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Research Article

A qualitative method for determining the surfaces between asphalt layers using ABAQUS software

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Abstract

The analytical models are mainly combined with numerical equations for the problems of the pavement under the wheel load. Different assumptions can be considered, such as elastic asphalt and viscoelastic as well as static or dynamic load. Mainly on deformation at the bottom of asphalt and tension layers focus on subgrid. The pavement structure was considered as layers with uniform characteristics. Therefore, this analytical model calculates the three-dimensional contact tension between the wheel and the pavement and the shape of the contact area. Basis and subgrid are considered linear and the asphalt layers can be linear or viscoelastic. This model is based on the results of direct shear stress tests at an axial load constant. The curves obtained from this experiment can be defined by three parameters: the maximum shear stress (shear stress curve versus shear displacement), the interaction modulus between the layers (the same curve slope) and the friction coefficient after the failure. Due to the ability of ABACOUS software, this project is done with this software. One of the methods widely used to predict viscoelastic responses of asphalt mixtures is the finite element method. ABAQUS software is one of the tools that can simulate mixed asphalt behavior based on a finite element method, taking into account all the determinant parameters. The use of the Prony series is one of the common techniques for describing the viscoelastic behavior of asphalt mixtures in ABAQUS software. For this purpose, it is necessary to determine the parameters required for this field, including proven constants, moment elastic modulus, and asphalt mixture poison ratio. On the other hand, the determination of these parameters through testing in addition to spending time and costs requires laboratory equipment. Therefore, in this thesis, a three-dimensional finite element model with ABAQUS software was constructed to analyze the persistent pavement using theoretical relations without conducting the experiment. Also, viscoelastic behavior of common asphalt mixtures and time dependence of its responses at different temperatures can be modeled in ABAQUS software. After performing the shear stress test for different axial loads, different temperatures, with or without a single coil, they found that all parameters are temperature dependent and the coefficient of friction does not depend on the applied axial load. This new model improves the accuracy of the finite element model and its important role can be an analytic expression that includes all the variables that are effective in the problem.

Introduction

As the functionality of computers increases, limited component modeling can help determine the variables that are important for the transverse and longitudinal strain of asphalt pavement. In addition, computer modeling of the pavement structure is more helpful to laboratory results [1,2].

Park and Martin (2005) studied the importance of considering the three-dimensional reality of contact stress in the responsiveness of flexible pavement. For this, a three-dimensional finite element model was developed that considered the asphalt layers as elastic-viscoplastic. To achieve accurate results, three-dimensional contact tensions were measured using VRSPTA. The results obtained from finite element analysis were compared

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with the track width profiles measured in West Track. It was concluded that non-uniform contact stress is important for prediction [3,4].

The studied a particular section in Virginia, in order to compare different computer programs, the comparison between the finite element model and empirical measurements. The mentioned section, in which the measuring equipment was fitted, was 7.5 inches thick asphalt, under the double or single wheel load, and the rectangular loading area was considered. This section was modeled using a variety of software, linear elastic theory, symmetric modeling and three dimensional finite element models. It was concluded that linear elastic theory is not effective in predicting flexible pavement behavior, since it designs unreliable low temperatures and non-economic temperatures at high temperatures. Therefore, analytical reforms for the transverse and stress strain were calculated and measured [5]. The measured values increased exponentially, while the calculated values followed a linear increase. An important variable in this study was not considered that this variable was thick. Only one section of this route was modeled, its thickness is less than the usual thickness used for pavement. This research confirms that the linear elastic model does not show the actual behavior of the asphalt [6].

The effect of two kinds of loading (trapezoidal and continuous) and the interaction between the layer (Coulomb and elastic) on flexible pavement looked back. The study was performed using Abaqus Limited Element software and was used for moving loads (8 and 72km / h). Linear grain aggregates were assumed and their properties were obtained from the FWD test. On the other hand, the viscoelastic asphalt layers are assumed that its elastic properties are obtained from the modulus of the resonance test and its viscoelastic properties were obtained from the creep test. The distribution of trapezoidal load, uniform load on elements and the distribution of triangles are assumed for the start and end of the wheel path [7,8]. In a model that was studied by Yo et al., transverse and longitudinal contact stresses were considered in the interaction between wheel and pavement. The results of the computer model were compared with the measured values from the pavement section and found that the continuous loading domain yielded better results. It was also concluded that the linear elastic adhesion model is more appropriate than the Coulomb model. Finally, they proved that the shear contact force has a small effect on the strain at the bottom of the asphalt layer [9,10].

The introduced another method for determining the viscoelastic behavior of asphalt, for the modeling of finite element. The results of this limited component model in ABAQUS were consistent with field measurements. Viscoelastic properties of asphalt were obtained using a creep yield test [11].

The modeling of finite element includes moving loads, coulomb interactions between layers, and time-dependent properties. In this paper, it was concluded that elastic models are not able to represent the actual behavior of materials. On the other hand, viscoelastic models are able to predict the delay and fast return. When viscoelastic materials are considered, the difference between measured and measured values is less than 15%. With the findings of this research, it is wrong to consider asphalt as linear elastic [12-15].

Presented a finite element analysis under the influence of three-dimensional contact stresses and dynamic loading on a permanent pavement. To do this, the authors used Abaqus to perform a dynamic analysis of three times at a constant pressure. The mentioned model is designed for viscoelastic behavior of asphalt, and both of the three-dimensional and steady-state contact stresses are assumed [16-18]. As the operation time increases, the length of the contact area increases to a fixed length and width. After comparing the results of the assumed contact compounds, they found that the tensile strain at the bottom of the asphalt layer was in line with the actual values. Also, for the transverse tensile strain, the results of the three-dimensional contact stress were larger than the steady state. The authors concluded that as the applied load increases, the difference between the values obtained from constant or three-dimensional contact tensions decreases. In this research, we examined an analytical model for estimating the response of loaded asphalt pavements under load on any number of layers. Also the finite element modeling of an experimental path using ABAQUS software was performed to determine the effect of different parameters on the performance of this pavement.

Material and Methods

Pavement analysis models

Asphalt layers, after casting, should be compressed to handle loads, better distribute pressure pressures, and create a smooth and smooth surface. As a result of the condensation, the layers stick together to form a dense and seamless structure and to act better against the shearing forces resulting from traffic. With less space in the asphalt, its resistance to weather conditions, as well as erosion and more durability will be asphalt, and with the reduction of surface roughness, traffic safety and driving comfort will increase, and the traffic load on the asphalt will be reduced [19,20].

The instrumental models used to analyze the response of pavements to traffic loads and environmental conditions vary from simple experimental models based on limiting the resistance to complex models that are realistically describing the behavior of materials [21-23].

The choice of model type depends on the designer's ability to examine the information required for the materials and the interpretation of the results of these models. The formulation of the models involves the idealization of the real problem and transforming it into a mathematical form. The general mathematical form for pavement models consists of a series of partial differential equations that are exposed to different boundary conditions. In the solution of problems, there are two main perspectives: (1) analytical or classical methods, (2) numerical or approximate techniques. The theory of reactionary layer and skin panels are examples of analytical views. The finite element model is an example of a numerical view [24,25].

Analytical views: The Birmistor solution for an elastomeric two-layer system led to the establishment of the theory of multiple layers. The two-layer system equations are relatively simple and can be solved with a calculator. But the generalization of this theory to multiple layers complicates the problem, and problem solving requires practical analysis of the computer. In this study, the ABAQUS computer program was used for this analysis [26,27].

The hypotheses used to develop the model are:

1. Properties of uniform materials
2. Limit thickness of layers except in the substrate layer that is unlimited.
3. Isotropic properties of materials
4. Full friction between layers
5. Lack of tension on the surface
6. The material is linear-reactionary and follows Hooke's law. In addition, the load is assumed to be constant and is distributed uniformly over a circular surface in a uniformly distributed load [28].

Modeling by means of finite element methods: ABAQUS software is a collection of highly capable modeling programs based on a finite element method and problem-solving capabilities from a simple linear analysis to the most complex nonlinear modeling (including hyper-elastic and visco-elastic materials) [29].

In this paper, ABAQUS finite element software has been used to investigate the effect of different layers on concrete pavement malfunctioning. According to conventional pavement layers, modeling has been carried out, further specification of the model made in ABAQUS is presented.

Model geometry

In this paper, 20 centimeters of concrete on a base layer with a thickness of 30 cm was used to simulate a pavement and the length and width of all layers were 5 meters.

Specifications of materials

In this modeling, the behavior of the underlying layers and subgrid are considered elastic. This assumption is realistic given that under loads that pass through the pavement in the underlying layer of major deformations (in the plastic range) it does not seem to be realistic. The behavior of concrete materials is also considered elastic. When concrete is not cracked, the assumption of such behavior is correct for concrete. Common asphalt pavements in Iran consist of four layers of asphaltic, basement, subsoil and substrate, each of which has its own behavioral characteristics. Different layers of the pavement from the point of view of behavioral characteristics can be divided into two groups of elastic and viscoelastic so that the asphalt layer has viscoelastic behavior and other elastic behavioral pavement layers. In the ABAQUS software, viscoelastic properties of materials can be defined with the help of the Provence series [30-32]. For this purpose, it is necessary to determine the Prony constants, moment elastic modulus and the Poisson ratio of the asphaltic mixture. In this paper, used model is based on the results of direct shear stress tests at an axial load constant. The curves obtained from this experiment can be defined by three parameters: the maximum shear stress (shear stress curve versus shear displacement), the interaction modulus between the layers (the same curve slope) and the friction coefficient after the failure.

Findings

Layer modules are one of two important factors that play a major role in resistance to pavement failures. Theoretically, less thickness is required for pavement if asphalt materials have a higher modulus. In this section, the effect of the modulus of the layers on the longitudinal tensile strain is studied maximally. The three values for the tensile strain modulus are given in table 1, and the effect of this change in values is shown in table 2.

According to table 2, it can be seen that the FRL layer plays the most important role on the maximum tensile strain compared to other layers. With a 30% increase in the modulus of this layer, the tensile strain decreases from 80.6 µg to 70 µm.

Table 1: The values of the modulus intended to examine the effect of the modulus of the layers.

Layer	(Gp) Layer Module		
	30%	measured value	-30%
SMA	3.409	4.78	6.331
ODOT442	2.55	3.65	4.745
ODOT302	5.397	7.71	10.023
FRL	5.67	8.11	10.543

Table 2: The rate of change in the strain of each of the layers due to the modulus of the layers.

Layer	Maximum tensile strain variation (microstrin)	
	30%	-30%
SMA	2.99E-02	-2.72E-02
ODOT442	2.99E-02	-2.40E-02
ODOT302	2.72E-02	-2.09E-02
FRL	1.48E-01	-1.00E-01

Discussion

1. In hot mix asphalt, bitumen is considered as the only binder, and maintaining its quality during asphalt production should be taken into consideration. The bitumen contained in the storage tanks of the workshop or the beams entering the workshop for discharging into the reservoirs should never be heated to more than 175 ° C or smoke during heating. In some cases, however, temperatures above 210 ° C have been observed.

2. It is safe to say that the basic parameter concerning bitumen and asphalt, manpower is unfortunately the lowest level of manpower required, such as technician, operator to design levels, observer engineers, etc. We are faced with a shortage of skilled labor. The manpower employed in asphalt factories does not have a stable position and is not trained or tested in any way and does not qualify for scientific competence, and only act on the basis of experience.

3. According to the regulations of the pavement, in the asphalt pavers, to use the full automatic finisher, to use asphalt pavers and to correct the roughness of the existing and old asphalt surfaces as well as the freeways. The standard finisher conditions depend on various factors such as year of construction, hours of operation, maximum and minimum width of the finisher, sensors, vibrating rods, and no burnout for asphalt vibrations, helminthes are healthy. In road construction projects in Iran for the lifetime of finishers is even over 20 years old. The contracting companies have secondhand finisher and sometimes some hands. Most of them do not have sensors or their sensors are damaged. In some finisher, the binding machine is not visible so that the seam between the hot and cold layer can be executed in accordance with the regulations.

4. The temperature of the asphalt mixes with pure bitumen and continuous grading during loading should not be outside the range (160-120). The appropriate air temperature is also determined by the surface temperature of the road surface and the thickness of the asphalt layer, which is for typical thicknesses of 5 to 10 cm is between 120 °C and 140 °C. In many cases it is found that asphalt is loaded at temperatures above the standard temperature (above 163 °C), which can be caused by factors such as high bitumen temperatures or the temperature of rock materials, due to the unfamiliarity of hot The bitumen or the operator to the standard temperature or not the temperature sensor or its false function. The absence of a mixture of asphalt at the proper temperature at loading and loading will result in insufficient or excessive density in the applied procedure. Insufficient density and, in fact, excessive amount of free space, insufficient durability of the asphalt pavement. Excessive congestion, low vacancy required, and asphalt paving [32,33].

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References

1. Dave N, Scofield L. Quiet Pavements Raise the Roof in Europe. Hot Mix Asphalt Technology, National Asphalt Pavement Association. 2003; **Ref.:** https://tinyurl.com/y2errawy
2. James R. I-80 Davis OGAC Pavement Noise Study: Traffic Noise Levels Associated with an Open Grade Asphalt Concrete Overlay. Prepared for California Department of Transportation by Illingworth & Rodkin, Inc., Sacramento, CA, 2002; **Ref.:** https://tinyurl.com/y3wcrvhn
3. Brown ER. Experience with Stone Mastic Asphalt in the United States, Report No. 93-4, National Center for Asphalt Technology, Auburn University, Alabama. 1993; **Ref.:** https://tinyurl.com/y3bcqocp
4. Design and Construction of Stone Matrix Asphalt Mixtures. Report No. 425, National Cooperative Highway Research Program. J Trans Res Board. 1998; **Ref.:** https://tinyurl.com/y5t579qx

5. Hughs C. Designing and Constructing SMA Mixtures - State-of-the-Practice, QIP 122, National Asphalt Pavement Association, Lanham, Maryland. 1999; **Ref.:** https://tinyurl.com/yyutok36

6. Nunn ME, Brown A, Weston D, Nicholls JC. Design of long-life flexible pavements forheavy traffic, Report No. 250, Transportation Research Laboratory, Berkshire, United Kingdom. 1997; **Ref.:** https://tinyurl.com/y3wsgyfz

7. Brown SF, Tam WS, Brunton JM. Structural Evaluation and Overlay Design: Analysis and Implementation. Proc., Sixth International Conference on the Structural Design of Asphalt Pavements. Ann Arbor. 1987; 1: 1013-1028. **Ref.:** https://tinyurl.com/yyn3myr4

8. Lee HJ. Lee JH, Park HM. Performance evaluation of high modulus asphalt mixtures for longlife asphalt pavements, Department of Civil and Environmental Engineering, Sejong University, Seoul, Republic of Korea. 2005; **Ref.:** https://tinyurl.com/yx8n396x

9. Huddleston J, Bencher M, Newcomb DE. Asphalt Pavement Alliance, Perpetual Pavement. 2004; **Ref.:** https://tinyurl.com/y4n58z9e

10. Newcomb DE, Willis R, Timm DH. Perpetual Asphalt Pavements in America. 2010; **Ref.:** https://tinyurl.com/y4yd74mu

11. Advanced Asphalt Technologies (AAT), LLC. Developing a Plan for Validating an Endurance Limit for HMA Pavements. Draft Executive Summary. National Cooperative Highway Research Program Project 9-44. Transportation Research Board. Washington, DC. 2007.

12. Al-Qadi IL, Wang H, Yoo PJ, Dessouky SH. Dynamic Analysis and In-situ Validation of Perpetual Pavement Response to Vehicular Loading. Paper submitted to Transportation Research Board Annual Meeting. Transportation Research Board. Washington, DC. 2008; **Ref.:** https://tinyurl.com/y3qlaq9z

13. Liao Y. Viscoelastic FE modeling of asphalt pavements and its applications to U.S. 30 perpetual pavement. Ph.D. Dissertation, Civil Engineering Department, Ohio University, Athens, OH. 2007; **Ref.:** https://tinyurl.com/y3opeane

14. Asphalt Pavement Alliance (APA). Perpetual Pavements. A Synthesis. APA 101, Lanham, Maryland. 2002; **Ref.:** https://tinyurl.com/y36qqljc

15. Asphalt Pavement Alliance. I-695 – a classic example of perpetual pavement. 2010.

16. AASHTO. Pavement Design Guide, American Association of State Highway and Transportation Officials, Washington, DC. 2002; **Ref.:** https://tinyurl.com/y2oggarz

17. Abraham H. Asphalts and Allied Substances: Their Occurrence, Modes of Production, Uses in the Arts and Methods of Testing, Third Edition. D. Van Nostrand Co., Inc. New York. 1929; **Ref.:** https://tinyurl.com/y3ubzmdg

18. Elseifi MA, Al-Qadi IL, Yoo PJ, Janajreh I. Quantification of pavement Damage Caused by Dual and Wide-Base Tires. Journal of the Transportation Research. Board No. 1940, 2005; 125-135. **Ref.:** https://tinyurl.com/y2bm9uhm

19. Elseifi MA, Al-Qadi IL, Yoo JP. Viscoelastic Modeling and Field Validation of Flexible Pavements. ASCE Journal of Engineering Mechanics. 2006; 132: 172-178. **Ref.:** https://tinyurl.com/y28255gb

20. Instrumentation for Flexible Pavements-Field Performance of Selected Sensors. 1992; **Ref.:** https://tinyurl.com/yxzbuojb

21. Kim SS, Sarggand S, Masada T, Hernandez J. Ohio Department of Transportation Office of Research and Development and the United States Department of Transportation Federal Highway Administration. 2010; State Job Number 4377046.

22. Liao Y, Sargand SM, Khoury IS, Harrigal A. In-Depth Investigation of the Premature Distresses of Four Ohio SHRP Test Road Sections," 86 TRB Annual Meeting (CD-ROM), Transportation Research Board, National Research Council, Washington, DC. 2007.

23. Masada T. Laboratory Characterization of Materials and Data Management for Ohio-SHRP Project (U.S. 23), Report No. FHWA/OH-2001/07, Department of Civil Engineering, Ohio University, Athens, Ohio. 2007; **Ref.:** https://tinyurl.com/y265wjxh

24. Masada T, Sargand SM, Liao Y. Resilient Modulus Prediction Model for Fine-Grained Soils in Ohio: Preliminary Study International Conference on Perpetual Pavement (CDROM), Columbus, Ohio. 2006; **Ref.:** https://tinyurl.com/y3jwnzoq

25. Sargand SM, Khoury IS, Romanello MT, Figueroa JL. Seasonal and Load Response Instrumentation of the Way-30 Perpetual Pavement. International Conference on Perpetual Pavement (CDROM), Columbus, Ohio. 2006.

26. Perpetual Bituminous Pavements. Transportation Research Circular 503, Transportation Research Board, National Research Council.

27. Hernandez JA. Evaluation of the Response of Perpetual Pavement at Accelerated Pavement Loading Facility: Finite Element Analysis and Experimental Investigation, Russ College of Engineering and Technology of Ohio University, In partial fulfillment of the requirements for the degree Master of Science. 2010; **Ref.:** https://tinyurl.com/y2vneqhw

28. Al-Qadi IL, Wang H, Yoo PJ. Dessouky SH. Dynamic analysis and in-situ validation of perpetual pavement response to vehicular loading. Transportation Research Record: J Trans Res Board. 2008; 2087: 29-39. **Ref.:** https://tinyurl.com/yxmmeqfe

29. Garcia G, Thompson MR. Strain and pulse duration considerations for extended-life hot-mix asphalt pavement design. Transportation Research Record: J Trans Res Board. 2008; 2087: 3-11. **Ref.:** https://tinyurl.com/y6tboshu v

30. Hornyak N, Crovetti JA. Analysis of load pulse durations for Marquette interchange instrumentation project. Transportation Research Record: J Trans Res Board. 2009; 2094: 53-61. **Ref.:** https://tinyurl.com/yxtppxjf

31. Loulizi A, AL-Qadi IL, Elseifi M. Difference between in situ flexible pavements measured and calculated stresses and strains. J Trans Eng. ASCE. 2006; 132: 574-579. **Ref.:** https://tinyurl.com/yxa4e4yg

32. Park D, Martin AE, Masad E. Effects of no uniform tire contact stresses on pavement response. J Trans Eng. 2005; 131: 873-879. **Ref.:** https://tinyurl.com/yxa5otcy

33. Robbins MM, Timm DH. Proceedings from International Conference on Perpetual Pavement 2009: Effects of strain pulse duration on tensile strain in a perpetual pavement. Columbus, OH. 2009.