

CONFERENCE PROGRAM GUIDE AND ABSTRACTS

Edited by Aristos P. Brandt

GMT	TRACK 1 Rigid Pav, Geo, Statistics, Others	TRACK 2 Structures	TRACK 3 Mixes	TRACK 4 Binders
FRIDAY (July 31st) TESTING				
1300 - 1400		901 Test your connection for AM3P (Link	902 Test your connection for AM3P (Link	
VIII emailed a day before) VIII emailed a day before)				
1300 - 1400		PO3 Test your connection for AM3P (Link	Test your connection for AM3P (Link	
	(August 2rd)	will emailed a day before)	will emailed a day before)	
Welcome: Tom Papagiannakis. Chair				
1300 - 1310	AM3P 20			
1310 - 1320	SIAC			
1320 - 1400	Keynote Address: Prof. Eyad Masad		· · · · · · · · · · · · · · · · · · ·	
1405 - 1605		311 Functional pavement characteristics and vehicle-pavement interaction	411 Modeling in mixes - Part 1 - Fatigue and fracture	611 Chemo-mechanics and microstructure of asphalt binders
		Moderator: Karim Chatti, Michigan State Univ.	Moderator: Yong-Rak Kim, Texas A&M Univ.	Moderator: Michael Greenfield, Univ. of Rhode Island
1610 - 1910	Workshop - PASSRigid for the integration of concrete mixture design, pavement design, and durability			
	Jason Weiss, Oklrahoma State Univ. and Matt Corrigan, FHWA			
1915 - 2215	Workshop - PASSFlex for the integration of asphalt mixture design, pavement design, and performance			
	Richard Kim, North Carolina State Univ. and Matt Corrigan, FHWA			
TUESDAY	(August 4th)			
1300 - 1345	Keynote Address: Prof. Richard Kim			
1355 - 1615	Modeling, performance prediction and design of rigid pavements	Advances and evaluation of pavement analysis and design methodologies - 1	414 Design and performance evaluation of asphalt mixes	614 Modeling binder rheology and performance - 1
1555 101-	Moderator: Lev Khazanovich, Univ. of Pittsburgh	Moderator: Elie Hajj, Univ. of Nevada, Reno	Moderator: Shane Underwood, North Carloina State U	Moderator: Kamilla Vasconcelos, Univ. of Sao Paolo
WEDNESD	PAY (August 5th)			<u> </u>
1300 - 1345	Keynote Address: Prof. Markus Oeser			
1.355 - 1615	Pavement Geotechnics: characterization, modeling, and stabilization	Advances and evaluation of pavement analysis and design methodologies - 2	421 Performance evaluation of green mixes - Part 1 - RAP	615 Modeling binder rheology and performance - 2
1992 1013	Moderator: Erol Tutumluer, U Illinois Urbana Champaign	Moderator: Ghassan Chehab, American Univ. of Beirut	Moderator: Zhen Leng, Hong Kong Poly U	Moderator: Kamilla Vasconcelos, Univ. of Sao Paolo
THURSDA	Y (August 6th)			
1300 - 1430	511 Variability and sensitivity in performance and modeling	Monitoring & modeling to predict performance of pavement structures - 1	412 Modeling in mixes - Part 2 - Computational and analytical methods	612 Asphalt binder aging - Part 1
	Moderator: Katherine Petros, FHWA	Moderator: Emin Kutay, Michigan State Univ.	Moderator: Eshan Dave, Univ of New Hampshire	Moderator: Katerina Varveri, TU Delft
1435 - 1605	531 Al, Big Data, Machine Learning	Monitoring & modeling to predict performance of pavement structures - 2	413 Modeling in mixes - Part 3 - Porous asphalt mixes	613 Asphalt binder aging - Part 2
	Moderator: Wynand Steyn, Univ. of Pretoria	Moderator: Emin Kutay, Michigan State Univ.	Moderator: Eshan Dave, Univ of New Hampshire	Moderator: Katerina Varveri, TU Delft
FRIDAY (A	ugust 7th)		<u></u>	
1300 - 1345	APSE panel on careers; Moderator Silvia Caro. Univ. of Los Andes			
1355 - 1615	Novel materials and other technological advancements in pavements		422 Performance evaluation of green mixes - Part 2 - Cold mixes and others	813 Impact of aggregate and filler properties on performance
	Moderator: TBD		Moderator: Zhen Leng, Hong Kong Poly U	Moderator: Silvia Caro, Univ. of Los Andes

TABLE OF CONTENTS

MONDAY AUGUST 3rd
Keynote Speech by Dr. E. A. Masad5
Session 311 Functional pavement characteristics and vehicle-pavement interaction; Moderated by Karim Chatti, Michigan State U
Session 411 Modeling in mixes - Part 1 - Fatigue and fracture; Moderated by Yong-Rak Kim, Texas A&M Univ8
Session 611 Chemo-mechanics and microstructure of asphalt binders; Moderated by Michael Greenfield, Univ. of Rhode Island
TUESDAY AUGUST 4TH15
Keynote Speech by Dr. Youngsoo Richard Kim15
Session 111 Modeling, performance prediction and design of rigid pavements; Lev Khazanovich, Univ. of Pittsburgh15
Session 331 Advances and evaluation of pavement analysis and design methodologies - Part 1; Moderated by Elie Hajj, Univ. of Nevada, Reno
Session 414 Design and performance evaluation of asphalt mixes; Moderated by Shane Underwood, North Carolina State U
Session 614 Modeling binder rheology and performance - Part 1; Moderated by Kamilla Vasconcelos, Univ of Sao Paolo
WEDNESDAY AUGUST 5TH
Keynote Speech by Dr. Markus Oeser
Session 211 Pavement Geotechnics: characterization, modeling, and stabilization; Moderated by Erol Tutumluer, U Illinois Urbana Champaign
Session 333 Advances and evaluation of pavement analysis and design methodologies - Part 2; Moderated by Ghassan Chehab, American Univ. of Beirut
Session 421 Performance evaluation of green mixes - Part 1 – RAP; Moderated by Zhen Leng, Hong Kong Poly U
Session 615 Modeling binder rheology and performance - Part 2; Moderated by Kamilla Vasconcelos, Univ of Sao Paolo
THURSDAY AUGUST 6TH

Session 511 Variability and sensitivity in performance and modeling; Moderated by Katherine Petros, FHWA 42
Session 531 AI, Big Data, Machine Learning; Moderated by Wynand Steyn, Univ. of Pretoria
Session 321 Monitoring and modeling techniques to predict performance of existing pavement structures - Part 1; Moderated by Emin Kutay, Michigan State Univ
Session 322 Monitoring and modeling techniques to predict performance of existing pavement structures - Part 2; Moderated by Emin Kutay, Michigan State Univ
Session 412 Modeling in mixes - Part 2 - Computational and analytical methods; Moderated by Eshan Dave, Univ of New Hampshire
Session 413 Modeling in mixes - Part 3 - Porous asphalt mixes; Moderated by Eshan Dave, Univ of New Hampshire
Session 612 Asphalt binder aging - Part 1; Moderated by Katerina Varveri, TU Delft
Session 613 Asphalt binder aging - Part 2; Moderated by Katerina Varveri, TU Delft
FRIDAY AUGUST 7 _{TH} 62
Session 811 Novel materials and other technological advancements in pavements; Moderated by Sandra Erkens TU Delft
Session 422 Performance evaluation of green mixes - Part 2 - Cold mixes and others; Moderated by Zhen Leng, Hong Kong Poly U
Session 813 Impact of aggregate and filler properties on performance; Moderated by Silvia Caro, Univ. of Los Andes

Monday August 3rd

Keynote Speech by Dr. E. A. Masad



Dr. Eyad Masad is a professor in the Zachry Department of Civil Engineering at Texas A&M University and a professor in the Mechanical Engineering Program at Texas A&M at Qatar. He is also the Executive Director of Global Initiatives in the Texas A&M Engineering Experiment Station. He received his BSc from the University of Jordan and his MSc and PhD from Washington State University. Dr. Masad is a fellow of the American Society of Civil Engineers (ASCE) and a fellow of the American Association for the Advancement of Science (AAAS). He is the recipient of the James Laurie Prize for 2019 from ASCE. Dr. Masad research focuses on multi-scale characterization of pavement materials, computational modeling, analysis and design of pavement systems.

Multiscale Characterization and Computational Modeling of Asphaltic Materials: Opportunities and Challenges

The past two decades have witnessed significant advances in computational modeling of asphaltic materials. This was paralleled with the development of sophisticated instruments and methods for the characterization of material properties at various scales. These advances have shown great potential and supported the design and construction of sustainable pavements. However, we have not realized their full benefits due to scientific and practical limitations. The presentation will give critical review of advances in multiscale characterization and computational modeling: what did they help to accomplish and where did they fall short? This will be followed by sharing ideas for overcoming their current limitations in order to support the design of innovative materials and delivering sustainable pavements.

Session 311

Functional pavement characteristics and vehicle-pavement interaction; Moderated by Karim Chatti, Michigan State U.

Effect of thresholding algorithms on pervious pavement skid resistance

A. Jagadeesh & G. P. Ong National University of Singapore, Singapore

Y. M. Su

National Kaohsiung University of Science and Technology, Taiwan

ABSTRACT: The primary usage of pervious concrete mixtures in pavement construction is to improve the functional performance of pavements through increasing skid resistance and hydroplaning speeds (by dispersing the hydrodynamic pressure developed at the tire-pavement interface) and increasing the water infiltration and tire-pavement contact area at higher speeds, thereby reducing the wet weather accidents. Past skid resistance simulation models for pervious pavements considered the use of artificial pore grid models, but with today's advanced X-Ray computed tomography (XRCT) technologies, it is now possible to develop realistic pavement models for skid resistance simulation. This paper aims to investigate the effect of thresholding - a crucial step in image segmentation - on skid resistance of pervious concrete pavements, whose pore structures are derived from XRCT. It was found from the analysis presented in this paper that the various thresholding algorithms are found to be either under- or over-estimating the uplift and drag forces, as compared to the discharge-based thresholding algorithm. Errors in skid number due to thresholding are however found to be marginal (with up to 2 SN or 3% error).

Investigation of the motion and the flow-field of a wheel tracking device

K. Kavinmathi, Ph.D. Research Scholar

Indian Institute of Technology Madras, Chennai, India

ABSTRACT: Wheel tracking device is used to find the rutting susceptibility of asphalt concrete. Typically in most of these devices, like the French rutting tester and the Hamburg Wheel tracking device, the wheel follows a to-and-fro motion while subjecting the sample to a moving load. This motion is unlike what is observed in highways. It is widely known that at higher temperatures, a moving vehicle subjects the pavement to permanent deformation in the longitudinal direction in addition to the permanent deformation in the vertical direction. Thus, both the direction of wheel motion and the longitudinal component of force can affect the flow-field of the tested samples. Hence, these factors must be considered while modelling their mechanical behavior. In this study, the influence of the direction of the wheel loading and the influence of longitudinal force on the flow-field was examined by conducting a finite element analysis on an asphalt concrete at 60^o C. A sensitivity analysis was conducted with three different coefficients of friction (0, 0.1, and 0.35), and two different modes of wheel motion (to-and-fro motion, and unidirectional motion). Preliminary analysis showed a significant difference in rut depth, for samples subjected to "to-and-fro" wheel motion, with and without longitudinal force.

Overview of pavement vehicle interaction research at the MIT concrete sustainability hub

J. Mack CEMEX USA, Houston, Texas

M. Akbarian, F. J. Ulm, Randolph Kirchain, & Jeremy Gregory Dept. of Civil and Env. Engineering, Massachusetts Institute of Technology, Cambridge, MA

A. Louhghalam

Dept. of Civil and Env. Engineering, University of Massachusetts Dartmouth, Dartmouth, MA

ABSTRACT: In 2009, the US cement and concrete industries established the Concrete Sustainability Hub at the Massachusetts Institute of Technology. A primary thrust of MIT's activities has been improving the Life Cycle Assessment practices to better quantify the environmental impacts over the life of a pavement. In their research, the MIT CSHub determined that the "use phase," and specifically Pavement Vehicle Interaction (PVI) has a very large impact

on a Pavement's sustainability aspects. This paper will summarize the CSHub PVI research findings to date.

Parametric and sensitivity analysis of PVI-related surface characteristics models for fuel consumption

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D. Merritt The Transtec Group Inc., Austin TX, USA

N. Sivaneswaran

Turner-Fairbank Highway Res. Center, Federal Highway Admin. (FHWA), McLean, VA, USA

H. Dylla

Federal Highway Administration (FHWA), Washington DC, USA

ABSTRACT: Pavement surface characteristics and the associated pavement vehicle interaction (PVI) affects vehicle operating costs (VOC) and excess fuel consumption (EFC). This paper summarizes an evaluation of six current PVI models that consider pavement roughness and/or texture through a parametric study of the model inputs. The intent of the study was to gain a better understanding of the sensitivity of the different models to the various PVI input parameters, and to further assess the impacts of pavement surface characteristics on EFC. In general, all models indicated that increase in roughness, texture, speed and vehicle weight results in increased fuel consumption. Exceptions are noted along with some unidentifiable contradictions that may be associated with the empirical nature of some of the models.

Measurement of structural rolling resistance at two temperatures

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C.P. Nielsen Greenwood Engineering A/S, Brøndby, Denmark

P.G. Hjorth

DTU Compute, Lyngby, Denmark

ABSTRACT: In this study, we investigate how an increase in road temperature influences the structural rolling resistance of a heavy vehicle. The structural rolling resistance (SRR) is defined as the dissipated energy due to pavement deflection under a moving load. It is measured using a newly proposed method, which is based on the relationship between SRR and the slope of the deflection basin underneath the load. Using the Traffic Speed Deflectometer technology, we measured SRR on the same road under two different road temperatures, 18°C and 35°C respectively. On average, an increase in SRR of 59% was observed, with some areas of the road having up to 400% increase. This indicates that under warm road conditions SRR might have a significant effect on the overall rolling resistance of a heavy vehicle.

Mechanistic modeling of macro-texture's effect on rolling resistance

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Intertek-PSI, Dallas, TX, USA

K. Chatti

Civil and Env. Engineering Department, Michigan State university, East Lansing, MI, USA

ABSTRACT: Rolling resistance of a vehicle plays an important role in its fuel consumption. There are different mechanisms involved in the rolling resistance, namely, vehicle dynamics, tire bending and deformation, and tire tread deformation. Pavement surface macro-texture is one of the factors that influences the rolling resistance mechanisms of tire bending and tire and tread deformations. The main aim of this study is to develop a mechanistic model that is able to capture the effect of macro-texture on the tire's rolling resistance. For this purpose, a 3D finite element model of a tire is developed. The profile macro-texture is extracted from measured profiles and characterized using the root mean square (RMS) parameter. The rolling resistance coefficient is then calculated for surfaces with different RMS values. A comparison of the results with previous experimental studies shows that the model is capable of capturing the effect of macro-texture accurately.

Session 411

Modeling in mixes - Part 1 - Fatigue and fracture; Moderated by Yong-Rak Kim, Texas A&M Univ.

Effect of load eccentricity on uniaxial fatigue test results for asphalt concrete mixtures using FE modeling

A. Seitllari & M.E. Kutay, Ph.D., P.E.

Michigan State University, East Lansing, MI, USA

ABSTRACT: Fatigue phenomenon in asphaltic layers is caused by repeated traffic loading applications and predominantly happens at intermediate temperatures. To better understand and assess the resistance of asphalt mixtures to fatigue cracking, running uniaxial fatigue tests became quite common. However, the mostnchallenging issue with the uniaxial testing is premature end-failures, which is primarily due to load eccentricity effects. While studies provide very valuable technical insights towards reduction of load eccentricity, an investigation of the effects of the eccentricity in fatigue life of asphalt mixtures has not been conducted. The objective of this study was to evaluate the effects of load eccentricity on stress and strain distribution obtained through 3D finite element approach. In general, it was observed that the maximum axial stresses and corresponding strains at the sample ends increases sharply with the increase in load eccentricity, but follow a steady state after load eccentricity of 50%. On the other hand, the corresponding strains at the center of the sample decrease with the increasing load eccentricity. These central strains are the LVDT-measured strains typically used for evaluation of fatigue performance of asphalt mixtures. In the presence of load

eccentricity, their use may indicate false fatigue performance of the asphalt mixture. Overall, this research study highlighted the impact of load eccentricity of stress-strain distribution in cylindrical samples used for evaluation of fatigue performance of asphalt mixtures. With the use of efficient finite element modelling approach, there is a potential in development of correction factors for eliminating the effects of load eccentricity for loaded cylindrical samples.

Multiscale study of the fracture properties of asphalt materials

L.M. Espinosa, S. Caro & J. Wills

Universidad de los Andes, Bogotá, Colombia

ABSTRACT: A proper mechanical characterization of asphalt mixtures is needed to improve the performance and durability of asphalt materials. This study aims at evaluating the influence of the air void content over the fracture properties of asphalt mixtures at two different length scales. To achieve this goal, Semi-Circular Bending (SCB) tests were conducted on a Hot Mix Asphalt (HMA) and its corresponding Fine Asphalt Matrix (FAM), under three different air void contents (i.e. 4, 7, and 10%). Peak load and fracture energy of FAM and HMA samples exhibited air voids dependency, while the area of its fracture zone did not. The fracture response of FAM samples could be used as an initial insight of the expected behavior of the full mixture, since the trend of the properties studied as a function of AV were quite similar in both materials.

Energy dissipation approach to quantify the fatigue damage of glass fiber grid inlaid asphalt mixture

Arbin Raj & B.S. Abhijith

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J. Murali Krishnan

Department of Civil Engineering, IIT Madras, Chennai, India

ABSTRACT: The glass fiber grid in asphalt mixtures can act as a stiffener as well as enhance the fatigue life. Four-point beam (4PB) bending test is usually carried out to evaluate the fatigue life of such composite mixtures. While there are several post-processing methods used to define the fatigue failure criterion from the 4PB test data, the total energy dissipation approach is predominantly used. In this paper, the fatigue dissipation for the computation of fatigue life is used instead of total energy dissipation. In this investigation, 4PB tests were carried out on asphalt mixtures integrated with and without the grid at 600 and 800 $\mu\epsilon$. The fatigue life computed using fatigue dissipation shows that the grid is more effective at 800 $\mu\epsilon$, and the fatigue life of the grid inlaid sample is 5.7 times higher than the samples without the grid.

Determining fracture properties of reclaimed asphalt pavement-based cement mortar using semicircular bending test

X. Shi & Z.C. Grasley

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ABSTRACT: While critical stress intensity factor (K_{lc}^s) and critical crack tip opening displacement $(CTOD_c)$ are conventionally tested using single edge notched beam (SEN(B)) specimens, the test method suffers some drawbacks. A new test to characterize the fracture properties of the two-parameter fracture model (TPFM) using semi-circular bending (SCB) specimens has recently been developed by the authors. In comparison with the SEN(B) specimens, the SCB specimens can be readily made in lab from the commonly used cylindrical specimens. The geometry is also more suitable for field applications due to the ease of extracting cylinder specimens from concrete structures. In this study, the fracture properties of the TPFM for a reclaimed asphalt pavement (RAP) based cement mortar and a plain mortar at different curing ages were characterized using the SCB fracture test. The test results show that the RAP-Mortar (cement mortar containing 100% RAP) has lower K_{lc}^s is less significant than that of the compressive strength or splitting tensile strength. On the other hand, the RAP-Mortar was found to have higher $CTOD_c$ than the CON-Mortar. The increased $CTOD_c$ indicates that cement mortar containing RAP could potentially have a higher capacity to sustain cracking.

Improved testing and analysis of uniaxial tension fatigue test

J. Uzan

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ABSTRACT: The paper presents two major improvements to the testing and analysis of the uniaxial tension fatigue test. A displacement transducer is proposed to control the strain on the specimen and avoid the problems caused by the crosshead displacement control. The fatigue test, with more than one million data points, is analyzed using the numerical integration proposed by Uzan (2020). The analysis of one fatigue test suggest that the pseudo stiffness, calculated from the peaks of the stress and pseudo strain, may not represent the material state at the end of loading cycle.

Evaluation of volumetric effects on asphalt fatigue performance with VECD theory

Y. D. Wang, A. Ghanbari, B. S. Underwood & Y. R. Kim North Carolina State University, Raleigh, North Carolina, USA

ABSTRACT: Volumetric properties have been widely used in the routine-based activities in the asphalt industry. The paper utilized the Simplified ViscoElastic Continuum Damage (S-VECD) model to evaluate the effects of the mixture volumetric property changes on their fatigue performance in a case study. A systematic experimental design was conducted, and performance tests were done on one asphalt mixture with nine different volumetric conditions. The index parameter, S_{app} , was applied to evaluate the mixture fatigue resistance on the material level while structural level analyses were performed using FlexPAVETM program. The test results indicate that the volumetric properties have great impacts on mixture fatigue resistance, and using the index

parameter and structural performance simulations are both effective approaches to evaluate asphalt mixture fatigue performance.

Development of a damage growth rate-based fatigue criterion

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Department of Transportation, AECOM

E. V. Dave & J. E. Sias

Department of Civil and Environmental Engineering, University of New Hampshire

ABSTRACT: The simplified viscoelastic continuum damage (S-VECD) theory to has gained wide-spread attention as a tool to characterize the fatigue behavior of asphalt concrete. One major challenge in using the S-VECD approach is determination of the crack localization point to compare mixtures' fatigue performance. In addition, the currently available index parameters from this approach are not highly correlated to the field performance as standalone parameters and they need to be paired with mechanistic pavement modeling to discriminate between performance of different asphalt mixtures. In this study, the three main components of the S-VECD approach: number of cycles to failure (*N_f*), accumulated decrease in pseudo stiffness ($\int_{a}^{N_f} (1-c)dN$), and

damage parameter (S) were used to develop a new damage growth rate-based fatigue criterion. An index parameter based on this approach was found to be highly correlated to the field fatigue performance for six mixtures.

Chemo-mechanics and microstructure of asphalt binders; Moderated by Michael Greenfield, Univ. of Rhode Island

Dissolution simulation of polymers in bitumen

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² Department of Civil Infrastructure and Environmental Engineering, Khalifa University of Science and Technology, Abu Dhabi, United Arab Emirates.

ABSTRACT: Fundamental models should be developed and utilized in order to facilitate the chemo-mechanical design of modified binder systems for paving applications but not only. Especially, the fact that the incorporation of new chemical substances used as bio-based modifiers or alternative binders is attracting great interest to replace traditional technologies, the development of tools able to provide insight into the various physio-chemical phenomena is crucial. Among other polymer-bitumen interaction phenomena, the dissolution mechanism of polymers in bitumen is a significant aspect that should be considering in order to enhance binder properties through polymer modification. The current research gives emphasis on modelling the mechanism of dissolution for rubbery polymers in bitumen.

A review of asphalt and aggregate interface behavior studies using MD

H. Gong, J. Tao, X. Luo, and F, Wang

Texas State University, San Marcos, USA

ABSTRACT: Interface behavior between asphalt and aggregate plays a very important role in the performance of asphalt concrete. Molecular Dynamics (MD) simulation was being adopted for asphalt concrete research in the micro scale in the last decades. In this paper, MD simulation applications in interface behavior between asphalt and aggregate were summarized to achieve better results in further simulations. Fundamental theory of simulation, such as potential energy and Force Field are discussed. Model construction of asphalt and aggregate molecules are discussed and verified. Mechanical behavior under load investigated through MD simulation are given. The review results show that MD simulation is a viable approach to predict the performance of asphalt concrete and to bridge the gap between macro and micro scale behaviors. Future study should be focused on building more accurate molecular models, optimizing simulation environment, and developing comprehensive verification criteria.

Asphalt complex modulus and phase angle by equilibrium molecular dynamics

M Masoori & M.L. Greenfield Dept. of Chemical Engineering, University of Rhode Island, Kingston, RI USA ABSTRACT: Relating changes in asphalt mechanics to asphalt chemistry would be useful for understanding pavement performance. Towards that end, stress relaxation modulus from prior molecular dynamics simulations of a model asphalt was converted to complex modulus, and random noise was decreased with tools from signal processing. Time-temperature superposition was found for magnitude of complex modulus over 400 to 533 K, while phase angle showed less good superposition. Time shift factors were in a similar range to those from rotation rates of individual molecules. Trends were described by the CAM asphalt rheology model.

Molecular dynamics simulation of tensile failure of asphalt binder

W. Sun & H. Wang

Department of Civil and Environmental Engineering, Rutgers University, New Brunswick, USA

ABSTRACT: This study proposed an innovative computer modeling method to investigate tensile strength and cohesive crack of asphalt binder using Molecular Dynamics (MD) simulation. The tensile stress-strain curve was obtained from MD simulations and fracture properties were calculated using cohesive zone models. The result showed that the effect of loading rate on cohesive failure properties was not significant, which agreed with previous experiment findings. The increase of temperature reduced tensile strength but increased fracture toughness of asphalt binder. The simulation results suggest the potential of MD simulation in studying chemomechanical link of asphalt binder.

A review of molecular dynamics simulation based asphalt self-healing property studies

J. Tao, H. Gong, X. Luo, and F. Wang

Texas State University, San Marcos, Texas, USA

ABSTRACT: The fatigue-cracking life of asphalt binders observed in experiments is significantly different from the actual fatigue-cracking life due to the self-healing characteristics of asphalt binders. An asphalt binder can repair the micro-cracks by itself under certain circumstances. A great number of research studies have been conducted in investigating the self-healing properties of asphalt binders. However, the asphalt binder behaviors during the self-healing processes are still unclear. The Molecular dynamics (MD) method has been used to explain the asphalt binder self-healing properties is presented. First, a background review of self-healing is introduced. Then, some representing MD simulation studies of self-healing behaviors of MD simulations in asphalt self-healing behaviors in asphalt self-healing behavior studies, which may provide useful information for future research.

Macroscopic evaluation method for adhesive performance of warm mix asphalt based on AFM

X.J. Zhang, Y.N. Wang, S.L. Song, J.H. Luan, W, Hong, H.G. Gao

Gansu Henglu Traffic Survey And Design Institute Co., Ltd, Lanzhou, Gansu, China

ABSTRACT: The objective of this study is to investigate the adhesive properties of warm mix asphalt, one base asphalt binders, one warm agent are used to produce the modified binders. Surface roughness and bee area ratio index are tested by AFM. The relationship between the microscopic adhesive performance characterization method (surface roughness, bee area ratio) and the macroscopic adhesive performance index (adhesive work) was established. The test results indicated that, with the extension of aging time, the adhesive performance of warm mix asphalt decreases gradually, and tends to be stable at 200h. There is a good correlation between the micro parameters and macro adhesive performance index. It is suggested that the bee area ratio be used to characterize the micro adhesive performance of warm mix asphalt under the condition of ultraviolet aging.

Keynote Speech by Dr. Youngsoo Richard Kim



Dr. Kim is the Jimmy D. Clark Distinguished University Professor and Alumni Association Distinguished Graduate Professor in the Department of Civil, Construction, and Environmental Engineering at North Carolina State University and Changjiang Scholar in the Department of Materials Science and Engineering at Chang'an University in China. He has over 30 years of experience in both the laboratory and field aspects of the performance evaluation of asphalt materials and pavements. His research is recognized by over \$18 million research funding. He is a Fellow of the ASCE and the Korean Academy of Science and Technology. He holds a PhD from Texas A&M University.

What is Asphalt Concrete Telling Us? A 37-Year Story

This keynote presentation summarizes Dr. Kim's findings on the different ways that asphalt concrete behaves. Dr. Kim will describe the various mechanisms that are critical in modeling the behavior of asphalt concrete, along with experimental data and models. The presentation will demonstrate how the fundamental modeling of asphalt concrete can be applied to practice and will end with a few thoughts on ways to become a successful researcher in pavement engineering.

Session 111

Modeling, performance prediction and design of rigid pavements; Lev Khazanovich, Univ. of Pittsburgh

Reconsidering shoulder type for low volume concrete roads

N. Buettner, L. Khazanovich, & J. Vandenbossche

University of Pittsburgh, Pittsburgh, PA

ABSTRACT: Structural contribution of a shoulder to the performance of concrete pavements is well recognized. However, it is traditionally quantified through reduction of critical stresses in concrete slabs when the load is applied at the traffic lane/shoulder edge. Oversized vehicles, such as farm equipment, tend to wander across the joint and onto the shoulder of the road. Conventional mechanistic models predict that placement of a portion of a wheel load on an aggregate shoulder causes stresses in the concrete slab to significantly reduce. As a result, such loading scenario is not considered in the design procedures. In this study, the effect of wheel wander on stresses in the concrete slab is reconsidered. Two structural models are developed using the finite element program ISLAB2005. Both tied concrete and aggregate shoulders are considered. The performed analysis provides an insight into the effect of vehicle loads that span across the lane/shoulder joint.

Recommended considerations for refinement of the current concrete pavement design practices for low volume concrete roads are provided.

Chemo-mechanical properties of synthesized tricalcium silicate

Shayan Gholami & Yong-Rak Kim

Zachry Department of Civil & Environmental Engineering, Texas A&M University, College Station, TX, USA

Hani Alanazi

Department of Civil and Environmental Engineering, Majmaah University, Al-Majmaah, Saudi Arabia

ABSTRACT: Tricalcium silicate based binder provides a simple matrix with only two hydration products: calcium silicate hydrate (C-S-H) and calcium hydroxide (CH). This feature is attractive to researchers who like to more accurately assess the Portland cement-based binders' phases separately. However, different purity than ordinary Portland cement clinkers could alter the properties of hydrated gels. This paper compared the nano-mechanical and chemical properties of synthesized tricalcium silicate (C3S) paste with ordinary Portland cement (OPC) paste using nanoindentation and energy dispersive X-ray spectroscopy (EDS) method. The deconvolution statistical method was used to further analyze the nanoindentation test results and compare with the EDS chemical mapping. Results indicated that C3S paste has a stiffer and more homogeneous (as the C3S paste consists only high-density C-S-H and CH) micromechanical properties than OPC although the calcium to silica ratio of C3S paste is in the range of OPC binders. In addition, the C3S paste seems to have lower porosity than OPC paste due to the lack of observation of the low elastic moduli.

Effect of nominal maximum aggregate size on fatigue damage in concrete

S.R. Kasu Indian Institute of Technology Kharagpur, India

S. Gunda CVR College of Engineering, Hyderabad, India

N. Mitra & A.R. Muppireddy Indian Institute of Technology Kharagpur, India

ABSTRACT: Fatigue damage of the cement concrete pavements is progressive under vehicular loads and these pavements are designed based on cumulative fatigue damage principle where stress level and material characteristics are considered. From the literature, contradictory results on aggregate size with fracture parameters are reported. An attempt is made in this study, to understand the influence of nominal maximum aggregate size (NMAS) on flexural fatigue of concrete specimens without a notch. The main objective is to understand the effect of concrete mixtures made with two NMAS having similar strength range on stiffness change. The results

indicated that the concrete made with NMAS of 10 mm had higher the fatigue life and thus loss in stiffness is less compared to the mix with NMAS of 20 mm. The damage model is used to predict the stiffness degradation and found that the model is excellent with a very low root mean square error.

A Study on Concrete Pavement Growth

J.H. Lee, T. Sok, Y.K. Kim & S.W. Lee

Department of Civil Engineering, Gangneung-Wonju National University, South Korea

ABSTRACT: Pavement growth (PG) is a phenomenon in which the overall length of a concrete pavement increases. This length increase induces an axial compressive force in the concrete pavement slab, resulting in blowup and damage of adjacent structures such as a bridge structure. PG is influenced by several interacting factors, including climatic conditions, pavement materials, joint systems, incompressible particles (IP) infiltrating into the joints or cracks of the slab, and an expansion caused by reactive aggregate in the concrete. In this paper, a review study on PG of concrete pavement is conducted on the long-term monitoring data of three concrete pavement sections in Maryland state of United State. Trigger temperature for pavement growth (TTPG), defined as the concrete temperature corresponding at time where all transverse joints or cracks between the expansion joints completely close. It is introduced and estimated based on the data of expansion joint movements of these three sections. The results showed the concrete pavements exhibited different overall growths depending on the IP infiltration, pavement materials and boundary conditions. The TTPG of concrete pavements gradually decreases over time although there were no significant changes in the yearly maximum concrete pavement temperature.

Short Continuously Reinforced Concrete Pavement Structural Model

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ABSTRACT: Short continuously reinforced concrete pavement (CRCP) have been proposed as a solution for bus stops and terminals. Experimental sections designed with 50 m long concrete slabs, short in comparison to traditional CRCP, showed a unique cracking behavior. From a structural point of view, only a continuous model without cracks or joints was able to match field stresses in the short CRCP. However, since transverse cracks are visible at the slab surface, the continuous model may not be the most ideal structural model for short CRCP. Concerning this, partially developed cracks based on fracture mechanics were incorporated in a new model for this structure. Results show that, in contrast to the cracked model currently used for traditional CRCP, both the continuous and the partial crack models accurately match field deflection basis. However, both models also show different critical stresses under negative thermal differentials.

Model for airfield pavement resiliency against extreme dynamic events analysis

David Whitmore, Victor Aguilar Vidal & Marta Miletić Auburn University

Alessandra Bianchini Air Force Civil Engineer Center

James Davidson Auburn University

ABSTRACT: Infrastructure resiliency has become an important element to assure community recovery after unexpected events. Resilience can be achieved through a different design approach by understanding the fundamental elements to damage limitation and thus allowing rapid recovery. The objective of this study focused on designing a model for optimal pavement layer combination with the ability of mitigating damage determined by specific dynamic events. The parametric analyses showed the limited benefits to damage mitigation of adding an asphalt overlay or an aggregate base layer. Nevertheless, the analyses allowed to conclude the importance of concrete material characteristics to damage mitigation. In fact, as concrete compressive strength increases, its ductility decreases, and the damage resistance is greatly lowered. Furthermore, for stiffer subgrade soils, the concrete penetrates less into the soil medium and, thus, less plastic strain occurs. The best damage mitigation occurred when the impulse wave travelled from a stiff material (concrete) into a soft layer (soil). The results of this study should be further validated through field testing, which will allow further model refinement and more fidelity of the pavement damage predictions.

Advances and evaluation of pavement analysis and design methodologies - Part 1; Moderated by Elie Hajj, Univ. of Nevada, Reno

Evaluation of reflective cracking in composite pavement based on different rheological models

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ABSTRACT: Three rheological models including a newly developed formulation based on the current Christensen Anderson and Marateanu (CAM) model, named sigmoidal CAM model (SCM), are used to predict the evolution of reflective cracking in a typical composite pavement structure currently used in South Korea. Three different asphalt mixtures were selected and dynamic modulus tests were performed. The mechanistic-empirical pavement design guide (MEPDG) was then used for evaluating the pavement distress and to estimate the effect of the three different models on such phenomena. It is found that while the CAM model may not be entirely reliable due to its inability in fitting the data in the high-temperature domain, the SCM might result in relatively more conservative pavement design.

Assessment of reflective cracking performance life for high polymermodified asphalt overlays

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Pavement Engineering & Science Program, University of Nevada, Reno, Nevada, USA

ABSTRACT: Reflective cracking is one of the major type of distresses associated with the use of asphalt concrete (AC) overlays for rehabilitating deteriorated asphalt pavements. This paper briefly describes the research effort completed to evaluate the reflective cracking performance life of high polymer-modified (HP) AC mixtures used as overlays. Sixteen AC mixtures were produced in the laboratory using conventional polymer modified (PMA) and HP asphalt binders. These mixtures were evaluated in terms of their dynamic modulus and resistance to reflective cracking. The engineering property and laboratory performance data were combined into a mechanistic analysis that took into consideration the existing AC pavement condition, mix-specific material properties, traffic condition, and climate. Overall, the HP AC mixes resulted in an increase in both time to reach initial cracking and reflective cracking performance life of the AC overlay when compared to their respective PMA AC overlay mixes.

Layered Nonlinear Cross Anisotropic Model for Pavements with Geogrids

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E. Levenberg

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ABSTRACT: This paper reports the details of a new layered elastic nonlinear cross anisotropic model that can consider the confinement effects of geogrids within pavements. The algorithm, herein called MatLEACANGG, was verified against well-known programs such as ELLEA2 (Layered Elastic-Cross Anisotropic model) and MichPave (Nonlinear Finite Element Model). Influence of the Geogrid on the vertical microstrain of unbound layers was illustrated via runs on four different structures (with and without Geogrid).

Calibration/Validation of the Texas mechanistic-empirical flexible pavement design method

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ABSTRACT: This paper summarizes a study dealing with the calibration/validation of the Texas mechanistic-empirical (TxME) flexible pavement design approach. In doing so, Texas-specific data were used, sourced from DSS, a Texas DOT maintained pavement performance database. Calibration coefficients were established for the layer rutting, bottom-up fatigue cracking and transverse (thermal) cracking models. For each distress, analysis of variance was conducted to establish the factors that affect prediction errors. Calibration factors were estimated through different optimization techniques such as the generalized reduced gradient (GRG) and curve fitting algorithms. The calibration coefficients resulted in significant quality of fit improvements compared to those obtained using the default calibration factors.

Dealing with non uniqueness of calculated asphalt pavements responses

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ABSTRACT: The availability of several analysis tools and utilized models for Asphalt Concrete (AC) material characterization implies that the calculated pavement responses are non-unique. Potential variations are expected to have an impact on the bearing capacity assessment and the pavement life expectancy estimation. In the present research study, the investigation considers two powerful and worldwide used viscoelastic analysis tools, namely the 3D-Move and the ViscoRoute. Although both programs are similar, there are differences in the formulation and the way the input information is provided in the format required. This study emphasizes on the produced output (in particular the calculated tensile strains at the AC bottom, related to AC fatigue

performance) and its potential impact on pavement engineering and decision-making issues, considering locally utilized AC materials.

Experimental Performance of Buried Concrete Utility under Flexible Pavements Subjected to Heavy Dynamic Loads

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ABSTRACT: Concrete culverts are underground conduits located under roadways. These culverts are required to withstand soil overburden as well as vehicular surface loads. Previous studies investigated the integrity of the culverts by applying surface loads directly on top of the soil which represents the worst-case scenario. While this may be a good design practice, for realistic buried utility assessment subjected to superheavy load (SHL) vehicles, the role of existing pavement layers should be addressed. To gain insight into the performance of buried culverts under SHL vehicle, two full-scale pavement experiments were designed and carried out at the University of Nevada, Reno. A concrete culvert was buried in the subgrade of a typical pavement structure constructed in $10 \times 10 \times 7$ ft box. Falling Weight Deflectometer (FWD) loads ranging from 9,000 to 27,000 lb were applied on top of the asphalt concrete layer. This paper describes the experiment and presents the captured culvert performance.

Evaluation of Emerging Performance Tests and Pavement Performance Prediction Models Using the FlexPAVETM Software

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Turner-Fairbank Highway Research Center, McLean, Virginia, USA

ABSTRACT: This paper outlines the impact of changes in material properties, mixture density levels, and pavement structure on FlexPAVETM outputs. This study is focused on evaluating the rutting and fatigue performance characteristics of asphalt pavements throughout pavement life cycle using FlexPAVETM software. A dense grade asphalt mixture from a field project is utilized in this evaluation. The results of this study provide insight on FlexPAVETM pavement performance predictions for various factors.

Design and performance evaluation of asphalt mixes; Moderated by Shane Underwood, North Carolina State U.

A Comparative Study of SMA and Dense Graded HMA Mixtures Using a Laboratory Rutting Test and Accelerated Pavement Testing

Dario Batioja-Alvarez1, Jeong Myung1, Yu Tian2, Jusang Lee3, & John E. Haddock1 1Purdue University, 2Tongji University, and 3Indiana Department of Transportation

ABSTRACT: The objective of the study was to evaluate stone matrix asphalt (SMA) and hot mix asphalt (HMA) rutting performance using accelerated pavement testing (APT) and the Hamburg wheel track test (HWTT) and to understand how their performance relates to rutting predictions obtained from the Pavement-ME. To do this, rutting results from a recent APT study that analyzed the performance of both SMA and HMA in a typical Indiana full-depth pavement structure were compared to HWTT and PavementME rutting results. It was found that both the APT and HWTT provide clear distinctions between the SMA and HMA mixtures and both showed trends of relative rutting resistance. Results also indicate the HWTT and APT out-comes are not comparable in magnitude. This could be explained by the HWTT having a testing environment that is more aggressive than the APT. PavementME predictions were comparable to total pavement rutting measurements from the APT, but the software was not capable of identifying the superior rutting performance of SMA.

Evaluating effects of volumetric properties on asphalt rutting using SSR test

A. Ghanbari, Y. D. Wang, B. S. Underwood & Y. R. Kim North Carolina State University, Raleigh, North Carolina, USA

ABSTRACT: The stress sweep rutting (SSR) test is a test method to characterize the resistance of asphalt mixtures to rutting using the permanent deformation shift model. This test was developed at North Carolina State University. The SSR test measures the permanent strain characteristics of asphalt mixtures as a function of deviatoric stress, loading time, and temperature. The permanent deformation shift model is based on the permanent deformation behavior of an asphalt mixture in the primary and secondary regions. The results from two SSR tests at each of the high and low temperatures are used to develop the shift model. The shift model has been implemented into the pavement performance prediction program, FlexPAVETM, to predict the permanent deformation of asphalt layers under various deviatoric stress levels, loading times, and temperatures as a function of pavement depth and time. In this paper, the SSR and FlexPAVETM model are used to show the effect of different volumetric properties on the rutting resistance of asphalt mixtures. A typical asphalt mixture in North Carolina was chosen as a case study, and the volumetric properties were changed systematically. The results state that the permanent deformation shift model can capture the effect of binder content, in-place density, and volumetric properties on the rutting behavior of asphalt mixture.

Rutting Resistance and High-Temperature PG of Asphalt Mixtures

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ABSTRACT: The Incremental Repeated Load Permanent Deformation (iRLPD) test is specified in AASHTO TP 116. The test is improvement over the Flow Number test in several aspects. The main advantage of the iRLPD test is that it determines resistance of asphalt mixtures to rutting at any temperature and stress level in half an hour. In this study, a modified method of iRLPD test, which is performed on volumetric samples in unconfined mode, is introduced. The test determines High-Temperature Performance Grade (HTPG) of the mixture as well as grade bump for traffic level. The modified method is included as Method A in TP 116. Several different materials, including mixtures with modified binders and RAP/RAS, are tested according to the Method A and the results are correlated to the known properties of the binder and mastic.

Workability quantification of bituminous mixtures using an improved workability meter

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ABSTRACT: Quantification of the workability of bituminous mixtures has always been challenging due to the associated complexity during mixing, laying and compaction. The transitory response of the rheological behavior of the binder, the particle size distribution and the quantum of work applied during mixing and compaction are a few of these factors. A few attempts exist in the literature to quantify the workability of bituminous mixtures, and such attempts have computed the torque required indirectly at a constant angular speed and constant temperature. Also, the relationship between workability during mixing and during compaction requires detailed investigation. This study presents initial results of workability equipment fabricated in-house at IIT Madras, India. Direct torque measurements recorded for different bituminous mixtures at different temperature conditions are reported and their sensitivity is discussed.

Laboratory permeability testing of chipseal road surfaces

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ABSTRACT: Thin bituminous chipseal surfaces are used on low volume roads through-out the world. Chipseals provide the required surface functionality for the traffic spectrum between unsealed roads and higher trafficked roads that requires asphalt surfacing. Increasing traffic

loadings and a changing climate are increasing the demand on these seals to perform and protect the underlying pavement. It is becoming more accepted that thin bituminous surfaces are not waterproof, and the water resistance of various seals need to be measured. This paper presents the development of static and dynamic water permeability tests that measure the water resistance of thin bituminous road surfaces in a laboratory setting.

Design of rubberized asphalt mixtures for noise and vibration damping layers

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ABSTRACT: Traffic-induced vibrations challenge road authorities due to their harmful effects on humans and buildings. The use of rubberized binders seems to improve the damping properties of asphalt mixtures reducing the vibratory mechanism. However, a reliable design method lacks definition. This work aims at designing two mixtures for damping layer prepared with large volumes of rubberized binder. The mixtures were prepared by increasing the binder content and maintaining the same Dust Proportion of an Open Grade mixture used as reference. Tensile strength, moisture susceptibility, stiffness, and phase angle, and damping ratio were measured in laboratory. The latter was used to optimize damping properties. The mixtures show adequate tensile strength and, obviously, low moisture susceptibility. On the other hand, the increase in the binder content softens the mixtures. However, the reduction in stiffness is accompanied by an increase in damping ratio which indicates a higher energy dissipation under dynamic loadings.

Modeling binder rheology and performance - Part 1; Moderated by Kamilla Vasconcelos, Univ of Sao Paolo

Large amplitude oscillatory shear of modified asphalt binder

Saqib Gulzar & Shane Underwood

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ABSTRACT: The current rheological characterization of asphalt binders mostly uses oscillatory shear based peak stress-strain data. The linear viscoelastic (LVE) limit is also estimated using such data. In order to characterize the complete response of the asphalt binder, it is essential to consider the entire waveform recorded from oscillatory shear testing. In this paper, the response of a modified binder is studied based on the complete waveform recorded during oscillatory shear testing. The waveform was recorded for strain amplitude of 30%, 40% and 50% at the testing temperature of 30°C. Viscoelastic moduli based on the geometry of Lissajous-Bowditch plots were used to study the behavior of the binder and it was found that the asphalt binder exhibits nonlinearity under such strains. There is a need to study and characterize the nonlinear response of the asphalt binders and incorporate it into the current specifications.

Geometric nonlinearities of bituminous binder and mastic using large amplitude oscillatory shear (LAOS)

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Padmarekha A Department of Civil Engineering, SRM Institute of Science and Technology

Murali Krishnan J Department of Civil Engineering, IIT Madras

ABSTRACT: Fourier transformation rheology, geometric parameters from Lissajous-Bowditch plots, and Chebyshev polynomials are some of the techniques used for determining linear and nonlinear response while conducting Large Amplitude Oscillatory Shear (LAOS). In this investigation, LAOS technique is used to characterize the response of an unmodified bituminous binder and mastic. The bituminous binder and mastic are tested at 40 °C and subjected to 1 % and 5 % strain amplitude at frequencies of 0.1, 1, and 10 Hz. Lissajous-Bowditch plots based geometric measures are used in this study. The difference in the response of binder and mastic is observed at 10 Hz frequency. The elastic and viscous linear limit is observed to be different for bituminous binder and mastic at 10 Hz frequency. Strain stiffening ratio (S) and shear thickening ratio (T) defined from the geometric measures follow no particular trend across the test conditions.

Fourier transform rheology of asphalt binders

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ABSTRACT: In general, asphalt binders are characterized in a *low strain* regime where the response is linear viscoelastic (LVE). The shear stress response is independent of the strain amplitude within the LVE limit and the frequency of the response is same as the applied frequency. However, when the asphalt binder is subjected to strains beyond the LVE limit, the response becomes nonlinear. In this regime, the response is stress or strain level dependent and may be comprised of higher order frequencies that contribute to the overall nonlinear response. In this study, a crumb rubber modified asphalt binder is tested at large strains of 30%, 40% and 50% at an applied frequency of 0.5 Hz and testing temperature of 30°C. The total stress response is analyzed using Fourier transform rheology. It is found that there is an appearance of higher harmonics in the total stress response. The contribution of higher harmonic is characterized as a

Quantification of temperature susceptibility of bitumen using large amplitude oscillatory shear

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Murali Krishnan J

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ABSTRACT: Bitumen exhibits temperature sensitive characteristics and the performance of bituminous material depends on its temperature susceptible characteristics. In this study, the temperature susceptibility of bitumen was studied using model based relaxation time. Bitumen of VG30 and VG10 grade were subjected to oscillatory shearing using large amplitude oscillatory shear (LAOS) protocol. The strain controlled oscillatory shear test was conducted at every 5°C temperature increment from 10 to 80°C. The strain amplitude of 0.001% was used for testing at 10 and 15°C and 1% for higher temperatures and all the test was conducted at the frequency of 1 Hz. The stress and strain waveforms from LAOS test were modelled using frame invariant nonlinear viscoelastic model and the relaxation time of VG30 and VG10 binder follows Arrhenius expression and at lower temperature, the relaxation time deviated from the Arrhenius equation.

Importance of triaxial stress state on asphalt binder tensile failure

Ramez Hajj & Amit Bhasin

The University of Texas at Austin

ABSTRACT: The failure stress and strain, as well as ductility, depend greatly on the stress state to which the specimen is subjected. In previous studies of asphalt binders, the dependence of material behavior on temperature, loading rate, and aging has been well-examined. However, the influence of the triaxial state of stress that confines binders between mineral aggregates has not been studied extensively. In this work, a review of other materials indicates the importance of triaxiality on the failure of soft materials. Based on this review, the state of stress in asphalt materials was considered at three scales using a finite element simulation- a full depth asphalt pavement, a dense graded asphalt mixture, and a fine aggregate matrix (FAM) mix. Results indicated that the triaxiality increased as the scale became smaller. Further simulations also indicated that the poker chip test can serve as a "worst-case" scenario test where a very high triaxiality can be replicated in the lab for binder testing.

Wednesday August 5th

Keynote Speech by Dr. Markus Oeser



Since 2011 Markus Oeser is Professor and Director of the Institute of Highway Engineering, at the RWTH Aachen University and since 2015, the Dean of the Faculty of Civil Engineering. Previously, he was a lecturer at the Dep. of Geotechnics, Road Construction and Transport. at the U. of New South Wales in Sydney. After studying at the TU Dresden at the Institute for Urban Construction and Road Construction, he worked as a research associate at the TU Dresden and received his doctorate in 2004. His habilitation took place in 2010 at the Institute of Geotechnical Engineering, Road Construction and Transportation of the University of New South Wales.

Study of Asphalt Compaction and Asphalt Performance based on Numerical Simulation and Advanced Measurement Techniques

A high-quality compaction of the asphalt mixture is of great importance for the proper design and construction of high performance asphalt pavements. In order to improve the performance of asphalt, the compaction process of the hot asphalt mix is numerically simulated. The flow of material during the compaction under the paver screed is simulated by discrete element method (DEM). In addition, advanced measurement techniques were applied to monitor the movement of granular material during paver compaction, the movement or kinematic properties of material during paving and the contact force condition of paving materials can be detected. After the paving, the asphalt performance is simulated by finite element method (FEM) using the generated microstructure of the asphalt mixtures from X-ray Computer Tomography (X-ray CT). Different compaction methods and material properties of the asphalt mixtures. This study will help generating the currently missing theoretical framework to optimize in-situ compaction of asphalt pavement. Meanwhile, it can also be used for guiding the construction of better asphalt compaction equipment (pavers, rollers) and thus ensure the transfer of the acquired basic knowledge into application-oriented research and development.

Session 211

Pavement Geotechnics: characterization, modeling, and stabilization; Moderated by Erol Tutumluer, U Illinois Urbana Champaign

Organosilane and lignosulfonate: Road subsurface layers stabilisers

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S. Adomako

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ABSTRACT: The "Ferry-free coastal highway route E39" project entails the construction of several long tunnels along the southwestern Norwegian coast, causing the generation of a remarkable quantity of blasted rocks. The aggregates could be used in the road unbound layers close to the place of production to provide a sustainable cost-benefit application. The research investigates two types of stabilising agents adopted to improve the mechanical properties of the crushed rocks, especially the "weak" rocks not fulfilling the requirements specified by the design guidelines. One additive is based on organosilane and the other additive is based on lignosulfonate. Four types of aggregates are investigated in the laboratory by means of repeated load triaxial tests. Resilient modulus is assessed by Hicks & Monismith model and Uzan model. The resistance against permanent deformation is analysed by Coulomb approach. Results prove that both the mechanical parameters are significantly enhanced by the stabilizing agents.

Effect of Plastic Subgrade on Full-Depth Reclamation Mix Design

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A. R. Abbas

The University of Akron, Akron, Ohio, USA

ABSTRACT: This study examined the effect of the amount of subgrade soil and the cement application rate on the mix design of full-depth reclamation (FDR) blends. Four FDR blends containing varying amounts of subgrade soil (0%, 12.1%, 25.6%, and 40.8% by weight) were included in the laboratory testing plan. The FDR blends were mixed with different cement application rates (4%, 6%, and 8%). The test results showed a higher susceptibility to volumetric changes and lower unconfined compressive strength values for the FDR blends containing 0% subgrade was the only blend that met a minimum unconfined compressive strength of 300 psi, which is commonly used in the mix design of FDR mixtures. While using a higher cement application rate for the other blends resulted in somewhat higher unconfined compressive strength of 300 psi, even at a cement application rate of 8%.

Soil stabilization using cement and polyelectrolyte complexes

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A.K. Palanisamy

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E. Masad Texas A&M University, Doha, Qatar

ABSTRACT: There are frequent concerns related to the mechanical endurance of subgrade soils chemically stabilized with cement especially during moisture intrusion. In this study we evaluate the structural features of polyelectrolyte complexes and propose a working mechanism to consider them as both an alternative and an additive to cement to stabilize subgrade soils. An experimental evaluation of the mechanical properties is conducted to support the proposed mechanism and validate the impact of polyelectrolyte complexes towards increasing the fracture toughness and moisture resistance of limestone screens without compromising strength gain thereby enhancing their overall geomechanical durability.

Electrokinetic treatment of clay soil – A baseline case study introduction

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ABSTRACT: Although electrokinetic phenomena were relatively recently discovered, they have come a long way and even dominate certain sectors. However, they have rarely been utilized in the discipline of civil engineering. While the limited civil engineering applications are accompanied by inherent uncertainty and changing field conditions, laboratory applications that mitigate those challenges often suffer from conditions that differ substantially from real life engineering applications, thus making questionable the validity of extrapolating results from the laboratory to on-site projects. The work presented here aims to bridge that gap by conducting a laboratory experiment that reproduces – as closely as possible – the conditions that can be expected in civil engineering projects. To that end an experimental set-up is constructed that allows for electrokinetic treatment of clay soil and even though it facilitates constant monitoring of the desired parameters, it does not deviate substantially from how electrokinetic treatment would look like in an actual project.

High strength and good durability of stabilized dolomite fines

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Heather Shoup Illinois Department of Transportation, Springfield, IL, USA

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ABSTRACT: Dolomite and limestone are two most widely quarried carbonate aggregates in the State of Illinois available for use as pavement materials. In particular, dolomites are believed to have mineralogical compositions that can provide improved durability and functionality for certain pavement applications requiring better quality materials. This paper presents two case studies where dolomitic aggregates were utilized in closely-monitored field test sections and showed superior performance when compared to limestone aggregates. The first section is for dolomitic aggregate Quarry By-products (QB) used as cement-stabilized base/subbase in low to medium volume roads, while the second case is for dolomite used as an unbound material for a gravel (unsurfaced) road application. The performances of pavement sections with dolomite aggregate and their durability aspects are compared to those of limestone sections. Preliminary findings indicate that dolomitic fines contributed to improved durability and/or higher strength gain due to delayed reactions associated with carbonate cementation governed by 'dissolution precipitation' reactions when exposed to temperature and moisture changes induced by freeze-thaw cycles.

Simulation of granular material in Distinct Element Model based on real particle shape

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ABSTRACT: An innovative approach was developed in this research to generate aggregates based on real shape through DEM. The shape indexes of aggregates were captured by Aggregate Image Measuring System (AIMS). The output was then processed by MATLAB to obtain the edge points of particles. The edge points were used to generate aggregate in DEM. Based on the former procedures, the aggregates morphological database that record shape indexes were established. The generation of DE models was optimized in the study to approach more realistic model geometries. Clump-based models with real morphologies were compared with laboratory tests and conventional ball-based models in the repose angle test. The clump-based model fitted better with the laboratory tests compared with ball-based models. Finally, a pavement compaction model was established. The influence of aggregate gradation and the movement of asphalt mixture during the compaction were investigated.

Advances and evaluation of pavement analysis and design methodologies - Part 2; Moderated by Ghassan Chehab, American Univ. of Beirut

Mechanistic damage analysis of pavements: Concept and a case study

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ABSTRACT: In this study, a fully mechanistic analysis framework is proposed to simulate and evaluate the damage evolution mostly due to cracking and resulting performance of pavements. To do so, the viscoelastic and fracture properties of designated pavement materials are obtained through experiments and a fully mechanistic damage analysis is carried out using a finite element method (FEM). Different pavement configurations and traffic loads are considered based on three main functional classes of roads suggested by FHWA i.e., arterial, collector and local. For each road type, three different material combinations for asphalt concrete (AC) and base layers are considered to study damage behavior of pavement. A concept of the approach is presented and a case study where three different material combinations for AC and base layers are considered is exemplified to study progressive damage behavior of pavements when mixture properties and layer configurations were altered.

Highlights on interesting findings of high modulus asphalt concrete (HMAC/EME) for cold regions in cooperative research project

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ABSTRACT: This paper presents a methodology to support growth and implementation of a new asphalt mix, such as high modulus asphalt concretes (HMAC) for cold regions. This requires laboratory studies (fatigue, E* and sensitivity) and elaboration of trial sections with several steps. Even though that different fatigue test methods were used in this project (tension-compression and 2 points bending), similar Wohler's law parameters were obtained with referring to a discriminant failure criterion. Overall, the laboratory investigation shows good to excellent thermomechanical

properties of HMAC tested as regards stiffness, fatigue, low temperature, and rutting resistances. Moreover, the ongoing sensitivity study shows that HMAC mixes make with bitumen and filler dosage fluctuations in accordance to regulation are not more sensitive than usual HMA.

Characterizing low-temperature field produced asphalt mix performance

Joyce Kamau, Joseph Podolsky & Chris Williams

Iowa State University

ABSTRACT: The Northern United States and Canada experience winter between 4-6 months of each year and thus are more prone to experience low temperature cracking as the primary distress in their asphalt pavements. This cracking results from a sudden drop in temperature or repeated freeze and thaw cycles, causing thermal stress build-up that exceeds the asphalt pavement's tensile strength. Cracks may allow water infiltration into the pavement, causing moisture-induced damage, which reduces pavement life, and thus maintenance is required; this adds costs to the Department of Transportation (DOT). This research assesses the low-temperature cracking resistance of asphalt mixtures used in the State of Iowa by correlating the low-temperature performance of field-produced mix based on lab specifications. The disk-shaped compact tension (DCT) was used to evaluate low-temperature mixture fracture energy. From this Study, ten mixtures were found to have fracture energies ranging from 265.25J/m2 to 470J/m2 for the DCT test, where most do not meet the required fracture energy for their specified, designed levels of traffic and the minimum value of 400J/m2. Storage of asphalt as loose mixture, aging of mixture and reheating in the laboratory may have caused reduction in fracture resistance. A distress survey is recommended before the specification are revised.

Postmortem evaluation of in-service raveled pavements in arid climatic regions-case of Kuwait

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ABSTRACT: A postmortem evaluation of selected raveled pavements was completed in this research study as a step forward towards the overall effort to investigate the possible causes of asphalt pavement raveling in the arid climatic region of Kuwait. Pavement distress surveys accompanied with sand patch tests were conducted for the selected sections to identify the existed distresses and to estimate their pavement condition indices (PCIs). Several cores were extracted from the pavement sections for further laboratory evaluation of their as-built pavement properties. Pavement condition surveys and sand patch test results showed that all pavement sections, including the recently maintained sections within the last 3 years, were severely deteriorated due to the existence of raveling. Sections' PCIs ranked from "Fair" to "Serious", indicating significantly poor functional performance. Aggregate sieve analyses and as-built volumetric properties results showed slight deviations from the specified requirements by the state of Kuwait, which can be related to the raveling problem.

Investigation of Cracking Performance of Asphalt Mixtures in Missouri

Behnam Jahangiri, Hamed Majidifard, Punyaslok Rath, & William Buttlar Civil and Environmental Engineering Department, University of Missouri-Columbia

ABSTRACT: This study investigates the performance of four asphalt mixture types that were recently used on paving projects across the state of Missouri, USA. Three-of-four mixtures contained reclaimed asphalt pavement (RAP) with up to 35% asphalt binder replacement (ABR), while the fourth mixture possessed 33% ABR, entirely via recycled asphalt shingles (RAS). Performance testing including the disk-shaped compact tension (DC(T)) test, along with indirect tension (IDT) creep and strength testing were performed on field cores and plant-produced, lab-compacted (PPLC) samples to evaluate the cracking potential of each of the studied mixtures. Testing results suggested that each of the mixtures have high cracking potential, i.e., exhibit brittle behavior. ILLI-TC software was employed using creep and DC(T) inputs to simulate low temperature cracking potential in the Midwest climate.

HMA characterization under different Egyptian design conditions

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ABSTRACT: There is a lack of knowledge about locally produced HMA performance under different Egyptian local environmental and loading conditions. Such knowledge is very important to properly design hot asphalt mixes to suit site features. To overcome this problem, there is a need to sufficiently study the behavior/response of HMA under different design and loading factors pertinent to Egyptian conditions. These factors include; fine aggregate type (natural versus manufactured sand) and mineral filler type (cement dust versus stone filler), temperature, and loading time. The final findings of this research demonstrated that, using manufactured sand instead of natural sand results in significant increase in the Indirect Tensile Strength. Using cement dust instead of stone filler as mineral filler results in moderate to high increase in all used engineering properties. As for the effect of environmental and loading factors, it was found that; resilient modulus decreases significantly with the increase in temperature and with increasing loading time.

Performance evaluation of green mixes - Part 1 – RAP; Moderated by Zhen Leng, Hong Kong Poly U

Assessing permanent deformation of reclaimed asphalt blended binders using non-linear viscoelasticity theory

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ABSTRACT: In this study, the resistance of various RAP blended binders to permanent deformation was analyzed with consideration to the nonlinear response of asphalt binders. Multiple creep and recovery (MSCR) and repeated creep and recovery with multiple stress levels (RCRMS) were performed on the RAP blended binders at 64_{\circ} C. For the binder used in this study, it was found that the linear viscoelasticity framework is sufficient to capture the MSCR results. However, the use of a nonlinear viscoelastic model was necessary to predict the response of the binders when subjected to the RCRMS protocol. The results highlight the advantages of using a nonlinear viscoelasticity framework instead of relying only on the non-recoverable creep compliance (Jnr) to evaluate the rutting resistance of asphalt binders.

Rejuvenation of reclaimed asphalt pavement (RAP) binder appealing to design of experiments

M. Thirumalavenkatesh, V. T. Thushara & J. Murali Krishnan Department of Civil Engineering, Indian Institute of Technology Madras, India

ABSTRACT: Reclaimed asphalt binder blending involves a lot of mixture variables and experimentation. The objective of this study is to adopt statistical experimental design framework to design a ternary mixture consisting of Reclaimed Asphalt Pavement (RAP) binder, vacuum tower bottom (VTB) and rejuvenator to meet target steady shear viscosity, Performance Grade (PG) pass/fail temperature and softening point of a typical Viscosity Grade 30(VG30) binder. I-Optimal design algorithm is used to design the experimental matrix. Response prediction models are developed for steady shear viscosity, high temperature performance grade (PG) (pass/fail) and softening point based on the measurements carried out on the prepared blends. From the predicted response models, the possible RAP binder blend space which yield target responses is identified.

Modeling changes in asphalt mixture properties with RAP content

N. F. Saleh, D. Mocelin, C. Castorena, and Y. R. Kim North Carolina State University, Raleigh, USA

ABSTRACT: This paper investigates whether an existing framework that predicts the changes of asphalt mixture properties as a result of changes in asphalt binder modulus caused by oxidative aging can be expanded to predict changes caused by the inclusion of recycled asphalt pavements (RAP). This study stipulates that mastercurves of mixtures of similar gradation and component material sources but with different RAP contents can coincide if shifted horizontally along the log frequency axis, such that the shift factor can be related to the change in binder modulus. Changes in mixture fatigue properties are also shown to be a result of changes in asphalt binder properties. Under the right conditions, this study shows that the properties of a mixture containing a certain RAP content and of a certain age level can be predicted from the short-term aged properties of a mixture containing no RAP, or vice-versa.

Determining optimum doses of palm oil rejuvenators for recycled blends

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A.E. Alvarez

Universidad Industrial de Santander (UIS), Colombia

ABSTRACT: This study aims at exploring different methodologies to select the amount of two palm-oil based rejuvenators that allows maximizing the restored properties of recycled blends; that is, the blend of virgin binder, Reclaimed Asphalt Pavement (RAP) binder and rejuvenator. Three dosage selection methods based on Penetration, Softening Point and High Temperature Superpave Performance Grade (PGH) of the recycled blends in their unaged and aged states were evaluated. In addition, an approach based on the thermodynamic properties of the recycled blends was also explored. The dosage selection was determined as a function of the target virgin binder properties in unaged and aged conditions. The optimum palm-oil rejuvenator dose recommended corresponds to the average dose that restores penetration in unaged conditions and the PGH of the recycled blend.

Effect of recycling agents on the homogeneity of high RAP binders

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F. Kaseer

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ABSTRACT: Increased costs of virgin asphalt pavement materials have encouraged transportation agencies to allow higher quantities of reclaimed asphalt pavement (RAP) in their recycled asphalt mix design if performance can be maintained. Recycling agents or rejuvenators are organic materials used to reduce the stiffness and brittleness of RAP binders and make recycled mixtures less prone to cracking. Recycling agents can facilitate the use of higher quantities of RAP; however, there is limited understanding on their effect on the homogeneity of the final blend of virgin and recycled binders and recycling agents. This study utilized Atomic Force Microscopy (AFM) to assess the effect of recycling agents on the homogeneity of different blends of virgin and RAP binders. AFM results revealed that the addition of recycling agents improved the homogeneity of blends at unaged and short-term aging conditions; however, this effect diminished after long-term aging.

Effectiveness of polymer modified emulsion based rejuvenator

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Manoj Kumar Shukla CSIR-Central Road Research Institute, New Delhi, India

ABSTRACT:

The growth of economy of any country depends upon the development of transportation and there is a growing demand for air transportation in developing country. In runway construction, the flexible pavements typically have a functional life of 12 to 15 years between major maintenance treatments. Pavement preservation plays a significant role in maintaining the pavement infrastructure under severe budget constraints. Numerous methods are being employed for asphalt pavement preservation including rejuvenator, bitumen emulsion fog seals surface treatments (including slurry and micro surfacing technologies), and emerging bituminous thin overlay technologies. The present study investigated the field performance and mechanical properties of bituminous mixtures treated with polymer modified emulsion based rejuvenator.

Impacts of unblended reclaimed asphalt on volumetric mixture design

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Department of Civil, Construction, and Environmental Engineering

ABSTRACT: Increasing reclaimed asphalt pavement (RAP) contents in asphalt mixtures has economic benefits, however many assumptions which simplified the usage of lower RAP contents break down at higher RAP contents. One of the most fundamental is the assumption of complete and uniform blending between RAP and virgin materials. Energy dispersive spectroscopy (EDS) has been trialed in several previous studies to assess the blending between RAP and virgin binders and is used in this work to assess blending variability across a sample surface. The implications of

incomplete blending on volumetric mixture design parameters is discussed as volumetric properties are used for mixture acceptance.

Modeling binder rheology and performance - Part 2; Moderated by Kamilla Vasconcelos, Univ of Sao Paolo

Micro-scale observations of fatigue damage mechanism in asphalt binder

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Kiran Mohanraj, Amit Bhasin

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ABSTRACT: The fatigue cracking mechanism of asphalt binders in asphalt mixtures is often described using mathematical modeling and theoretical diagrams but has yet to be observed using optical microscopy techniques. We use dark field optical microscopy to observe the bulk microstructure of asphalt binder subjected to high amplitude cyclic loading. This preliminary observation informs that once cavitation begins in asphalt binder, the cavities serve as nucleation sites for microcracks to form. In the first stage of material failure, the cavities grow until they collapse and form macrocracks connecting individual cavities, which serves as stage two of failure. Finally, the cavities are joined by microcracks to form a macrocrack in the specimen. As this process happens, bulk microstructures are pushed between the existing cracks to form high density areas of structure in the undamaged region.

Improved test method for low-temperature PG of asphalt binders

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ABSTRACT: A new low-temperature test on DSR, called iCCL, is introduced in this paper and it is shown that it provides the same Low-Temperature Performance Grade (LTPG) as the BBR test method for 583 binders of 20 different grades. Results of round robin testing in six different laboratories was used to devel-op precision and bias statement for iCCL, which shows that iCCL is at least two times more precise than BBR. iCCL is significantly faster, safer, and more practical than BBR. The test only takes 30 minutes to conduct and does not use any chemicals, air pressure, or liquid bath. iCCL is also able to provide a good es-timate of LTPG using original binders, which makes it useful for asphalt plants and terminals. This study shows that iCCL significantly improves the current asphalt binder testing technology.

Discrete fracture modelling of rubber-modified binder

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ABSTRACT: A strength-softening model combined with Burger's model was applied to investigate the fracture behavior of rubber-modified binder in this study. Based on the commercial software Particle Flow Code in 3-Dimensions (PFC3D), the interaction between rubber and binder was visually illustrated. Results from a virtual bending beam test and a newly-designed binder cracking test were integrated to arrive at the required parameters for viscoelastic and fracture constitutive models in the DEM simulation. Simulation results revealed a close agreement with experimental data, which verify the modelling methods used herein. It was found that the presence of rubber particles in asphalt leads to a crack-pinning toughening behavior that enhances the ability of the asphalt specimen to inhibit cracking at low temperatures.

Stress decomposition of nonlinear response of modified asphalt binder under large strains

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ABSTRACT: The current characterization of asphalt binders is based on linear viscoelasticity wherein the testing is performed under small strains. It ensures that the binder stress response is independent of the strain amplitude and is sinusoidal in nature with frequency same as input frequency. However, the asphalt binders may be subjected to large stains as part of asphalt mixture in the pavement under field conditions and the response may well be nonlinear. The linear viscoelastic measures lose their meaning in the nonlinear range and it is essential to decipher the nonlinear binder response under large stains. In this study, a crumb rubber modified asphalt binder is tested at large strains of 30%, 40% and 50% at an applied frequency of 0.5 Hz and testing temperature of 30°C. A stress decomposition technique based on geometric interpretation of nonlinear response is utilized to obtain the elastic and viscous contributions in the total response. Further, Chebyshev polynomials of the first kind are used to obtain meaningful viscoelastic measures in the nonlinear regime. It is observed that third order elastic and viscous contribution appear in the nonlinear response, and the binder shows strain stiffening and shear thinning behavior under the tested conditions of large strains.

Evaluation of models for binder dynamic shear modulus and phase angle

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ABSTRACT: An evaluation of the predictive capabilities of the Bari-Witczak and the Onifade-Birgisson models for the prediction of dynamic shear modulus and phase angle from conventional steady-state viscosity is performed. The study considers five different geographical locations with a wide range of temperature in order to account for the range of in-service pavement temperature conditions in the US. The Bari-Witczak models predicted accurate tendencies of dynamic shear modulus and phase angle for pavement sections in the warmer regions, while several irregularities in model predictions were observed for the pavement sections in the colder region. On the other hand, the Onifade-Birgisson model is sensitive to the variations in the pavement temperature with realistic tendencies predicted for the different pavement locations and seasons. The results of the model predictions can have serious implications for the reliable estimation of mixtures dynamic modulus, evaluation of susceptibility of binders to low-temperature cracking, and the evaluation of pavement long-term performance.

DSR Geometry Impact on Asphalt Binder Linear Viscoelastic Properties

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ABSTRACT: Asphalt binder is a rheological complex material with elastic and viscous components response, according to the temperature and loading conditions, being its rheological characterization an important tool to better predict the material performance. The Dynamic Shear Rheometer (DSR), using parallel-plates geometry, is so far the most common oscillatory testing carried out for rheological characterizations in bituminous materials. However, the rheological response needs to be characterized considering the stages of binder application and use, as the material have different behavior for each phase during hot asphalt mixture production, application and design life performance. So, the setup of rheological tests must be adequate to correctly represent the real conditions during each stage. The main purpose of this work was to compare the impact of different test configurations (using parallel-plate, Vane and DIN) in the response of a neat asphalt binder applying the strain sweep test at different temperatures.

Thursday August 6th

Session 511

Variability and sensitivity in performance and modeling; Moderated by Katherine Petros, FHWA

Sensitivity analysis of AASHTOWare PMED to climatic inputs and depth of water table

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ABSTRACT: Sensitivity analysis is conducted on AASHTOWare Pavement Mechanistic Empirical Design (PMED) by using a Design of Experiment method that considers 2k factorial design, an unbiased method that analyses the effect of climatic inputs and depth of water table to flexible pavement distress predictions. This study used three LTPP sites located in Tennessee; these sites are of Functional Classes 1, 2 and 7. From the analysis of climatic inputs and depth of water table, temperature was observed to be the most sensitive climatic input followed by Wind speed and the depth of water table. Percent sunshine has a less significant influence on the distress predictions while relative humidity was observed to have a negligible effect to the flexible pavement distress predictions.

Sensitivity analysis of simplified viscoelastic continuum damage fatigue model

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ABSTRACT: This paper investigates the parametric sensitivity in the Simplified Viscoelastic Continuum Damage (S-VECD) fatigue model of asphalt mixture by using model-based and experimental data-based sensitivity analysis. The model-based sensitivity analysis characterizes the change of model response with respect to individual parameters. The experimental data-based sensitivity analysis incorporates the parameter correlation and characterizes the change of model response with respect to correlated parameters. In this study, experimental data from a total of 31 specimens were used to generate parameters through the Markov Chain Monte Carlo (MCMC) technique to account for parameter correlation. Then, the simulated parameters were used to

construct the experimental data-based sensitivity indices. The model-based analysis results in the parameter sensitivity ranking as $C_{11} > C_{12} > D_R > \alpha > |E*|$. The experimental data-based analysis gives the sensitivity ranking as $D_R > C_{11}$, $C_{12} > |E*| \approx \alpha$.

On uncertainty in asphalt binder unit response master curves

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ABSTRACT: Various temperature shift factor approaches are used to account for timetemperature equivalencies while constructing master curves. Even with good quality control measures, significant scatter in dynamic shear modulus ($|G^*|$), phase angle (ϕ) data is observed. This, in turn, results in uncertainty in finalized relaxation modulus, G(t) and creep compliance, J(t) master curves when interconversion techniques are used. This uncertainty could be ascribed to factors like material testing practices, human errors, experimental errors, numerical approximations etc. This study presents a comprehensive approach to evaluate the uncertainty that is propagated to J(t) and G(t) values during master curve construction and interconversion process. Two shift factor construction methods, i.e, asymmetric Kaelble shift factor method and symmetric free shifting approach are considered during the master curve construction process. The uncertainty parameters such as Normalised Uncertainty Range (NUR) indicated that asymmetric-Kaelble method results in lower uncertainty when compared to symmetric-free shifting approach.

Pavement performance prediction using mixture performancevolumetric relationship

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ABSTRACT: This paper describes the relationship between pavement performance (based on fatigue damage and rutting) and the volumetric information of mixtures used in asphalt field projects. This study, as part of shadow projects for the Federal Highway Administration's Asphalt Mixture Performance-Related Specifications deployment research project, focuses on (1) a procedure to calibrate the performance-volumetric relationship (PVR) and (2) predicting pavement performance under field conditions using the developed PVR. In addition, the performance of asdesigned and as-constructed mixture samples is predicted and compared.

Impact of WIM Systematic Bias on Axle Load Spectra – A Case Study

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ABSTRACT: Weigh-in-motion (WIM) is a primary technology used for monitoring and collecting vehicle weights and axle loads on roadways. One way to evaluate the quality of WIM

measurements is to analyze axle load spectra over time. Class 9 single-axle (SA) normalized axle load spectra (NALS) can be modeled as a single normal or log-normal distribution with a mean value corresponding to the NALS's peak load frequency value (bell-shaped distribution). The changes in the location of the peak of this distribution can be related to the changes in mean error. Similarly, tandem axle (TA) NALS could be modeled by using a mixture of two normal or lognormal distributions (i.e., the bi-modal distribution). This paper presents a case study for WIM site where the WIM sensor exhibited a drift within a year after calibration. The loading data from single and tandem axles were analyzed to quantify the decline in WIM accuracy and precision. The results presented in the paper can be used as a guideline to select calibration frequency for the WIM sites.

Effect of uncertainty in dynamic modulus on performance prediction

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ABSTRACT: Pavement design methods have been developed from the purely empirical 1993 AASHTO Guide towards the more realistic Mechanistic-Empirical Pavement Design Guide (MEPDG). The ME Design is more accurate and realistic as it overcomes the limitations of the empirical pavement design methods through the incorporation of the principles of material mechanics. Still, it lacks a robust quantification of the reliability of the resulting pavement design. ME Design recognizes that pavement performance is governed by a large amount of uncertainty and variability related to design, construction, traffic loading, and climatic conditions over the expected design life. However, ME Design provides an analytical solution that incorporates reliability uniformly for all pavement types allowing the design of a pavement within a desired level of reliability. This study aims at studying the effect of the uncertainty in the dynamic modulus (|E*|) of asphalt concrete (AC) on the performance prediction using MEPDG. Monte Carlo Simulations are used to model the uncertainty in the |E*| mastercurve of various AC mixtures. Simulated |E*| mastercurves are used as input for MEPDG to predict rutting and fatigue cracking for various pavement structures under different loading speeds and climatic conditions resulting in a suit of 15,000 MEPDG runs. A sensitivity analysis is carried out to check how the uncertainty in |E*| will be forward propagated to predict the performance of pavements. Such results are utilized to assess how uncertainties in material properties, presented by |E*|, need to be incorporated in quality assurance practices of pavement construction.

AI, Big Data, Machine Learning; Moderated by Wynand Steyn, Univ. of Pretoria

Neural Network Models for Flexible Pavement Structural Evaluation

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ABSTRACT: In this study, multilayer pavement structure is simplified into one layer of equivalent thickness by using Equivalent Layer Theory (ELT). Artificial Neural Network (ANN)-based pavement structural analysis models were developed to find an equivalent thickness and elastic modulus of the modeled pavement system. The synthetic databases used as inputs in ANN forward and backcalculation models were created using MnLayer, a Layered Elastic Analysis (LEA) program. ANN models were trained to obtain the critical responses at the top and bottom of such layers in pavement systems. The multilayered flexible pavements were subjected to a 20-kip of Falling Weight Deflectometer (FWD) load in a circular area with uniform pressure. ANN models were found to represent a useful alternative approach for not only determining equivalent thickness

Development of machine-learning performance prediction models for asphalt mixtures

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ABSTRACT: The primary objective of this study is to investigate the effect of in-place air voids (AV), asphalt content (AC), bulk-specific gravity (BSG), and maximum specific gravity of asphalt (Gmm) on the fatigue cracking of asphalt mixtures using the Long-Term Pavement Performance (LTPP) database. This study includes 13 sections from different locations covering different mix designs, pavement age between 20-30 years, and two climate zones across the United States. All data were derived from LTPP database. A multiple linear regression, random forest (RF) and support vector machine (SVM) methods between the selected explanatory properties and the fatigue cracking were used for the investigation. A multiple significant linear regression model was developed, and it confirmed the significant relationships between the AC, AV, Gmm, percent of aggregate Pass.No.200, BSG and the fatigue cracking. RF and SVM methods were established using the same data. They validated significant properties and the accuracy of the model.

Characterization of road fleet weight using big data tools

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ABSTRACT: This paper investigated 2 years of WIM datasets from a Brazilian highway to compare the results obtained by a large dataset versus simplifications usually taken by Brazilian

pavement designers about the traffic parameters, especially the ESAL. Since the database contained more than 3.4 million entries, it was key to use tools for Big Data analysis; Python programming with the Pandas, NumPy and Matplotlib libraries were employed for this purpose. In addition, to generate axle loads spectra from the dataset, ESAL per year were calculated on different scenarios of the fleet : (i) considering each axle weight contribution (maximum use of dataset); (ii) considering the weight means of each axle type (medium use of dataset); (iii) considering the 100% of the axles are operating on the Brazilian legal limits (minimum use of dataset). The results highlighted the adequateness of the tools used in the analysis and pointed out the importance of considering all available entries to characterize the fleet in order to improve traditional premises in pavement design.

Digital twinning of asphalt pavement surfacings using visual simultaneous localization and mapping

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ABSTRACT: Quantification of pavement surfacing characteristics relates performance indicators pertaining to the mean texture depth, coarseness and loss of aggregates. Traditional measurement methods require skilled personnel and methodical execution of established methods to indirectly infer these characteristics. High accuracy Visual Simultaneous Localization and Mapping (VSLAM) techniques has seen widespread adoption in areas of robotics and visual odometry. Advances in hardware miniaturization, digital processing of optical imagery and reconstruction has seen the development of commercial scanners that provide mobile platforms and accuracies comparable to that of traditional, laboratory-grade laser scanners. Incorporating state-of-the-art, non-destructive digitization technology, together with well-established investigative methods, aims to improve both the fidelity and speed of surface data acquisition. The pipeline for the creation of a digital twin is simple in its execution, producing sub-millimeter accuracy and dense reconstructions over a wide range of dimensional scales. The twin model enables not only calculation of texture and profile characteristics, but also describes the orientation and curvature of particles along with changes in surface coarseness over time. The digitization process ties in directly with the continued drive toward digitization as part of improving pavement rehabilitation using predictive analytics and machine learning, improving existing preventative maintenance strategies.

Monitoring and modeling techniques to predict performance of existing pavement structures - Part 1; Moderated by Emin Kutay, Michigan State Univ.

Modified area under pavement profile for the light weight deflectometer measurements

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Roger Green

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ABSTRACT: Non-destructive test equipment such as falling weight deflectometer and light weight deflectometer are commonly used to measure pavement responses by recording the deflection of sensors produced by dropping a known load from a known height. Although they have a similar operating principle, few studies have examined the relationships between the devices, addressing light weight deflectometer testing with multiple geophones applied to layered systems. In this study, falling weight and light weight deflectometer tests were performed to establish a correlation between their measurements, and the resulting relationships were used to devise a new pavement deflection basin parameter called Area under Pavement Profile (AUPP) based on the light weight deflectometer measurements. The devised AUPP can be used to predict tensile strain at the bottom of an asphalt layer without performing back-calculation and/or structural modeling. Three-dimensional Finite Element Model (FEM) was developed in the ABAQUS program to validate the results. Comparison of the FEM and the field data shows close agreement.

New methods of structural assessment on project level

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ABSTRACT: The so-called RSOs are the first set of standardized guidelines in Germany to describe a systematic approach to structural assessment of pavements at project level. The target group includes both public road construction authorities and private operators. For asphalt pavements, the procedure is fully described; for concrete pavements, the rules and regulations are currently being drawn up. The method is based on the principles of mechanistically-empirical pavement design and requires testing on drill core samples within predefined structurally homogeneous sections. For the formation of the sections, non-destructive testing methods are used in particular, which will also play a greater role in the assessment in the future. The transfer of the principles described for application at the project level to the network level is a goal that is pursued in ongoing research projects. The paper describes the method.

Towards a mechanistic-empirical IRI prediction

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ABSTRACT: International Roughness Index (IRI) is a widely accepted measure for pavement smoothness and is considered as one of the most important factors affecting the functional performance of pavement structures. As such, may researchers in the past have developed empirical IRI models to forecast future IRI as well as the remaining life of existing pavements. In this paper, a methodology for mechanistic-empirical IRI prediction is introduced. The methodology utilizes the pavement structure and the initial surface profile (rather than initial IRI) to predict the spatially varying dynamic load and rut depth values. The nonhomogeneous rut depth is then used to update the pavement surface profile from which the IRI is evaluated again. Following the description of the methodology, the paper provides a simple example comparing the mechanistic-empirical IRI results against those from an empirical model.

A parameter back-calculation technique for pavements under moving loads

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Athanasios Skarpas

Khalifa University, Abu Dhabi, United Arab Emirates & Delft University of Technology, Delft, The Netherlands

ABSTRACT: Maintenance and rehabilitation strategies of pavements are usually made based on the results of performance evaluation. An efficient tool for pavement structural evaluation at network level is the traffic speed deflectometer (TSD) test. In order to deal with TSD measurements, this paper proposes a parameter back-calculation technique. Firstly, the sensitivity of the surface response for an elastic pavement structure with hysteretic damping to different structural parameters is investigated. Then, the ability of the parameter back-calculation technique is verified by conducting a case study. The results show that the proposed technique is able to back-calculate the structural parameters of pavements by analysing TSD measurements. The presented work contributes to the development of parameter back-calculation techniques for the TSD test.

Effect of seasonal and daily FWD Measurements on back-calculated parameters for pavements – LTPP SMP study

Syed W. Haider, Hamad B. Muslim & Karim Chatti *Michigan State University, USA*

ABSTRACT: Falling weight deflectometer (FWD) test is used to evaluate structural capacity of an existing pavement. However, FWD measurements are influenced by the temporal variations

and therefore, consideration of such effect is essential for accurate assessment of pavement structural condition. Long-term Pavement Program (LTPP) Seasonal Monitoring Program (SMP) was designed to evaluate the influence of such temporal variations on pavement structural characteristics. This paper presents typical effects of seasonal and daily variations on pavement deflections and back-calculated moduli. Available FWD deflection measurements and back-calculated moduli, in the LTPP database for different pavement layers for all SMP pavement sections were evaluated. Results showed that HMA moduli decrease from morning to afternoon (i.e., increasing FWD pass number), and for different seasons in a year (i.e., different months). PCC moduli and k-values also exhibited significant variations with increasing FWD pass number. Sub-surface layer material properties for both flexible and rigid pavement sections also showed noticeable variations when measured in different seasons of the year.

Monitoring and modeling techniques to predict performance of existing pavement structures - Part 2; Moderated by Emin Kutay, Michigan State Univ.

Monitoring asphalt pavement behavior through in-situ instrumentation

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D. M. Mocelin

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ABSTRACT: This paper presents a study of the mechanical responses from an in-service road section, in terms of strains and vertical stress, comparing data obtained from sensors installed at the bottom of the asphalt layer to the pavement-modeled responses in two different approaches: using a linear elastic analysis software (AEMC) and a viscoelastic analysis software (FlexPAVETM). Data in situ was gathered by means of a customized acquisition system with embedded signal processing. The temperatures measured in-situ were also compared to those estimated by the MERRA (Modern-Era Retrospective Analysis for Research and Applications) climate database, which is embedded in the newest AASHTOWare Pavement-ME version. The results demonstrated high quality of the signal processing capabilities of the data acquisition system developed to the project and returned excellent affinity to the modeled response, thereby demonstrating high potential to serve as a continuous structure monitoring tool.

Pavement instrumentation with near surface LVDTs

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ABSTRACT: This paper presented an approach for mechanical pavement condition monitoring based on post-construction installation of near surface LVDTs. The concept calls for making shallow grooves or blind holes at the pavement surface, and then fixing horizontal LVDTs to measure any changes in groove length or hole diameter resulting from nearby vehicle passes. A field experiment was designed and executed to demonstrate the approach involving the deployment of two LVDTs in an existing asphalt road, and recording the effects of a passing truck. It is shown that the LVDT readings can be matched with a layered elastic pavement model, leading to the inference of in situ layer moduli. The investigation is considered a first step towards practical application of a real-world sensing platform for pavements.

Study on the health monitoring technology of saline soil subgrade and the distribution law of subgrade water temperature

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ABSTRACT: In order to explore the mechanism of salinized soil disease, the real subgrade in Hexi area, Gansu Province, China was selected and the health monitoring system of salinized soil subgrade was established. The response effect of the test system was good. In this paper, the temperature and moisture content of the system are selected to study the water temperature of the subgrade. The results show that the dissipation of the residual heat of the subgrade changes steadily with the seasons in winter. The distribution of subgrade moisture content is effected by temperature gradient of subgrade, partition layer and pavement cover. The research results have important guiding significance for the establishment of monitoring methods of saline soil subgrade and the research on the change law of subgrade water temperature.

Evaluation of pavement service life reduction in overload corridors

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ABSTRACT: Texas has experienced a big boom in energy-related activities such as natural gas and crude oil production since 2008. These activities have created large volumes of Over-Weight (OW) truck operations that have adversely affected the longevity of the pavement infrastructures. This was the motivation to devise a framework for the mechanistic characterization of the Pavement Life Reduction (PLR) of the impacted pavements. To achieve this objective, initially, the authors collected the site-specific traffic information by deploying Portable Weight-in-Motion (P-WIM) devices to ten representative energy corridors in the Eagle Ford Shale region. Subsequently, the traffic information associated with the current and pre-energy development era, pavement layers properties from the field Non-Destructive Testing (NDT), as well as the climate information, were then incorporated in the Mechanistic-Empirical pavement design software to determine the PLR associated with the changes in traffic patterns. The analysis results indicated that the reduction of service life was more pronounced for Farm-to-Market (FM) roads, with less robust structural capacity compared to State and US highways.

Modeling in mixes - Part 2 - Computational and analytical methods; Moderated by Eshan Dave, Univ of New Hampshire

A dissipated energy approach for flow number determination

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ABSTRACT: The dissipated energy concept was used to investigate the permanent deformation behavior of asphalt mixes. It was found that the dissipated energy can be used to identify the stages of asphalt mixture permanent deformation accumulation. In addition, the dissipated energy can provide better information about the degree of internal damage occurring during the secondary stage of permanent deformation accumulation that leads to the tertiary flow. A new proposed method of determining the flow number was developed based on the dissipated energy. One main advantage of proposed dissipated energy method is that it reflects the changes of the strength and the deformational state of the samples with the number of load cycles. The developed method was able to accurately determine the flow number and reduce variability in the obtained flow number values.

A step towards a multiscale model of frost damage in asphalt mixtures

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ABSTRACT: Damage in the asphalt layers of pavements due to frost action can be a major problem during winter in cold and wet regions. To develop effective prevention measures it is important to understand the damage mechanism inside the material and how it interacts with other damage phenomena. To obtain this understanding, a multiscale model is currently developed in this research project. This paper presents the idea for the multiscale model framework, as well as utilizes a developed micromechanical model to investigate two parameters required for developing the damage envelope needed for the multiscale model: the two types of damage modes (adhesive and cohesive) and the increase of air void volume due to damage. From the results it was concluded that the relation between the two damage modes significantly, and sometimes counterintuitively, affects their combined effect, and that the relation between the air void content and the induced damage is nonlinear.

Mix design and linear viscoelastic characterization of fine aggregate matrix (FAM)

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ABSTRACT: The testing of Fine Aggregate Matrix (FAM) is gaining wide attention in the asphalt pavement research community since this phase is considered the most representative one of the overall asphalt mixture response. Moreover, it is characterized by a notable testing efficiency. In this study, an experimental campaign has been carried out on FAM specimens to investigate their rheological behavior within the linear viscoelastic range over a wide range of testing temperatures and frequencies. The experimental data, in terms of complex shear modulus and phase angle, were modelled with the 2S2P1D model. Results highlighted that the 2S2P1D model simulates in an excellent way the linear viscoelastic properties of FAM, both made with unmodified and modified binders. For each tested FAM the Time-Temperature Superposition principle was validated as well.

Asphalt mixture compaction in gyratory compactor using bullet physics engine

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ABSTRACT: Engineering and optimization of asphalt mixtures in laboratory is very important to achieve the desired performance of the pavements and to reduce the likelihood of expensive premature failures. Since there are several variables in play to produce an optimal mix, identifying an optimal design would require a systematic evaluation of innumerable combinations. However, such an effort is not feasible in a laboratory setting using conventional experimental methods. This study demonstrates the feasibility of using Bullet Physics engine to virtually compact the asphalt mixtures in a gyratory compactor. The model developed in this study can then be used to conduct broad parametric analyses, and together with computational tools, can serve as a screening tool for the optimization of asphalt mixtures.

Constitutive properties of materials from digital image correlation

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ABSTRACT: This study proposes a method to characterize constitutive behavior and properties of materials by integrating non-linear optimization of local displacement data from DIC (digital image correlation) and finite element modeling (FEM). Toward that end, the Neader-Mead algorithm was used to minimize an objective function constructed from multiple discrete points

from DIC and FEM simulation. The developed method was then used to determine constitutive properties of LE (linear elastic) and LVE (linear viscoelastic) materials. Polyetheretherketone (PEEK) and fine aggregate matrix (FAM) were selected for the LE and LVE investigations, respectively. The DIC-FEM method herein can converge to optimal solution in less than 60 iterations for both LE and LVE materials. The integrated DIC-FEM method can vastly improve testing efficiency by reducing the number of replicates and also provide a better understanding of localized behavior of materials such as cracking and damage, in particular of inelastic heterogeneous materials and composites such as asphaltic materials.

Modeling in mixes - Part 3 - Porous asphalt mixes; Moderated by Eshan Dave, Univ of New Hampshire

Design of poroelastic wearing course with the use of direct shear test

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ABSTRACT: Poroelastic Road Surfaces (PERS) are characterized by porous structure with at least 20% of air void content and stiffness almost 10 times lower than typical asphalt course. Such properties enable noise reduction up to 12 dB in comparison to SMA 11 mixture. However, the main disadvantage of previously used poroelastic mixtures, based on resin type binders, was their low durability, which resulted in raveling and delamination from the lower layer. This paper presents initial results obtained for new type of PERS mixture, based on highly modified bitumen as a binder instead of resin type binder. The direct shear test was applied to estimate resistance of the mixture to raveling as well as to evaluate interlayer bond quality. Observations of first short test sections with different compositions of new PERS mixtures yielded promising results.

Simulation of Performance of PA Mixtures with Different Mastics

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ABSTRACT: In this study, the effect of mastics with four different mineral fillers (limestone, granodiorite, dolomite and rhyolite) on the mechanical performances of porous asphalt (PA) mixtures was investigated. X-ray computer tomography (X-ray CT) scanning and digital image processing (DIP) techniques were applied to detect and reconstruct the microstructure of PA specimens. Finite element (FE) simulations were conducted to simulate indirect tensile tests. The results show that the mastics with different fillers have significant influence on the mechanical performances of PA mixtures. The PA mixture with limestone exhibits the least load-bearing capacity while the specimen with granodiorite exhibits the highest values. Although the distribution and the magnitude of the creep strain in the different mastic are similar, the locations of the maximum creep strain are not the same. Further investigations should be carried out to facilitate the improvement of the pavement design process.

Challenges in the generation of 2D Permeable Friction Courses (PFC) microstructures

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ABSTRACT: The use of computational mechanics tools has increased in pavement engineering due to their capacity to assess phenomena that are difficult to simulate in laboratory; and to their overall low cost in comparison to laboratory or field experiments. Thus, computational mechanics could be an efficient technique to understand the mechanical behavior of Permeable Friction Courses (PFC) mixtures and identify the causes of their main distresses. PFCs are gap-graded hot asphalt mixtures that are placed as thin layers over conventional pavements. Although PFC mixtures have several benefits, their main shortcoming is the difficulty to preserve their functionality and durability. This paper discusses the relevance of the geometry that is selected to represent the microstructure of PFCs mixtures in computational mechanics models and introduces a two-dimensional gravimetric method to numerically and randomly build those microstructures. In addition, this paper assesses different input parameters of the proposed gravimetric method and shows how those parameters impact different microstructural characteristics of the generated PFCs microstructures.

Micromechanical modelling of porous asphalt mixes at high temperatures

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ABSTRACT: Micromechanical modelling has been widely used to predict the properties of asphalt mixes. In comparison to numerical micromechanical models, analytical micromechanical models have the benefits of consuming much less time and facilities. The most commonly used analytical micromechanical models are the Eshelby-based micromechanical models. However, without the consideration of particles' interactions, these models fail to accurately predict the properties of asphalt mixes, especially at high temperatures. In porous asphalt (PA) mixes, due to the formation of an interconnected aggregate network, the particles' interactions under a compressive loading condition at high temperatures mainly refer to the packing effects. In order to describe the behavior of packed aggregates in PA mixes, Walton's model which predicts the effective moduli of a pack of spherical particles is possible to be a suitable way. However, to the best of authors' knowledge, this model has not been utilized for asphalt mixes. Therefore, this paper aims to investigate the application of Walton's model for predicting the properties of PA mixes at high temperatures.

Aging and moisture induced adhesion reduction of high viscosity modified bitumen in porous asphalt mixture

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ABSTRACT: Aging and moisture induced adhesion reduction of high viscosity modified bitumen in porous asphalt mixture was studied. Specifically, PAV and water bath were adopted to simulate the aging and moisture damage process of porous asphalt mixture in the field respectively. Meanwhile, photoelectric colorimetry were utilized to measure the adhesion rates between high viscosity modified bitumen and basalt aggregates after aging and moisture conditioning. Moreover, pull-out test were conducted to test the adhesion strength of aggregate-bitumenaggregate (ABA) system after aging and moisture conditioning. Results show that after same water bath duration, the adhesion rates of high viscosity modified bitumen and the adhesion strength of ABA system decreased 16.0% and 58.3% respectively in the first 20h PAV aging. The first 5 days' water bath had obvious effects on adhesion reduction of high viscosity modified bitumen (reduced by 47.7% for average). Moreover, the adhesion strength of ABA system would reduce obviously in the first 10d water bath (reduced by 48.4% for average). Compared with aging induced damage, moisture induced damage had more significant effects on the adhesion rates of high viscosity modified bitumen. Meanwhile, both aging and moisture induced damage can obviously lead to the adhesion strength reduction of ABA system.

Asphalt binder aging - Part 1; Moderated by Katerina Varveri, TU Delft

Assessment of different long-term aging effect on FAM mixtures

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ABSTRACT: Aging is considered as one of the major factors which increase stiffness and brittleness to asphaltic mixture. This study aimed at evaluating the effect of different aging protocol on viscoelastic and fatigue cracking of Fine Aggregate Matrix (FAM) mixtures. To evaluate this, six different long-term aging levels were considered. Linear Visco-Elastic (LVE) limit of each FAM mixtures was initially determined by conducting strain sweep test. Viscoelastic properties ($|G^*|$ and δ) and master curve shape parameters of FAM mixtures were further determined from temperature and frequency sweep test. Fatigue cracking of FAM mixtures was evaluated using G-R parameter. Irrespective of the aging level applied to the FAM specimen, LVE limit was found almost constant for all FAM mixtures. Viscoelastic properties for FAM specimen aged for 24 hrs at 135°C, and 12 days at 95°C aged FAM mixtures showed similar results from the master curve plots. Despite of the similar viscoelastic properties, the FAM mixtures with 12 days at 95°C and 24 hrs at 135°C were not shown similar crack potential.

Kinetics of epoxy-asphalt oxidation

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ABSTRACT: In-depth understanding of the temperature effect on oxidative aging in epoxyasphalt blends is needed to enable accurate predictions on material response through their service life. Details of the significance of developing prediction models and tools on oxidative aging of pavement materials are presented in a companion paper (Apostolidis et al., *Oxidation Simulation of Thin Bitumen Film*. AM3P). In this research, the chemical compositional changes of epoxy modified asphalt binders, with and without filler, were analysed after oven-conditioning by means of Fourier transform infrared (FTIR) spectroscopy. With the carbonyl and sulfoxide compounds as aging indices, the sensitivity of chemical compositional changes of bituminous and epoxy-based systems due to the applied temperatures was observed.

Preliminary study on using lignin as aging inhibitor in bitumen

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ABSTRACT: During oxidative aging, oxygen reacts with active molecules present in bitumen producing polar compounds, principally ketones and sulfoxides, and increasing in the portion of asphaltenes. In general, oxidation reactions in bitumen yields to change its generic chemical composition and finally its colloidal structure deteriorating the physico-mechanical properties. Lignin is a natural polymer, which has been used in this study as an aging inhibitor to bitumen. Particularly, the effect of aging on the microstructure morphology, surface properties, chemical composition and rheological changes of lignin and the impact of latter as anti-oxidant in bitumen were evaluated. For the purposes of this study, Environmental Scanning Electron Microscope, Helium Pycnometer, Dynamic Vapor Sorption devices and were used to analyze the microstructure, density and specific surface area, respectively. Moreover, Fourier Transform Infrared spectroscopy was used to track the compositional changes in lignin-modified bitumen after PAV aging. Dynamic Shear Rheometer was used to analyze the rheological properties. Overall, decreasing in the carbonyl and sulfoxide compounds were tracked in lignin-modified bitumen.

Limitations of using sulfoxide index as a metric to quantify asphalt aging

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ABSTRACT: Fourier Transform Infrared (FT-IR) spectroscopy is a convenient and quick way to investigate chemical changes for asphalt aging. The aging process changes the concentration of both Carbonyl and Sulfoxide in an asphalt binder. In this study, the limitation of considering the sulfoxide as an aging indicator for asphalt binders is investigated. Laboratory binder and mix aging showed that, increase in Sulfoxide index is dependent on laboratory aging method. Inconsistent increase of sulfoxide index made it unreliable to be considered as a metric for quantification of aging. Furthermore, Sulfoxide index for aged mixtures showed unusually higher values contributed by the presence of fines in the mixtures. This is also another disadvantage to establish this index as an indicator to quantify mixture aging. Although Sulfoxide index changes with the extent of aging, this study affirms that it should not be considered as a reliable indicator to detect the aging of an asphalt binder or a mixture.

Asphalt binder aging - Part 2; Moderated by Katerina Varveri, TU Delft

Oxidation simulation of thin bitumen film

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ABSTRACT: Oxidative aging is a complex phenomenon in bitumen and its fundamental understanding is needed to optimize paving materials with long-lasting characteristics. This research reports on a diffuse-reaction model for predicting the oxidation of bituminous binders over time and under different conditions. As known, the oxidation of bitumen is affected by the material chemistry, film thickness and temperature. Thus, these factors were considered in this research to simulate the oxidation of a thin bitumen film. Carbon compounds were assumed as the oxidation index of a model bitumen and analyses were performed enabling prediction of chemical compositional changes. In the future, the current model can be used to simulate the actual oxidative aging in (un)modified binders, such as epoxy modified asphalt, presented in a companion paper (Apostolidis et al., *Kinetics of Epoxy-Asphalt Oxidation*. AM3P).

Aging differences within RAP binder layers

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ABSTRACT: The degree of binder activation of reclaimed asphalt pavement (RAP) is a critical aspect the design of the recycled asphalt mixtures. Assuming RAP binder activation of less than 100% insinuates that part of the RAP binder will be inactive in the mixing process. It is important to comprehend if there is any difference between the active and the inactive binder as the recycling agent to be used could be chosen considering only the active binder characteristics. The objective of this study is to evaluate aging differences within different RAP binder layers. Stages of binder extraction were performed on two different RAP materials in order to simulate different binder activation levels. After each extraction, the binder recovered was evaluated in terms of its rheological properties and the saturate-aromatic-resin-asphaltene (SARA) fractions. The results imply that the outer layer (external RAP binder layer) is more oxidized as compared to the inner

layer (binder close to the aggregate). This indicates that the more oxidized RAP binder will be available to be blended.

Laboratory and field ageing of asphalt mixtures

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ABSTRACT: Ageing of bituminous materials contributes to various forms of pavement failures, thus leading to the degradation of pavement performance. To understand the evolution of pavement performance, the development of a proper laboratory protocol to simulate long-term ageing process of asphalt mixtures is of uppermost importance. In this study, the porous and dense asphalt slabs with thickness of 5 cm were exposed to oven ageing at 85 °C for 3 and 6 weeks in the laboratory. Cyclic Indirect Tensile tests were performed to investigate the effect of ageing on the mechanical properties of asphalt mixture. The results were used to correlate with the change in the mechanical properties of the porous and dense pavement in the field. Pavement test sections were constructed in 2014 and have been exposed to actual environmental conditions since then. To study the temporal changes in the mechanical properties of the porous asphalt aged at 85 °C for 3 and 6 weeks in the laboratory have the same stiffness change as that aged 3 and 3.5 years in the field, respectively. Dense asphalt aged at 85 °C for 3 weeks in the laboratory have the same stiffness change as that aged 4 years in the field.

Effect of aging on the molecular structure of bitumen

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ABSTRACT: Bitumen imparts most of its properties to the asphalt mixture. The chemical composition and molecular structure are the key factors affecting the ageing of bitumen. The objective of this study is to construct the average molecular structure of bitumen and study the effect of aging on its micro characteristics. To achieve this goal, the chemical characteristics of bitumen was analyzed by Fourier Transform Infrared Spectroscopy (FTIR), Nuclear Magnetic Resonance (NMR), Gel Permeation Chromatography (GPC) and Elemental Analysis. Then the average molecular structure parameters were calculated by the improved B-L method. Results show that bitumen is a complex compound composed of aromatic rings, naphthenic and alkyl chains. After aging, the molecular mass and polydispersity increased obviously. The oxygen reacted with bitumen to form polar functional groups. The aromatization and ring scission may occur during ageing. There were more aromatic rings, less naphthenic rings and the ring structure became more complicated.

Friday August 7th

Session 811

Novel materials and other technological advancements in pavements; Moderated by Sandra Erkens TU Delft

Application and evaluation of NovaSurfacing technology

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ABSTRACT: In order to solve the problems of poor adhesion and durability at conventional micro surfaces, The process of spraying modified emulsified asphalt, paving and mixing super-abrasive layer containing glass fiber, novasurfacing are used. The SCB semi-circular bending test compares the performance comparison between the novasurfacing and the conventional micro-surfacing. The coefficients of friction, flatness, and PCI are used to compare the performance changes before and after the repair of the road section. Use the net annual value method to evaluate its economic benefits. The results show that the supervised abrasion layer has advantages in both performance and economic benefits.

Field performance experience of sulfur extended asphalt (SEA) pavement in Saudi Arabia

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ABSTRACT: Elemental sulfur is a material that is available in abundant quantities in its natural form as well as an industrial waste product. Sulfur is a viable alternative and sustainable binding agent that can be used as a construction material in large scale. One example is sulfur extended asphalt (SEA) that replaces approximately 30% of asphalt binder by weight in a typical asphalt mixture. Since the introduction of sulfur material in the 1970s, several different technologies for the use of SEA have been developed. A detailed review of these technologies can be found in the literature (Sakib et al. 2019). While most of the work was done in the 1970s-80s, Saudi Aramco has continued the investigating the use of elemental sulfur in pelletized form (to reduce dust and related problems) as a bitumen extender for the sulfur extended asphalt (SEA). In 2006, three roads in the Kingdom of Saudi Arabia (KSA) were built using this approach: Khuraniyah access road, Shedgum-Hofuf road, and Dhahran-Jubail expressway. These sections were evaluated after three years and found to be in satisfactory condition. The main goal of this paper is to present a summary of the materials design, evaluation, and construction practices as well as performance from three projects that utilized significant amounts of SEA in pavement construction in 2017: Wasea Bulk Plant, the Jizan Economic City Mega-Project, and the Fadhili Gas Plant Program. Although these sections have been in place for 2 years, it is important to highlight that these projects were access roads leading in and out of major plants, and therefore experienced a high volume of heavy traffic.

Therefore, with the exception of the influence of long-term oxidative aging, these sections serve as an excellent indicator for the performance of SEA mixes.

Curing and Adhesive Characteristics of Single-Component Polyurethane Binders

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ABSTRACT:Polyurethane is a relatively new type of binder for pavements. In this paper, curing and adhesion characteristics of two single-component polyurethane (PU) binders were studied. And chemical compositional, pull-out and shear analyses were performed to evaluate the curing performance of two PU binders. Meanwhile, the strength of PU were also adopted to represent adhesion characteristics (the binding capacity to the aggregate). With the increase of natural curing conditions, the results show that the isocyanate index of PU-I and PU-II decreases , while the Urea Index have the opposite trend. Both the isocyanate index and urea index of PU are stable after 4 days natural curing, indicating that PU are nearly fully cured after 4 days curing. As for pull-off and shear strength, PU-I and PU-II have better binding capacity to stone and rubber. Meanwhile, the binding capacity of stone-PU-rubber system is the worst.

Towards the application of drones for smart pavement maintenance

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ABSTRACT: Drones have benefited multiple sectors because of their simplicity, low cost, and adaptability. However, the use of this technology for pavement monitoring is not well extended. The main goal of the present research is evaluating the application of Unmanned Aerial Systems (UAS) for pavement monitoring, by means of case study in the Norvik Port, Sweden. The study presents different aspects and issues that should be considered while implementing a UAS. The main results of the work show the improvement opportunities, successes, capability and feasibility of the UAS selected by the Norvik operator to capture the different defects that can occur in the pavement of the port. As a conclusion, it was suggested that UAS are a viable tool for monitoring defects in the pavement. However, the precision, accuracy, quality and relevancy of the data are influenced by the rigor and quality control applied during the implementation process.

Microwave heating simulation of asphalt pavements

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ABSTRACT: Microwave heating is a promising heating technology for the maintenance, recycling and deicing of pavement structures. Many experimental studies have been conducted to investigate the microwave heating properties of asphalt mixtures in the laboratory. However, very few studies investigated the application of microwave heating on asphalt pavements. This study aims to simulate microwave heating of paving materials using the finite element method. Results show that the developed three-dimensional model, which couples the physics of electromagnetic waves and heat transfer, shows a great potential for optimizing the design of microwave heating prototypes for pavement applications.

Application of phase change self regulating temperature material in asphalt pavement

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ABSTRACT: with the global warming and the frequent occurrence of extreme weather, many roads and urban roads are often damaged by ice and snow under the low temperature, rain, snow and freezing climate. The problem of ice and snow pavement has been puzzling the road maintenance department. In this paper, from the point of view of active control of the temperature of asphalt concrete pavement, the mix design and mixture performance of phase change self regulating asphalt mixture are briefly described, and the effect of engineering application is tracked and monitored. The results show that the phase change material can improve the ability of asphalt mixture to deal with the change of environment temperature, keep the asphalt mixture in a good temperature range for a long time, not only play the role of snow melting and ice melting, but also avoid the early diseases such as low temperature cracks, effectively improve the safety of highway driving, and ex-tend the service life of pavement.

Performance evaluation of green mixes - Part 2 - Cold mixes and others; Moderated by Zhen Leng, Hong Kong Poly U

Stress-strain-time response of emulsified cold recycled mixture in repeated haversine compression loading

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ABSTRACT: Emulsified cold recycled mixtures (ECRM) consists of reclaimed asphalt pavement materials, water, cement and bituminous emulsion. ECRM has a high air void of approximately 15%. Very little information is available on the stress-strain-confinement pressure-time response of ECRM and such data is necessary to prescribe an appropriate constitutive relationship. In this study, ECRM was subjected to repeated haversine compression loading at 0°C and 50°C, with and without confinement pressure over ten frequencies (25 Hz to 0.01 Hz). The influence of confinement pressure on the mechanical response of ECRM was observed to be significant at high temperature when compared to low temperature. The material exhibited diverse mechanical response, and it was seen that the phase angle increased as the frequency increased at high temperature without confinement pressure. The experimental data collected underlines the multiple retardation times of the material, and this will come in handy when developing appropriate constitutive models.

Mix design approach of cold mix asphalt using response surface method

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ABSTRACT: Cold mix asphalt (CMA) has been increasingly recognized as an important alternative technology to hot mix asphalt (HMA) worldwide. The present study investigates the optimum proportions of fine content (FC) and emulsion content (EC) to gain suitable levels of both mechanical and volumetric properties. A factorial design with response surface method (RSM) was applied to optimize the mix design parameters. This work aimed to investigate the interaction effect between these parameters on the mechanical and volumetric properties. The stability and indirect tensile strength (ITS) tests were performed to obtain the mechanical response. The results indicate that the interaction of both FC and EC influences the bulk density. However, the EC tended to influence the ITS more significantly than FC. Further, the experimental results for the optimum mix design were in agreement with model predictions. It is found that optimization using RSM is an effective approach for mix design of CMA.

Effect of biochar on the basic characteristics of asphalt mixtures

X. Sanchez, T. Somers, H. Dhasmana, O. Owolabi University of New Brunswick, Fredericton, NB, Canada ABSTRACT: This study explores the potential of using biochar, which is a renewable, more accessible, and sustainable asphalt additive. Fine biochar passing a 75μ sieve was used in different percentages to prepare asphalt mixes in the laboratory. 4, 8, and 12% by weight of biochar was added to a mix designed for a surface course. The theoretical maximum specific gravity of the asphalt mixes decreased with an increase in biochar percentage and reached an inflection point between 8 and 12%. An improvement in workability in samples with biochar was found during compaction. To study the moisture susceptibility of asphalt mixes made with biochar, Modified Lottman test was also conducted. No signs of stripping were observed in any specimen. Results revealed an improvement in the tensile strength ratio with the inclusion of biochar.

Low density polyethylene for asphalt binder modification

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ABSTRACT: Nowadays, the use of polyethylene (PE) for bitumen modification has become widespread due to the major advantage of environmental sustainability. For the application of PE modified binder, it is necessary to first study the compatibility of polyethylene and bitumen. In this study, low density polyethylene (LDPE) was blended with the binder in five different dosages (1, 2, 3, 4 and 5%) and PE wax (3% and 2% LDPE+1% Wax) was added to the binder in two dosages (3% and 2% LDPE+1%wax). The dispersion of polyethylene in binder was observed using an optical microscopy and images were captured at different time intervals of 30 and 150 minutes. It was noticed that the equivalent diameter of PE particles increased with time. When PE wax introduced to the blend, the total polymer content was maintained as 3%, because the polymer started forming large size agglomerates above 3% dosage. The addition of PE wax improved the polymer dispersity in blend. To understand the phase separation, viscosity-temperature profile of these binders were studied using temperature sweep experiment, in which the viscosity values were measured during temperature decrement from 160 to 100_{\circ} C and increment from to 100_{\circ} IC. The higher difference in viscosity values represent the instability of binder and the binder with higher LDPE content was found to be more instable.

Impact of aggregate and filler properties on performance; Moderated by Silvia Caro, Univ. of Los Andes

Influence of nanoclay in viscosity graded asphalt binder at different test temperatures

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ABSTRACT: Nanotechnology has been progressively insinuating into the research field of asphalt binder modification. However, studies on various characteristics of nanoclay modified binder including resistance to ageing, temperature susceptibility and rheological performance, are still obscure. This study focuses on studying the efficacy of nanoclay modification on the properties of viscosity graded (VG 30) asphalt binder. High shear mixer was employed for the modification of different dosage (2-6%) of nanoclay to counteract the above mentioned performance characteristics. Conventional tests along with the rheological performance were evaluated for nanoclay modified and unmodified binders. Master curves at 20°C and 60°C obtained from the frequency sweep (FS) test data revealed that improvement in rheological properties is more obvious at lower frequencies. Different Indices were evaluated analyzing FS data across different temperatures. A satisfactory and translucent level of modification was observed from Modification Index. Alongside, decrease in ageing index confirms the resistance to ageing potential of nanoclay modified asphalt binder. A noticeable change in black curve was observed for 6% NC modified asphalt binder while 2% and 4% NC modified asphalt binder was found to be less significant. However, the improvement with 2% and 4% NC inclusion was still higher than VG 30. From the fabrication of nanoclay modified asphalt binder to the rheological characterization process, this study confirms that nanoclay holds great prospective in alleviating the performance of VG 30 binder at all the test temperatures.

Influence of filler-binder ratio and temperature on the linear viscoelastic (LVE) characteristics of asphalt mastics

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ABSTRACT: This study describes an investigation into the Linear Viscoelastic (LVE) limit/range of asphalt mastics prepared with different fillers. Effect of temperature and Filler-Binder (F/B) ratio on the LVE limits of mastics has been studied. The interrelation between Linear Viscoelastic Complex Modulus (G*LVE) and corresponding LVE limit has been examined. To compare the denouement of the study, the SHRP LVE strain criteria is also included which quantifies the applicability of the criteria to asphalt mastics. The lower LVE limit at high F/B ratio is the antithesis of the LVE limit at higher temperatures. The change in coefficient of determination (R₂)

was prominent with change in F/B ratio whereas temperature shows a marginal shift in R₂ value indicating the dominance of F/B in the LVE range. The LVE limits obtained from the study were relatively conservative compared to those from SHRP study showing the unsuitability of applying SHRP criteria directly to mastics.

Nanomaterial to resist moisture damage of pure siliceous aggregates

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ABSTRACT: Moisture damage of flexible pavements hinders construction of durable pavements. Siliceous aggregates are found to aggravate the damage. Hydrated Lime (HL) fillers provide resistance to such damage. In this study, purely siliceous aggregates were considered, and the increment of resistance to moisture damage was studied using nano hydrated lime (NHL). NHL was synthesized using planetary ball milling. A comparative study was carried out on the improvement of moisture damage resistance using both HL and NHL particles. It was observed that although mix fails for unmodified mixes, addition of HL and NHL particles reduce the moisture susceptibility and results in development of moisture resistance mixes. Mix prepared with 1% addition of NHL showed best results in terms of resisting moisture damage.

Aggregate properties affecting adhesive quality in asphalt mixtures

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ABSTRACT: Asphalt-aggregate adhesion is a complex phenomenon influenced by properties from both materials. This work aims at stablishing the influence of aggregate's chemistry, mixing temperature and surface texture over the quality of the asphalt-aggregate interface. To accomplish this goal, different asphalt-aggregates combinations were tested with a pull-off debonding test in which these properties of aggregates were changed accordingly. It was found out that SiO₂ content within aggregates promote moisture damage, whereas Fe₂O₃ and CaO contents seems to inhibit it. Low mixing temperatures when performing the initial asphalt-aggregate bonding were also related to low adhesive performance. Finally, aggregate surface texture did not seem to have an effect over the dry quality of the asphalt-aggregate interface but does seem to have a positive effect over its performance under moisture conditions.

Investigating the factors which influence the asphalt-aggregate bond

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ABSTRACT: Moisture damage is a problem that has plagued asphalt concrete pavements ever since their introduction in the late nineteenth century. Water infiltrates into the pavement structure and weakens its structural integrity by degrading the asphalt-aggregate adhesive bond, or by

weakening the cohesive bond between the molecules of the asphalt binder itself. Despite being a topic of research since the 1930s, and with multiple methods currently available to test the moisture susceptibility of asphalt mixtures, it remains a critical issue till this day as results from the existing methods do not correlate properly with the field performance. The objective of this research is to introduce a new method for measuring the moisture susceptibility of asphalt mixtures. The tests presented within this paper will focus on studying the effect of the strain rate and asphalt film thickness, which are usually taken as constants for any mix design when conducting moisture susceptibility testing, on the strength and mode of failure of the samples. Testing was done on dry samples and this study will be followed up by another which includes moisture conditioning.