New insights on bitumen stiffness

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ABSTRACT

Proper pavement design among other parameters, requires the knowledge/determination of the fundamental properties of the pavement's constituent materials, such as their stiffness or elastic modulus. Pavement's asphalts' stiffness can be determined by knowing/calculating the bitumen stiffness and the volume fractions of the different mixture components (aggregates, bitumen, air). Bitumen is a viscoelastic material and thus its behavior depends on both temperature and the period of loading (usually referred to as 'loading time'). The most known predictive tool for bitumen stiffness determination has been the Van der Poel nomograph, developed by utilizing results from both creep and dynamic stiffness tests. Nowadays, bitumen stiffness is measured using methods mainly based on shear deformations, using the Dynamic Shear Rheometer and is expressed in terms of the shear modulus G*.

However, other disciplines (apart from pavement engineering) concerned with materials' properties as well, calculate the elastic properties with other means, e.g. the contact mechanics approach. In this approach the elastic moduli of different materials can be determined through penetration tests on a semi-infinite half space (e.g. indentation test – similar to the bitumen penetration test) and by tension tests on dog-bone shaped samples (similar to the force ductility bitumen test). By looking at the theory and practice behind such approaches, it seems feasible that they could be implemented to the calculation of bitumen stiffness exploiting measurements/results from the bitumen penetration test and the force ductility test.

This presentation will demonstrate the theory that could be implemented for bitumen stiffness determination out of the indentation and tension tests, will point out the major issues raised when using the latter theory for bitumen (viscoelastic materials) and will demonstrate an initial attempt to calculate bitumen stiffness modulus out of the Penetration and Force ductility tests, thus determining more than one property by using single and easy-to-handle well-known devices.

Keywords: bitumen, stiffness, contact mechanics, penetration, force ductility.

Session 3:
BIM and data driven research / Technologies for the future

BIM4Infra pavements

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ABSTRACT

As road authority, the Flemish Agency for Roads and Traffic (AWV) aims to design, build, manage and maintain its infrastructure as efficiently as possible. By using the BIM methodology (Building Information Management) AWV centralizes all relevant infrastructure asset data in one database, the 'Master Data Model'. This single source of truth allows us to collect and manage the asset information during the whole asset life cycle and use this asset information for example in the applications used for the daily maintenance and management of our road infrastructure.

The Master Data Model contains data on all AWV infrastructure assets: the asset type, its attributes and the mutual relations between the different assets. To standardize the information need and information exchange between all parties during the whole life cycle, a data standard was developed. The 'OTL' or 'Object Type Library' for infrastructure assets contains the information need for all infrastructure assets in the Flemish context. The part of the OTL on road pavements is of course an essential part that allows to collect relevant data on the road pavements, its characteristics, building conditions and its condition during maintenance phase. This data standard is currently in place and being used in more and more projects. The first OTL compliant data sets of newly built pavements are being delivered by the contractors and imported in the AWV Master Data Model. The more OTL compliant asset data is stored in the central database, the more this data can be used and updated during daily maintenance, incident handling etc.

Now there is a uniform data standard on infrastructure assets, and the delivery of OTL compliant data is more and more imposed on contractors, further steps can be analyzed. Focussing on pavements, further analysis should be done on how to handle in situ pavement measurements and tests during or right after the project's building phase. By handling the in situ measurements and tests as assets of their own and by linking them to the involved pavement assets, we cannot only obtain better test data management, but also gain more insight in the general pavement's condition and get new insights in how to maintain our road infrastructure more efficiently.

Keywords: BIM for infrastructure, data dictionary, Object Type Library, pavements

Connected Data for Effective Collaboration 'CODEC' pilot project 'tunnels'

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ABSTRACT

CoDEC is a CEDR (Conference of European Directors of Roads) funded project aiming to integrate data from different Asset Management Systems and Building Information Modelling (BIM) within the National Road Authorities. The objective of the project is to provide a standardized process across different Road Authorities to enable them to access, manage and use asset related data between Asset Management Systems and BIM platforms.

For the pilot project 'tunnels' a case was built around the air quality in the Beverentunnel in Flanders. The project starts from the CoDEC data dictionary and classifies the air quality sensors in the tunnel BIM model. The classified air quality sensors are stored in a graph database and made available through a SPARQL endpoint. A BIM-coordination software is used to integrate the BIM-model with the linked data sensors and the corresponding sensor measurement data. The pilot project shows that it is relatively straightforward to integrate datasets when all the data sets are data dictionary compliant.

In the integrated BIM-coordination environment we can visualize the data in different ways by interpreting the measurement data and using the BIM-model to project the results in an easy understandable way. This allows future end users like tunnel operators to better understand the operational status of a tunnel.

Based on the outcome of the pilot project we also reflect on possible future applications and integration in the AWV landscape. To start with both the BIM-model and the graph database must be OTL-compliant, our own internal data standard. When having that in place we can think of integrating existing systems in real-time to make real-time operational decisions, to simulate certain behavior in the tunnel and of course extend it to other road assets outside of tunnels… Also the ways we visualize the results in the model can become more advanced with dynamically generated virtual objects or by highlighting only relevant parts or faces of existing objects in the 3D-model.

Keywords: BIM for infrastructure, data dictionary, sensor data, linked data, visualization

Milieu-impact van een infra-project
Evaluatie via BIM, OTL en EPD's

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ABSTRACT

Zowel op Europees vlak met de "Green Deal" als in Vlaanderen en Wallonië is er een groeiende ambitie om milieubewust en circulair te bouwen, gelinkt met de klimaatverandering en het bewuster omgaan met de beperkte natuurlijke grondstoffen.

In het geval van gebouwen berekent de Belgische TOTEM software op een objectieve en neutrale manier de milieu-impact van een gebouw, op basis van de gebruikte materialen voor de volledige levenscyclus van het gebouw (LCA aanpak).

Door de huidige TOTEM software aan te passen aan de specifieke eigenschappen van infrastructuur-projecten ('Infra-TOTEM'), kan dit een essentiële tool worden om de milieu-impact van een infrastructuurproject op een objectieve en neutrale wijze te berekenen en te optimaliseren.

De Infra-TOTEM is gelinkt met het BIM model om de berekening te vereenvoudigen. Hierbij werden de standaardposten uit het SB250 voor de gebruikte bouwmaterialen al aan de OTL gemapt en kunnen de hoeveelheden eenvoudig via de meetstaat bepaald worden.

De milieu-impact van de bouwmaterialen wordt op een objectieve en geverifieerde wijze via de EPD's aangeleverd. Deze Environmental Product Declaration (EPD) van een bouwmateriaal is gebaseerd op een Life Cycle Analysis (LCA) studie en wordt door een 3de partij geverifieerd.

Wegens de start in de gebouwen-sector zijn de beschikbare EPD's voor bouwmaterialen in de infrastructuur nog relatief beperkt. Parallel met de uitbouw van de Infra-TOTEM zal dit stap voor stap voor de meest gebruikte bouwmaterialen uitgewerkt worden.

De eerste stap focust op de materialen in de wegstructuur waarbij de milieu-impact van de asfalt- of betonverharding een dominante rol speelt. Het opstellen van de rekenregels via de PCR-asfalt (PCR : Product Category Rules) zal een transparante en objectieve bepaling van de EPD's voor de verschillende asfalttypes waarborgen.

In de toekomst zullen deze EPD's via een digital formaat in een externe database aan de standaardposten uit het SB250 gelinkt worden zodat de evaluatie van de milieu-impact verder vereenvoudigd wordt.

Keywords: Infra-TOTEM, LCA, EPD, milieu-impact

High-resolution mapping to reveal material efficiency patterns and circular economy potentials in Belgian road infrastructure

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ABSTRACT

Road infrastructure is an integral part of built environment stocks, as it delivers essential social and economic services to humanity. Accurate and high-resolution mapping of materials accumulated in road infrastructure helps reveal material efficiency patterns and circular economy potentials in road infrastructure, shedding important light on how spatial configuration correlates with material efficiency and where urban mining potentials lie. In this study, we assembled data scattered across various sources and developed a comprehensive database to warehouse locational information on road typology, layer geometry and thickness, material characteristics, traffic volume, climatic conditions, and soil conditions. With this comprehensive database, we mapped the materials stocked in road infrastructure across Belgium, explored the patterns of material efficiency at multiple scales, and examined the recyclability of EoL road materials across space and by road layer. Our results reveal a strong but non-linear correlation between material efficiency and population density, indicating that improving material efficiency in road infrastructure requires appropriate spatial planning. Furthermore, urban mining potentials in road infrastructure hinge on multiple factors, such as the proximity to recycling facilities and the degradation of pavements. Therefore, clever material recycling plans can help realize circular economy potentials in road infrastructure moving forward.

Keywords: road infrastructure, material stock, spatially-refined mapping, machine learning, material efficiency

Session 4A:
Sustainable and climate-resilient pavement

Robust comparative LCA of circular pavement designs using a probabilistic approach

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ABSTRACT

As global climate change becomes evident, reducing CO2 emissions is regarded as one of the most pressing issues for our industry and society. The asphalt pavement industry is also identified as one of the important CO2 emission sources. Life cycle assessment (LCA) has been widely used to quantify the environmental benefits of designs or practices that can improve the sustainability of asphalt pavements, such as reusing end-of-life pavement materials in new asphalt mixtures. However, due to the paucity of representative and good quality data, LCA results of pavements are associated with considerable uncertainty, thus unable to ascertain the benefits of sustainable designs or practices. Against this backdrop, this study develops parametric models to characterize energy uses and CO2 emissions occurring in key life cycle stages (including bitumen production, asphalt mixing, and pavement construction). A probabilistic approach is employed to quantify the uncertainty of input parameters and LCA outputs under three scenarios: (1) Baseline, (2) 0% RAP, and (3) +4cm durability. The results indicate that reusing end-of-life pavement materials does not necessarily reduce the CO2 emissions of a pavement over its life cycle. The CO2 benefits of reclaimed asphalt pavement (RAP) depend on the durability of asphalt pavements. More interestingly, the certainty of conclusions varies across comparisons. When comparing the Baseline scenario (in which RAP accounts for 27% of asphalt mixture compatible with Belgium's construction requirements) with the +4cm durability scenario (in which more RAP is used to compensate for durability loss), we are highly confident that the former leads to less CO2 emissions. However, when comparing the Baseline scenario with the 0% RAP scenario (in which no RAP is used), we are less confident that the former leads to less CO2 emissions. In addition, the results reveal that transport contributes the most to the uncertainty of LCA outputs, suggesting that more high-quality data on transport is needed to improve the accuracy of LCA results and the confidence in the conclusions drawn from comparative LCA.

Keywords: LCA, comparative, RAP, uncertainty, parametric.

Analyse van de economische en milieueffecten van het gebruik van bitumen-gestabiliseerd granulaat als alternatief funderingsmateriaal voor asfaltverhardingen

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ABSTRACT

Bitumen stabilized material (BSM), is a base material which allows for high recycling rates of reclaimed asphalt pavement (RAP), which might provide economic and environmental benefits over more traditional bases. From a structural point of view, it is important to consider the effect of the base layer on the asphalt layers. Therefore, to correctly assess the sustainability of BSM mixtures, it is important to consider full pavement structures. This study will analyze five alternative pavement structures with varying base layers for two different test tracks from the FOAM project, namely: unbound, cement bound, lean asphalt, BSM type A including the asphalt base layer, and BSM type B excluding the asphalt base layer. To account for the difference in structural capacity, Flemish standard structures were used. Life cycle cost analysis (LCCA) and life cycle assessment (LCA) were used to assess the economic and environmental impact of the structures, respectively. Overall both test tracks and methods showed the same conclusion. Focussing on base materials alone, the unbound base and cement-bound base have the lowest impact compared to BSM and lean asphalt. However, the analysis showed that the results of the full structures were mainly determined by the thickness of the asphalt surface and base layer. Both the unbound and cement-bound structures require thicker asphalt layers, which fully offset the economic and environmental advantages linked to the production impact of the base layers. As the BSM type B structure can eliminate the entire asphalt base, this structure provided the lowest environmental and economic impact. Overall, the cement-bound structure has the highest impact, followed by the BSM type A structure. Finally, the lean asphalt and unbound structures show comparable results and fall in between the BSM type A and BSM type B structures.

Keywords: BSM, RAP, LCA, LCCA

Quantifying flexible pavement damage after flooding due to loss of stiffness: framework for developing time-depth-damage functions

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ABSTRACT

Damage functions have been widely used for buildings and bridges to quantify flood-induced damage. However, such damage functions do not exist for roadway pavements. It is known that significantly accelerated pavement damage (e.g. rutting and cracking) can occur on "weak" roads when they recover from flooding. The damage is primarily caused by the loss of pavement stiffness and thus traffic bearing capacity, due to moisture weakening in the unbound layers and subgrade. This study develops a methodological framework to quantify post-flooding road damage and establish time-depth-damage functions for typical pavement structures. It adopts hydraulic modeling using the seepage finite element method (FEM), empirical relationship between layer stiffness and moisture, multilayer elasticity theory, and damage transfer functions to derive the time-depth-damage functions. A laboratory apparatus is developed to examine the validity of the seepage FEM model. Different moisture recovery patterns are found to occur in pavements with different types of subgrade. Pavement post-flooding weakening and recovery phenomena are observed from both seepage FEM modeling and laboratory testing. Moreover, flooding inundation time can be as influential as flood depth to impact the saturation and recovery of flooded pavements (this study focused on saturation and not potential damage from flowing water). Therefore, an inundation time factor should be considered when quantifying pavement damage after flooding in addition to the depth-damage approach commonly used for buildings or bridges. The framework proposed by this study can be used to develop generic time-depth-damage functions which can be widely applied to any flexible pavements. Such functions will serve an important purpose to assess flood-induced pavement damage for road agencies and the insurance industry.

Keywords: flooding, pavement, damage, function, quantification.

How green is this asphalt? Recommendations for LCA of road pavements

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ABSTRACT

The sustainability assessment of road materials and road pavements differs largely amongst countries and organizations, depending on their goals, experience, history and data availability. Sustainability assessment can be used to optimize asset management and reduce costs, to operationalize or develop policies on climate targets, or to reduce environmental or societal footprints of businesses and organizations. How this works in practice, where to start, what scope to choose in which situation, where to find data and how to interpret and check (claimed) results, happens to be a challenge for many organisations and businesses. We present a framework for sustainability assessment which has been developed in the PavementLCM project in order to help organisations and businesses on various levels of experience and interest. To look ahead, we provide 12 recommendations for successful implementation of sustainability assessment.

Session 4B:
PhD defense of Georgios Pipintakos

Towards an enhanced understanding of the oxidative ageing mechanisms in bitumen

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ABSTRACT

The ageing phenomenon in asphalt and its binding medium, the bitumen, is well documented in the scientific literature with regard to its rheomechanical effects. To understand the 'whys' behind these alterations one should seek additionally on the chemistry of bitumen.

This dissertation supports experimentally the hypothesis of an oxidation scheme consisting of a fast and a slow rate-determining phase. This is achieved by utilising various unmodified bituminous binders of different origin of crude source, refinery process and performance both in oxidation kinetics and with standard lab ageing simulations. The findings of Electron Paramagnetic Resonance (EPR) and Fourier Transform Infrared (FTIR) Spectroscopy manage to distinguish the two phases, while Proton Nuclear Magnetic Resonance (1H-NMR) Spectroscopy and Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) unravel the main oxygenated products in bitumen. Chemical investigations of the SARA fractions show additionally the effect of ageing on the different fractions. Moreover, each contribution of the coupled reaction-diffusion is studied with FTIR and Dynamic Vapour Sorption (DVS).

Next, the fundamental mechanisms for the development of a peculiar microstructure, the bee structures in bitumen, were explored and validated via Differential Scanning Calorimetry (DSC) and Wide Angle X-ray Diffraction (WAXD). In this dissertation, the hypothesis that the crystallisable compounds in bitumen are the main reason for such structures is adopted, and thus various waxy binders were studied for the effect of lab ageing with Atomic Force Microscopy (AFM) and Confocal Laser Scanning Microscopy (CLSM). Image processing methods allowed to conclude that the bee coverage is reduced upon ageing.

Additionally, the oxygenated products as revealed by the ageing mechanisms in bitumen were linked via multivariate statistics to advanced rheological parameters extracted via the Dynamic shear Rheometer (DSR). Convergence of the fast rate-determining phase and the short-term lab ageing was found both for chemistry and rheology. The dissertation ends with the description of a thermodynamics of irreversible processes model for the fast rate-determining oxidation phase, with the model accounting for reasonable changes of the SARA fractions with oxidation.

All in all, this dissertation provides a deeper scientific insight into the oxidative ageing mechanisms in bitumen and clarifies the relationship between chemical and rheological characteristics, which may contribute as a guideline to a more sustainable road infrastructure in the future.

Keywords: PhD dissertation, bitumen, ageing, spectroscopy, rheology, microscopy.


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