FINITE ELEMENT SIMULATION OF PAVEMENT RUTTING

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1. INTRODUCTION

Rutting is a longitudinal depression near the wheel paths on asphalt concrete pavement surfaces. It is in essence plastic deformations arisen from the whole pavement layers. The most common methods to predict the rutting are from relations between plastic strain and the numbers of repeating loads, which are obtained from laboratory tests. This is totally empirical. In the present study, the rutting was simulated by an elasto-plastc finite element (FE) method. ANSYS FE program was employed in the study.

2. FE SIMULATION OF THE RUTTING

2.1. PAVEMENT STRUCTURE

This study was conducted with a typical multi-layered asphalt concrete pavement. It consists of five layers. The top layer is a 12 cm asphalt concrete. The base is an unbounded layer of 15cm. The subbase is 35 cm in depth of uncrushed materials. The fourth layer is a 20 cm protective layer. The fifth is the subgarde.

2.2. DRUCKER-PRAGER (DP) MODEL

Pavement materials do not always behave elastically. When the stresses in the pavement structure exceed the strengths of the materials, plastic strains will generate. Plastic strains are the main reasons of the occurrence of pavement rutting. A lot of elasto-plastic models have been set up. It has been proved that Drucker-Prager model can describe the behavior of pavement materials successfully. Thus, the Drucker-Prager model was adopted in the study.

2.3. CALIBRATION OF MATERIAL PROPERTIES

The characteristic value for the elastic model are modules of elasticity (E) and Poisson's ratio (μ), Two extra parameters are needed to describe DP model in order to determine the yield strengths. They are cohesion and internal friction angle(Φ) of the materials, which should be from a triaxial test under the condition similar to real structure. As we know, the modules of elasticity of the materials vary with the climate. So it is reasonable to characterize the value considering this factor. Four groups of modules of elasticity of the pavement materials are adopted, which correspond to the four seasons of a year, see Table 1. An average value of Poisson's ratio μ, 0.35, was utilized for all the pavement materials.

2.4. ANALYSIS MODEL OF THE STRUCTURE

A pavement structure acted by a wheel load can be regarded as a multi-layered half space acted by an uniformly distributed circular load. Actually, this is a typical axisymmetric problem. In the study, only an axisymmetric (2D) model was discussed. The geometry of the 2D model is 6 m wide and 3 m deep. The load used in the study is a standard traffic load, having a single axle with dual wheels each side. The total weight is 100KN. Thus, the load in the 2D model is 0.795 MPa on 10 cm near the symmetric axle. The boundary conditions are applied in such ways that no vertical displacement is prescribed to the bottom of the model, no displacement to the right side horizontally.

Table 1 Parameters of DP model for the pavement materials (E,C: MPa, Φ :degree)

	Winter (1)			Spring (2)			Summer (3)			Autumn (4)		
Pavement structure	E	C	ϕ	E	C	ϕ	E	C	ϕ	E	C	ϕ
asphalt layer	13500	1.0	43	6500	0.5	43	2500	0.2	43	8000	0.5	43
base	1000	0.0003	43	300	0.0002	40	450	0.0002	43	450	0.0002	43
subbase	1000	0.03	43	160	0.02	40	240	0.02	43	240	0.02	43
protective layer	1000	0.0003	43	70	0.0002	40	100	0.0002	43	100	0.0002	43
subgrade	1000	0.002	25	10	0.002	15	45	0.002	23	45	0.002	23

3. RUTTING OF THE PAVEMENT STRUCTURE

The FE simulation results of the pavement structure are shown in Fig. 1 below.

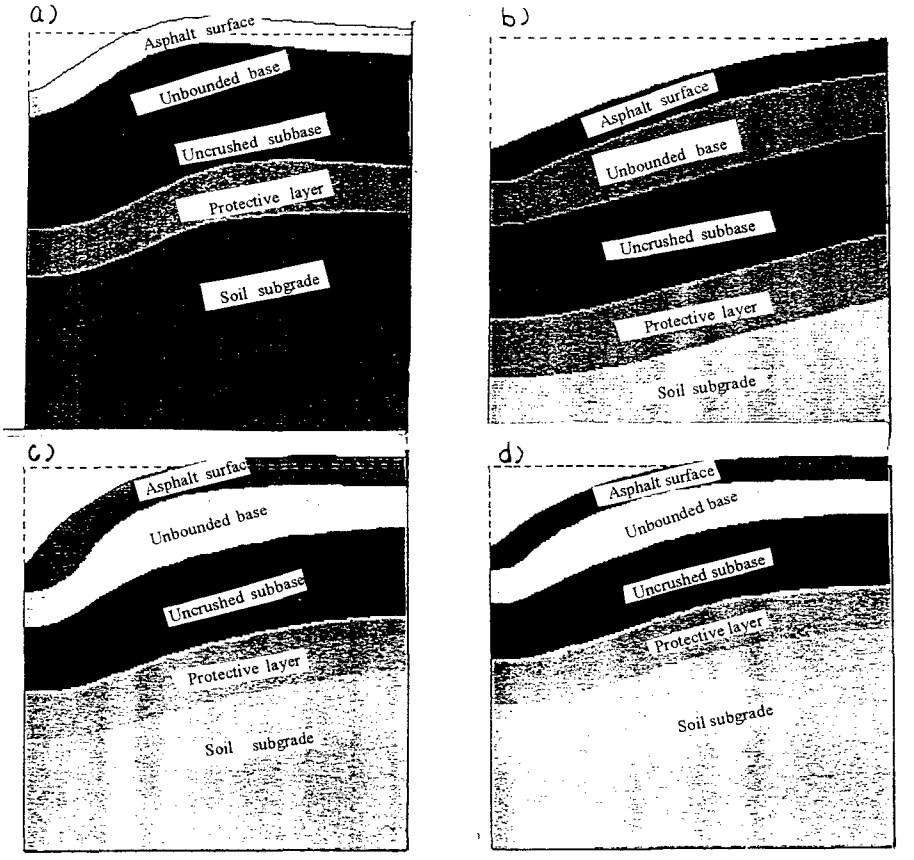

Fig. 1 Rutting of the pavement structures in four seasons a) winter (DMX=.188E-05), b) spring (DMX=.110E-03), c) summer (DMX=.271E-04), d) autumn (DMX= 485E-04). DMX: Maximum permanent displacement(m) after the first unloading

4. CONCLUTIONS

In the study, the rutting was simulated by an elasto-plastic FE model. The pavement structure was modeled by a 2D (axisymmetric) model. The behaviors of pavement material were modeled by Drucker-Prager model.

Research results show that rutting phenomena of asphalt concrete pavement can be simulated by FE Drucker-Prager method. Rutting was observed on the typical five layer asphalt concrete pavement. Usually, pavements in the spring, when the stiffness and strength of the structures are the lowest among the year, have most potential to contribute the rutting.

The uplift phenomena of the rutting were also observed in the study. Pavements in summer have the most potential to contribute the uplift along the wheel paths. That is due to the instability of the asphalt concrete in summer.

5. RRFERENCES

1) ANSYS User's Manual for revision 5.1(1993), Swanson Analysis Systems, Inc. P. O. box 65

2) Shen Junan, Finite element model of rutting phenomenon in road-pavement structure, report 97.2, Department of structure mechanics, Chalmers University of Technology, Gothenburg, Sweden.