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Original Research Paper

Addressing the permanent deformation behavior of hot mix asphalt by triaxial cyclic compression testing with cyclic confining pressure

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ABSTRACT

Rutting or permanent deformation is one of the major distress modes of hot mix asphalt in the field. Triaxial cyclic compression testing (TCCT) is a standardized and scientifically accepted test method to address this distress mode in the lab and to characterize the resistance to permanent deformation. In most labs and according to EN 12697-25, standard TCCTs are carried out with cyclic axial loading and a constant confining pressure. In road pavements on the other hand, dynamic traffic loading due to passing wheels leads to cyclic confining pressure. In order to bring the TCCT closer to reality, the radial reaction and its phase lag to axial loading in standard TCCTs are analyzed and an enhanced TCCT with cyclic confining pressure is introduced. The cyclic confining pressure takes into account the viscoelastic material response by the radial phase lag to axial phase loading. In a subsequent test program, TCCTs with different confining pressure amplitudes were carried out on two hot mix asphalts. Results from standard and enhanced TCCTs were analyzed, compared and discussed. It is shown that the resistance to permanent deformation increases significantly when the viscoelastic material response is taken into account in the TCCT by introducing cyclic confining pressure.

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1. Introduction

Besides low-temperature and fatigue cracking, permanent deformation at elevated temperature is a third major distress mode of bituminous bound pavements. Permanent deformation or rutting occurs especially as transverse profile deformations within the wheel paths but can also be seen as

longitudinal profile irregularities (Verstraeten, 1995). Rutting is an important deterioration mode since it affects the comfort and safety of road users. Thus, various test methods have been developed to address the permanent deformation behavior of hot mix asphalt (HMA). For comparison of the different HMAs and pavement design the wheel tracking test (WTT) (EN 12697-22, 2007) is commonly used. In this test method a moving wheel stresses a pavement slab at elevated

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Assessment Of Permanent Deformation Behavior Of Asphalt

**Douglas M. Marshall, Richard K.
Barnhart, Eric Shappee, Michael
Thomas Most**

Assessment Of Permanent Deformation Behavior Of Asphalt:

Bearing Capacity of Roads, Railways and Airfields Andreas Loizos, Imad Al-Qadi, Tom Scarpas, 2017-07-20 Bearing Capacity of Roads Railways and Airfields includes the contributions to the 10th International Conference on the Bearing Capacity of Roads Railways and Airfields BCRRRA 2017 28 30 June 2017 Athens Greece The papers cover aspects related to materials laboratory testing design construction maintenance and management systems of transport infrastructure and focus on roads railways and airfields Additional aspects that concern new materials and characterization alternative rehabilitation techniques technological advances as well as pavement and railway track substructure sustainability are included The contributions discuss new concepts and innovative solutions and are concentrated but not limited on the following topics Unbound aggregate materials and soil properties Bound materials characteristics mechanical properties and testing Effect of traffic loading In situ measurements techniques and monitoring Structural evaluation Pavement serviceability condition Rehabilitation and maintenance issues Geophysical assessment Stabilization and reinforcement Performance modeling Environmental challenges Life cycle assessment and sustainability Bearing Capacity of Roads Railways and Airfields is essential reading for academics and professionals involved or interested in transport infrastructure systems in particular roads railways and airfields *Introduction to Unmanned Aircraft Systems, Second Edition* Douglas M. Marshall, Richard K. Barnhart, Eric Shappee, Michael Thomas Most, 2015-10-26 The proliferation of technological capability miniaturization and demand for aerial intelligence is pushing unmanned aerial systems UAS into the realm of a multi billion dollar industry This book surveys the UAS landscape from history to future applications It discusses commercial applications integration into the national airspace system NAS System function operational procedures safety concerns and a host of other relevant topics The book is dynamic and well illustrated with separate sections for terminology and web based resources for further information

Functional Pavement Design Sandra Erkens, Xueyan Liu, Kumar Anupam, Tan Yiqiu, 2016-10-14 Functional Pavement Design is a collection of 186 papers from 27 different countries which were presented at the 4th Chinese European Workshops CEW on Functional Pavement Design Delft the Netherlands 29 June 1 July 2016 The focus of the CEW series is on field tests laboratory test methods and advanced analysis techniques and cover analysis material development and production experimental characterization design and construction of pavements The main areas covered by the book include Flexible pavements Pavement and bitumen Pavement performance and LCCA Pavement structures Pavements and environment Pavements and innovation Rigid pavements Safety Traffic engineering Functional Pavement Design is for contributing to the establishment of a new generation of pavement design methodologies in which rational mechanics principles advanced constitutive models and advanced material characterization techniques shall constitute the backbone of the design process The book will be much of interest to professionals and academics in pavement engineering and related disciplines **Pavement and Asset Management** Maurizio Crispino, 2019-02-21 Pavement and Asset Management

contains contributions from the World Conference on Pavement and Asset Management WCPAM 2017 Baveno Italy 12-16 June 2017. For the first time the European Pavement and Asset Management Conference EPAM and the International Conference on Managing Pavement Assets ICMPA were joining forces for a global event that aimed not only at academics and researchers but also at practitioners engineers and technicians dealing with everyday tasks and responsibilities related to transport infrastructures pavement and asset management. Pavement and Asset Management covers a wide range of topics from emerging research to engineering practice and is grouped under the following themes: Data quality and monitoring, Economics, political and environmental management strategies, Deterioration models, Key performance indicators, PMS case studies, Design and materials, M/R treatments, LCA, LCCA, Risk and safety, Bridge and tunnel management, Smart infrastructure and IT. Pavement and Asset Management will be valuable to academics and professionals interested and/or involved in issues related to transport infrastructures pavement and asset management.

PRO 28: 6th International RILEM Symposium on Performance Testing and Evaluation of Bituminous Materials (PTEBM'03) Manfred N. Partl, 2003

Transactions of the American Society of Civil Engineers American Society of Civil Engineers, 2006 Vols 29-30 contain papers of the International Engineering Congress Chicago 1893 v 54 pts A-F papers of the International Engineering Congress St Louis 1904. *Recycled Materials in Geotechnical and Pavement Applications* Amin Chegenizadeh, Hamid Nikraz, 2022-02-28. This book considers the application of recycled materials both in pavement and geotechnical engineering. Currently Australia has faced the fundamental concern of recycling waste plastic. On 1 January 2018 China enforced a prohibition on the importation of waste plastic. China's ban is followed by other countries like India, Indonesia and Malaysia. The ban caused many corporations to abandon waste collection agreements and the stockpiling of waste as there is nowhere to safely deposit this waste. This issue seems to a great extent to have placed Australia's recycling industry in a crisis. As a result local councils will have to find strategic ways of recycling accumulated waste that will become a more significant issue in the coming years. In Australia apart from economic growth the road pavement has weakened rapidly as the current pavement unable to withstand this urgent traffic load demand. The adding of polymers to the mixtures improves the stiffness, rutting resistance and fatigue cracking. 1. However the application of virgin polymer is costly. Thus using waste polymer such as waste plastic polymer is an inexpensive substitute. The potential for recycled plastic to improve the performance properties of asphalt mixtures has been demonstrated in many countries: the UK, Canada, The Netherlands and India. 2. Similarly another application of recycled materials can be in geotechnical infrastructure. This book considers the application of recycled materials both in pavement and geotechnical engineering. References: 1. Airey G D, Singleton T M, Collop A C 2002 Properties of polymer modified bitumen after rubber bitumen interaction. *Journal of Materials in Civil Engineering* 14(4): 344-354. 2. K O Farrell Australian Plastics Recycling Survey National Report Australian Government Department of Environment and Energy Australia Project reference 2018 A21502. *Proceedings of the 10th International Conference on Maintenance and*

Rehabilitation of Pavements Paulo Pereira, Jorge Pais, 2024-07-20 This book gathers the proceedings of the 10th International Conference on Maintenance and Rehabilitation of Pavements MAIREPAV10 held in Guimarães Portugal on July 24-26 2024. The conference series has been established to promote and discuss state of the art design, maintenance, rehabilitation and management of pavements. The respective contributions share the latest insights from research and practice in the maintenance and rehabilitation of pavements and discuss advanced materials technologies and solutions for achieving an even more sustainable and environmentally friendly infrastructure.

Modeling and Design of Flexible Pavements and Materials Dallas N. Little, David H. Allen, Amit Bhasin, 2017-09-25 This textbook lays out the state of the art for modeling of asphalt concrete as the major structural component of flexible pavements. The text adopts a pedagogy in which a scientific approach based on materials science and continuum mechanics predicts the performance of any configuration of flexible roadways subjected to cyclic loadings. The authors incorporate state of the art computational mechanics to predict the evolution of material properties, stresses and strains and roadway deterioration. Designed specifically for both students and practitioners, the book presents fundamentally complex concepts in a clear and concise way that aids the roadway design community to assimilate the tools for designing sustainable roadways using both traditional and innovative technologies.

Advances in Interlaboratory Testing and Evaluation of Bituminous Materials Manfred N. Partl, Hussain U. Bahia, Francesco Canestrari, Chantal de la Roche, Hervé Di Benedetto, Herald Piber, Dariusz Sybilski, 2012-10-17 This STAR on asphalt materials presents the achievements of RILEM TC 206-ATB acquired over many years of interlaboratory tests and international knowledge exchange. It covers experimental aspects of bituminous binder fatigue testing, the background on compaction methods and imaging techniques for characterizing asphalt mixtures including validation of a new imaging software. It focuses on experimental questions and analysis tools regarding mechanical wheel tracking tests, comparing results from different labs and using finite element techniques. Furthermore, long term rutting prediction and evaluation for an Austrian road are discussed, followed by an extensive analysis and test program on interlayer bond testing of three different test sections which were specifically constructed for this purpose. Finally, the key issue of manufacturing reclaimed hot mix asphalt in the laboratory is studied and recommendations for laboratory ageing of bituminous mixtures are given.

Environment-Friendly Construction Materials Shaopeng Wu, Inge Hoff, Serji Amirkhanyan, Yue Xiao, 2019-06-20 Construction materials are the most widely used materials for civil infrastructure in our daily lives. However, from an environmental point of view, they consume a huge amount of natural resources and generate the majority of greenhouse gases. Therefore, many new and novel technologies for designing environmentally friendly construction materials have been developed recently. This Special Issue, Environment-Friendly Construction Materials, has been proposed and organized as a means to present recent developments in the field of construction materials. It covers a wide range of selected topics on construction materials.

From Fundamentals to Applications in Geotechnics D. Manzanal, A.O. Sfriso, 2015-12-11 The

work of geotechnical engineers contributes to the creation of safe economic and pleasant spaces to live work and relax all over the world Advances are constantly being made and the expertise of the profession becomes ever more important with the increased pressure on space and resources This book presents the proceedings of the 15th Pan American Conference on Soil Mechanics and Geotechnical Engineering XV PCSMGE held in Buenos Aires Argentina in November 2015 This conference held every four years is an important opportunity for international experts researchers academics professionals and geo engineering companies to meet and exchange ideas and research findings in the areas of soil mechanics rock mechanics and their applications in civil mining and environmental engineering The articles are divided into nine sections transportation geotechnics in situ testing geo engineering for energy and sustainability numerical modeling in geotechnics foundations and ground improvement unsaturated soil behavior embankments dams and tailings excavations and tunnels and geo risks and cover a wide spectrum of issues from fundamentals to applications in geotechnics This book will undoubtedly represent an essential reference for academics researchers and practitioners in the field of soil mechanics and geotechnical engineering In this proceedings approximately 65% of the contributions are in English and 35% of the contributions are in Spanish or Portuguese **Recent Trends in Transportation Infrastructure, Volume 1** Rajat Rastogi,G.

Bharath,Dharamveer Singh,2023-07-24 This book presents the select proceedings of the 2nd International Conference on Transportation Infrastructure Projects Conception to Execution TIPCE 2022 and emphasizes the understanding of transportation infrastructure projects being conceptualized designed and executed so as to bring the desired development in the focused area It comprises case studies from the transportation sector construction industries consulting agencies and academia These studies present the bottlenecks experienced during the implementation of the projects from their conceptualization to their execution and the corrective measures that were incorporated to finish the work The book will be a valuable reference for beginners researchers and professionals interested in construction planning and technology

infrastructure engineering highway engineering traffic and transportation planning and systems **Long Term Durability of Structural Materials** P.J.M. Monteiro,K.P. Chong,J. Larsen-Basse,K. Komvopoulos,2001-08-29 Long Term Durability of Structural Materials features proceedings of the workshop held at Berkeley CA in October 2000 It brought together engineers and scientists who have received grants from the initiative NSF 98 42 to share their results on the study of long term durability of materials and structures The major objective was to develop new methods for accelerated short term laboratory or in situ tests which allow accurate reliable predictions of the long term performance of materials machines and structures To achieve this goal it was important to understand the fundamental nature of the deterioration and damage processes in materials and to develop innovative ways to model the behavior of these processes as they affect the life and long term performance of components machines and structures The researchers discussed their approach to include size effects in scaling up from laboratory specimens to actual structures Accelerated testing and durability modeling techniques

developed were validated by comparing their results with performance under actual operating conditions. The main mechanism of the deterioration discussed included environmental effects and or exposure to loads speeds and other operating conditions that are not fully anticipated in the original design. A broad range of deterioration damage such as fatigue overload ultraviolet damage corrosion and wear was presented. A broad range of materials of interest was also discussed including the full spectrum of construction materials metals ceramics polymers composites and coatings. Emphasis was placed on scale dependence and history of fabrication on resulting mechanical behavior of materials. *Sustainability, Eco-efficiency, and Conservation in Transportation Infrastructure Asset Management* Massimo Losa, Tom Papagiannakis, 2014-04-28 Worldwide there is a growing interest in efficient planning and the design construction and maintenance of transportation facilities and infrastructure assets. The 3rd International Conference on Transportation Infrastructure ICTI 2014 Pisa April 22-25 2014 contains contributions on sustainable development and preservation of transportation infrastructure assets with a focus on eco efficient and cost effective measures. Sustainability Eco efficiency and Conservation in Transportation Infrastructure Asset Management includes a selection of peer reviewed papers on a wide variety of topics: Advanced modeling tools LCA LCC BCA performance prediction design tools and systems Data management monitoring and evaluation Emerging technologies and equipments Innovative strategies and practices Environmental sustainability issues Eco friendly design and materials Re use or recycling of resources Pavements tracks and structures Case studies. Sustainability Eco efficiency and Conservation in Transportation Infrastructure Asset Management will be particularly of interest to academics researchers and practitioners involved in sustainable development and maintenance of transportation infrastructure assets. **Research and Applications in Structural Engineering, Mechanics and Computation** Alphose Zingoni, 2013-08-15 Research and Applications in Structural Engineering Mechanics and Computation contains the Proceedings of the Fifth International Conference on Structural Engineering Mechanics and Computation SEMC 2013 Cape Town South Africa 2-4 September 2013. Over 420 papers are featured. Many topics are covered but the contributions may be seen to fall Mechanistic Evaluation of the Georgia Loaded Wheel Tester for Superpave Asphalt Mixtures Robert Y. Liang, Atef Fatthy Saleeb, 2004 **Eleventh International Conference on the Bearing Capacity of Roads, Railways and Airfields** Inge Hoff, Rabbira Saba, Helge Mork, 2022-07-07 Innovations in Road Railway and Airfield Bearing Capacity Volume 3 comprises the third part of contributions to the 11th International Conference on Bearing Capacity of Roads Railways and Airfields 2022. In anticipation of the event it unveils state of the art information and research on the latest policies traffic loading measurements in situ measurements and condition surveys functional testing deflection measurement evaluation structural performance prediction for pavements and tracks new construction and rehabilitation design systems frost affected areas drainage and environmental effects reinforcement traditional and recycled materials full scale testing and on case histories of road railways and airfields. This edited work is intended for a global audience of road

railway and airfield engineers researchers and consultants as well as building and maintenance companies looking to further upgrade their practices in the field 7th RILEM International Conference on Cracking in Pavements A. Scarpas, Niki Kringos, I. Al-Qadi, Loizos A., 2012-08-30 In the recent past new materials laboratory and in situ testing methods and construction techniques have been introduced In addition modern computational techniques such as the finite element method enable the utilization of sophisticated constitutive models for realistic model based predictions of the response of pavements The 7th RILEM International Conference on Cracking of Pavements provided an international forum for the exchange of ideas information and knowledge amongst experts involved in computational analysis material production experimental characterization design and construction of pavements All submitted contributions were subjected to an exhaustive refereed peer review procedure by the Scientific Committee the Editors and a large group of international experts in the topic On the basis of their recommendations 129 contributions which best suited the goals and the objectives of the Conference were chosen for presentation and inclusion in the Proceedings The strong message that emanates from the accepted contributions is that by accounting for the idiosyncrasies of the response of pavement engineering materials modern sophisticated constitutive models in combination with new experimental material characterization and construction techniques provide a powerful arsenal for understanding and designing against the mechanisms and the processes causing cracking and pavement response deterioration As such they enable the adoption of truly mechanistic design methodologies The papers represent the following topics Laboratory evaluation of asphalt concrete cracking potential Pavement cracking detection Field investigation of pavement cracking Pavement cracking modeling response crack analysis and damage prediction Performance of concrete pavements and white toppings Fatigue cracking and damage characterization of asphalt concrete Evaluation of the effectiveness of asphalt concrete modification Crack growth parameters and mechanisms Evaluation quantification and modeling of asphalt healing properties Reinforcement and interlayer systems for crack mitigation Thermal and low temperature cracking of pavements and Cracking propensity of WMA and recycled asphalts

Advances in Materials and Pavement Performance Prediction II K. Anupam, A.T. Papagiannakis, A. Bhasin, D. Little, 2020-12-08 Inspired from the legacy of the previous four 3DFEM conferences held in Delft and Athens as well as the successful 2018 AM3P conference held in Doha the 2020 AM3P conference continues the pavement mechanics theme including pavement models experimental methods to estimate model parameters and their implementation in predicting pavement performance The AM3P conference is organized by the Standing International Advisory Committee SIAC at the time of this publication chaired by Professors Tom Scarpas Eyad Masad and Amit Bhasin *Advances in Materials and Pavement Performance Prediction II* includes over 111 papers presented at the 2020 AM3P Conference The technical topics covered include rigid pavements pavement geotechnics statistical and data tools in pavement engineering pavement structures asphalt mixtures asphalt binders The book will be invaluable to academics and engineers involved or interested in

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Table of Contents Assessment Of Permanent Deformation Behavior Of Asphalt

1. Understanding the eBook Assessment Of Permanent Deformation Behavior Of Asphalt
 - The Rise of Digital Reading Assessment Of Permanent Deformation Behavior Of Asphalt
 - Advantages of eBooks Over Traditional Books
2. Identifying Assessment Of Permanent Deformation Behavior Of Asphalt
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Assessment Of Permanent Deformation Behavior Of Asphalt
 - User-Friendly Interface

4. Exploring eBook Recommendations from Assessment Of Permanent Deformation Behavior Of Asphalt
 - Personalized Recommendations
 - Assessment Of Permanent Deformation Behavior Of Asphalt User Reviews and Ratings
 - Assessment Of Permanent Deformation Behavior Of Asphalt and Bestseller Lists
5. Accessing Assessment Of Permanent Deformation Behavior Of Asphalt Free and Paid eBooks
 - Assessment Of Permanent Deformation Behavior Of Asphalt Public Domain eBooks
 - Assessment Of Permanent Deformation Behavior Of Asphalt eBook Subscription Services
 - Assessment Of Permanent Deformation Behavior Of Asphalt Budget-Friendly Options
6. Navigating Assessment Of Permanent Deformation Behavior Of Asphalt eBook Formats
 - ePub, PDF, MOBI, and More
 - Assessment Of Permanent Deformation Behavior Of Asphalt Compatibility with Devices
 - Assessment Of Permanent Deformation Behavior Of Asphalt Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Assessment Of Permanent Deformation Behavior Of Asphalt
 - Highlighting and Note-Taking Assessment Of Permanent Deformation Behavior Of Asphalt
 - Interactive Elements Assessment Of Permanent Deformation Behavior Of Asphalt
8. Staying Engaged with Assessment Of Permanent Deformation Behavior Of Asphalt
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Assessment Of Permanent Deformation Behavior Of Asphalt
9. Balancing eBooks and Physical Books Assessment Of Permanent Deformation Behavior Of Asphalt
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Assessment Of Permanent Deformation Behavior Of Asphalt
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Assessment Of Permanent Deformation Behavior Of Asphalt
 - Setting Reading Goals Assessment Of Permanent Deformation Behavior Of Asphalt
 - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Assessment Of Permanent Deformation Behavior Of Asphalt
 - Fact-Checking eBook Content of Assessment Of Permanent Deformation Behavior Of Asphalt
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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