

3D FINITE ELEMENT MODEL FOR ASPHALT CONCRETE RESPONSE SIMULATION

S.M.J.G. Erkens¹, X. Liu² and A. Scarpas³

ABSTRACT

An extensive experimental, analytical and numerical investigation on the response of asphalt concrete is currently in progress at Delft University of Technology. The objectives of this Asphalt Concrete Response (ACRe) project are: (a) the formulation and finite element implementation of a 3-dimensional, strain rate sensitive, temperature and loading history dependent constitutive model, (b) the development of the necessary experimental set-ups, testing procedures and data-analysis methods for determination of the model parameters.

These objectives are strongly interrelated: on the one hand the model dictates what should be measured in a test, while on the other hand, the response observed in the tests sets the requirements for the model. As a result, model development/verification and experimental testing have been progressing in parallel throughout the project. In this contribution both, the finite element and the experimental aspects of the project will be presented.

The constitutive model has been implemented in the finite element system INSAP. The system has been used to simulate the initiation and propagation of damage in two flexible pavement structures due to repeated loading. The simulations illustrate the influence of geometry and material characteristics on the development of damage.

Key words: 3D, material model, response simulation, material parameter determination

1 INTRODUCTION

Most of the design procedures that are used in road engineering are based on linear elastic multi-layer analysis and simple laboratory tests. Unfortunately, design life and material degradation, which are essential issues in estimating the life time of a pavement, can not be addressed by linear elasticity. In the damage accumulation process the complex nature of asphalt concrete is essential and accurate performance predictions are possible only when that nature is modelled. This means that, besides the temperature and strain rate dependency, the state of stress dependency of the material response must be also taken into account. So far, this is often neglected although it is well known that the strength of asphalt concrete increases with increasing confinement. When it comes to failure predictions, this aspect of the material behaviour can no longer be neglected. The multitude of states of stress caused by a wheel load results in a multitude of different material strengths. As a result, the damage accumulation process is highly complex, since it depends not only on the material characteristics but also on the state of stress.

¹ Research engineer, Road & Railway Research Laboratory, Dept. of Civil Engineering and GeoSciences, Delft University of Technology, PO Box 5048, 2628 CN Delft, The Netherlands, email: S.Erkens@CTG.TUdelft.NL

² Research engineer, Section of Structural Mechanics, Dept. of Civil Engineering and GeoSciences, Delft University of Technology, PO Box 5048, 2628 CN Delft, The Netherlands, email: X.Liu@CT.TUdelft.NL

³ Associate Professor, Section of Structural Mechanics, A.Scarpas@CT.TUdelft.NL

Dept. of Civil Engineering and GeoSciences, Delft University of Technology, PO Box 5048, 2628 CN Delft, The Netherlands, email: A.Scarpas@CT.TUdelft.NL

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Bituminous Mixtures and Pavements VII A.F. Nikolaides, E. Manthos, 2019-05-24 Highway engineers are facing the challenge not only to design and construct sustainable and safe pavements properly and economically This implies a thorough understanding of materials behaviour their appropriate use in the continuously changing environment and implementation of constantly improved technologies and methodologies Bituminous Mixtures and Pavements VII contains more than 100 contributions that were presented at the 7th International Conference Bituminous Mixtures and Pavements 7ICONFBMP Thessaloniki Greece 12-14 June 2019 The papers cover a wide range of topics Bituminous binders Aggregates unbound layers and subgrade Bituminous mixtures Hot Warm and Cold Pavements Design Construction Maintenance Sustainability Energy and environment consideration Pavement management Pavement recycling Geosynthetics Pavement assessment surface characteristics and safety Posters Bituminous Mixtures and Pavements VII reflects recent advances in highway materials technology and pavement engineering and will be of interest to academics and professionals interested or involved in these areas

Futuristic Computational Systems and Advanced Engineering for the Society D. Jude Hemanth, Utku Kose, Nabi Ibadov, Ismail Serkan Uncu, Hamit Armagan, 2025-05-29 This book provides the most recent quality research papers accepted and presented in the 6th International Conference on Artificial Intelligence and Applied Mathematics in Engineering ICAIAME 2024 held in 26-27-28 September 2024 at Warsaw Poland Objective of the book is to provide important and innovative research for developments improvements within different engineering fields which are highly interested in using artificial intelligence and applied mathematics As a collection of the outputs from ICAIAME 2024 the book ensures a perspective in terms of especially futuristic solution approaches to advance the society through innovative engineering efforts The book allows researchers and practitioners from both academia as well as industry to exchange share their ideas and keep themselves up to date in terms of knowledge in the context of the latest research efforts and further opportunities arising As the proceedings of the ICAIAME 2024 the book eventually plays a remarkable active role in accumulating the most recent significant works of artificial intelligence and applied mathematics to shape both the present and future of engineering disciplines

Pavement Cracking Imad L. Al-Qadi, Tom Scarpas, Andreas Loizos, 2008-07-30 Internationally much attention is given to causes prevention and rehabilitation of cracking in concrete flexible and composite pavements The Sixth RILEM International Conference on Cracking in Pavements Chicago June 16-18 2008 provided a forum for discussion of recent developments and research results This book is a collection of papers from

Advanced Testing and Characterization of Bituminous Materials, Two Volume Set Andreas Loizos, Manfred N. Partl, Tom Scarpas, Imad L Al-Qadi, 2009-05-14 Bituminous materials are used to build durable roads that sustain diverse environmental conditions However due to their complexity and a global shortage of these materials their design and technical development present several challenges Advanced Testing and Characterisation of Bituminous Materials focuses on fundamental and performance

testing *Verification of Flexible Pavement Response from a Field Test* Gregers Hildebrand,2002 **Long and Deep Tunnels** Vittorio Guglielmetti, Shulin Xu, Gianni Alberto Arrigoni, Piergiorgio Grasso, 2016-04-15 The design and construction of long and deep tunnels i e tunnels under mountains characterised by either considerable length and or overburden represent a considerable challenge The scope of this book is not to instruct how to design and construct such tunnels but to share a method to identify the potential hazards related to the process of designing and constructing long and deep tunnels to produce a relevant comprehensive analysis and listing to quantify the probability and consequences and to design proper mitigation measures and countermeasures The design developed using probabilistic methods is verified during execution by means of the so called Plan for Advance of the Tunnel PAT method which allows adapting the design and control parameters of the future stretches of the tunnel to the results of the stretches already finished using the monitoring data base Numerous criteria are given to identify the key parameters necessary for the PAT procedure Best practices of excavation management with the help of real time monitoring and control are also provided Furthermore cost and time evaluation systems are analysed Finally contractual aspects related to construction by contract are investigated for best development and application of models more appropriate for tunnelling construction contracts The work will be of interest to practising engineers designers consultants and students in mining underground tunnelling transportation and construction engineering as well as to foundation and geological engineers urban planners developers and architects Asphalt Paving Technology Association of Asphalt Paving Technologists,2004 *Journal of the Association of Asphalt Paving Technologists* ,2006

Mechanistic Model to Predict the Impact of the Aggregate Matrix on the Permanent Deformation of Asphalt Mixtures Samer Hassan Dessouky, Eyad Masad, Dallas N. Little, 2005 Hot mix asphalt HMA is a granular composite material stabilized by the presence of asphalt binder The behavior of HMA is highly influenced by the microstructure distribution in terms of the different aggregate particles present in the mix the directional distribution of aggregates the distribution of voids and the nucleation and propagation of cracks Conventional continuum modeling of HMA lacks the ability to explicitly account for the effect of aggregate microstructure distribution features This report presents the development of elastic and visco plastic models that account for important aspects of the aggregate and microstructure distribution in modeling the macroscopic behavior of HMA The objective of Project 0 1707 is to develop tools by which engineers can judge the impact of the aggregate on the performance of HMA based on simple and repeatable tests Of greatest concern in Project 0 1707 is the ability of the HMA to resist permanent deformation or to rut which leads to safety concerns especially under wet surface conditions In this report the research team develops an approach is developed to introduce a length scale to the elasticity constitutive relationship in order to capture the influence of aggregate particle sizes on HMA response A finite element FE analysis is used to analyze the microstructure response and predict the macroscopic properties of HMA Each point in the microstructure is assigned effective local properties that are calculated using an analytical micromechanical model that

captures the influence of the number of particles on the microscopic response of the HMA. The moving window technique and autocorrelation function are used to determine the microstructure characteristic length scales that are used in strain gradient elasticity. A number of asphalt mixes with different aggregate types and size distributions are analyzed. An elasto-visco-plastic continuum model is developed to predict HMA response and performance. The model incorporates a Drucker-Prager yield surface that is modified to capture the influence of stress path direction on the material response. Parameters that reflect the directional distribution of aggregates and damage density in the microstructure are included in the model. The elasto-visco-plastic model is converted into a numerical formulation and is implemented in FE analysis using a user-defined material subroutine UMAT. A fully implicit algorithm in time step control is used to enhance the efficiency of the FE analysis. The FE model used in this project simulates experimental data and pavement section.

Evaluation of Effects of Tire Size and Inflation Pressure on Tire Contact Stresses and Pavement Response, 2006. A specific objective was to establish how tire contact stresses may be modeled in existing layered elastic programs to better approximate the effects of non-uniform tire contact pressure distributions and account for differences in tire construction, tire load, and tire inflation pressure on predicted pavement response. To this end, researchers assembled a data base of measured tire contact stresses and performed a comparative evaluation of methods for representing tire contact pressure distributions in existing models to predict performance-related pavement response variables. A computer program called TireView was developed that provides estimates of tire contact area as a function of tire type, tire load, and tire inflation pressure and predicts the stress distribution at the tire-pavement interface based on polynomial interpolations of measured tire contact stresses in the data base. A method for predicting pavement response using layered elastic analysis is proposed that is based on the predicted tire contact area.

Establishment of Subgrade Undercut Criteria and Performance of Alternative Stabilization Measures Roy H. Borden, 2010. The scope of this research includes the development of criteria to define the need for undercutting the depth of the undercut and the quality of the backfill material such that the cost and performance are optimized. In addition, chemical stabilization and geosynthetic reinforcement in combination with several thicknesses of the ABC were studied to provide comparative criteria for the enhancement of various poor subgrade soils encountered in N.C. with or in lieu of undercut and replacement with select fill. The criteria are presented along with the associated relative costs of each alternative.

Functional and Functionally Structured Materials Yafang Han, Ying Wu, Guangxian Li, Fu Sheng Pan, Runhua Fan, Xuefeng Liu, 2016-03-20. Selected peer-reviewed papers from the Chinese Materials Conference 2015, July 10-14, 2015, Guiyang, China.

Evaluation of Asphalt Concrete Pavement Service Life Using 3D Nonlinear Finite Element Analysis and Nonlinear Fatigue Damage Model Zhi Suo, Hong Kong Polytechnic University, Department of Civil and Structural Engineering, 2012. A study has been conducted at Hong Kong Polytechnic University to develop a procedure to better predict long-term performance of asphalt concrete pavements. To achieve this end, complicated finite element techniques are

employed and parametric studies are performed. The fatigue destructive mechanics, fracture mechanics, and damage mechanics are used to develop a 3D Finite element model that can be applied to characterize the nonlinear properties of the asphalt concrete materials. A set of materials tests is performed to evaluate various bituminous wearing course materials by using Universal Servo Pneumatic Testing System in Hong Kong Road Research Laboratory such as indirect tensile modulus, dynamic creep, indirect tensile fatigue, and wheel tracking. The materials for this study comprise conventional asphalt concrete wearing course ACWC and stone mastic asphalt SMA with a virgin 60/70 bitumen and different modified bitumen: Polypropylene Crumb rubber, Cellulose fiber, Asbestos fiber, and Gilsonite. The test results are analyzed in a multiple regression technique to capture the parameters in the proposed creep model. With the developed materials models, the typical flexible pavement structures are modeled in the finite element software ANSYS. The real vehicle loads are employed and the effects of the footprint shape, loading frequency, and curing time are studied by using this computer simulation technique. The simulation results show that the SMA has a better healing effect and a longer micro damage fatigue life than other mixtures with significantly enhanced healing effect. In addition, after the fatigue analysis and the prediction of the service life of flexible pavement, a sensitivity analysis is conducted to investigate the effect of cross section and load attributes factors on pavement response.

Finite Element Analyses of Reflective Cracking in Asphalt Concrete Overlays Rongzong Wu, 2005

Development of the Thickness Design for Concrete Pavement Overlays Over Existing Asphalt Pavement Structures Chul Suh, 2008 *Proceedings*, 1997

Three Dimensional Finite Element Programs for Pavement Analysis: Introduction & appendix 1, 1998 Transportation Research Record, 1999 **Pavement Design and Accelerated Testing 2004**

National Research Council (U.S.). Transportation Research Board, 2004. TRB's Transportation Research Record Journal of the Transportation Research Board 1896 examines a mechanistic empirical model to predict transverse joint faulting a multilayer boundary element method for evaluating top down cracking in hot mix asphalt pavements and one way and two way directional heavy vehicle simulator loading in this four part volume on education tools rigid pavements flexible pavements and accelerated pavement testing. The K B Woods Award winning paper on design and construction of transportation facilities Computer Based Multimedia Pavement Training Tool for Self Directed Learning by Stephen Muench and Joe Mahoney of the University of Washington also appears in this TRR Journal volume. TRB website The Role of Transit in Creating Livable Metropolitan Communities Transit Cooperative Research Program, 1997. Discusses how transit impacts and improves community life in the United States.

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