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A Strain Modeling of Asphalt Layer on Composite Pavement using Finite Element Method

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Abstract

In this study, modeling for determining maximum horizontal tensile strain of asphalt depending on Young's Modulus variation of asphalt on composite pavement was performed. Structure analysis using Abaqus 6.10 was conducted also in the study. Parameters used for structure analysis were selected through literature review and five parameters of Young's Modulus were applied to asphalt layer. And, this research was to conduct regression analysis of maximum horizontal tensile strain of asphalt by Young's Modulus of asphalt. As a result, Young's Modulus of asphalt layer had a significant effect on maximum horizontal tensile strain.

Keywords: Finite Element method, Composite Pavement, Abaqus 6.10, Strain.

1. Introduction

Asphalt pavement and concrete pavement are commonly used for road pavement. Asphalt pavement which is flexible pavement distributes the load from surface layer to base layer and sub-base layer and has the advantages of less noise, high riding quality and short curing period. Concrete pavement which is rigid pavement supports the load mainly by bending strength of slab and has the advantage of less maintenance requirement that reduces the need for traffic blocking as well as is appropriate for heavy load by heavy vehicle. The composite pavement which combines the advantages of asphalt and concrete pavement to have a long-term pavement performance has been increasingly used recently.

This study is to identify the relationship between Young's Modulus of asphalt layer and maximum horizontal tensile strain of composite pavement using finite element method. Abaqus6.10 was used in conducting infinite analysis and Young's Modulus of each layer was obtained based on material properties from literature. As a result, it was developed regression model equation between maximum horizontal tensile strain and Young's modulus of asphalt layer.

2. Structure Analysis

Abaqus 6.10 was used in this study for finite element method and the parameters for modeling composite pavement were selected and modeling was carried out referring to actual road data of expressway.

2.1 Determination of Parameters and Modeling

The parameters were classified into fixed parameter and variable parameter for structure analysis. Fixed parameter was used for modeling pavement structure while variable parameter was used to identify the effect of stiffness of Young's modulus of asphalt layer which was intended by this study. Among fixed parameters are friction factor that indicates adhesion state of each layer, load and Poisson's ratio while variable parameters include Young's modulus of each layer.

Adhesion of each layer was determined as Table 1 referring to the study of Park. et al.(2011) and sliding formulation of contact surface was set as finite sliding and discretization method was surface to surface and the load was 4.1ton which was estimated considering the load of two tires 8.2ton in ESAL Factor[1].

Table 1. Adhensive Conditions of each Layer(Park, et al., 2011[1])

Classification	Modeling Method	Friction Factor
Asphalt-Concrete	Tangential	0.6
Concrete-Lean Concrete	Tangential	0.1
Lean concrete-Base	Tangential	0.45

Material property of elasticity is selected absolutely by Young's modulus and Poisson's ratio which could be determined by pre-determined values. Variable isotropic elasticity behavior on Abaqus program is defined by homogeneous solid continuum element.

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The range of Young’s modulus of each layer was determined referring to the cases of other studies as Table 2.

Table 2. Young's Modulus and Possion's Ratio of other Research

Author	Asphalt		Concrete	
	Young’s Modulus (Mpa)	Poisson’s Ratio	Young’s Modulus (Mpa)	Poisson’s Ratio
Garzon et al.(2010)[2]	1400	0.35	28000	0.15
Park et al.(2011)[1]	-	-	28000	0.18
You et al.(2004)[3]	-	-	19400	0.15
Park et al.(2009)[4]	4000	0.39	28000	0.18
Park et al.(2005)[5]	3000	-	-	-
Park et al.(2010)[6]	2918	0.4	-	-
Author	Lean Concrete		Subgrade	
	Young’s Modulus (Mpa)	Poisson’s Ratio	Young’s Modulus (Mpa)	Poisson’s Ratio
Park et al.(2011)[1]	15000	0.2	70	0.3
You et al.(2004)[3]	12400	0.4	-	-
Park et al.,(2009)[4]	-	-	50	0.30
Park et al.(2005)[5]	-	-	30~100	-
Park et al.(2010)[6]	-	-	186	0.4

As shown in Table 3, representative value of Young’s modulus was determined and five Young’s modulus of asphalt layer were determined based on representative value. When it comes to Concrete, Lean concrete and Base, only a single value was applied because of small young’s modulus and total 5 cases were obtained.

Table 3. Young's Modulus of This Research

Classification	Young’s Modulus(Unit: Mpa)
Asphalt	2000, 4000, 6000, 8000, 10000
Concrete	28000
Lean Concrete	15000
Subgrade	50

Modeling pf pavement structure was made referring to Jung-bu Expressway design as shown in Figure 1 and pavement layers was consisted with asphalt, concrete, lean concrete and base[7]. Road width was 3.6m and tire width was assumed 0.2m. The load applied was 4.1ton on road center and mesh was set as 1cm to monitor the change to asphalt and concrete layer in detail and 5cm for lean concrete and base layer.

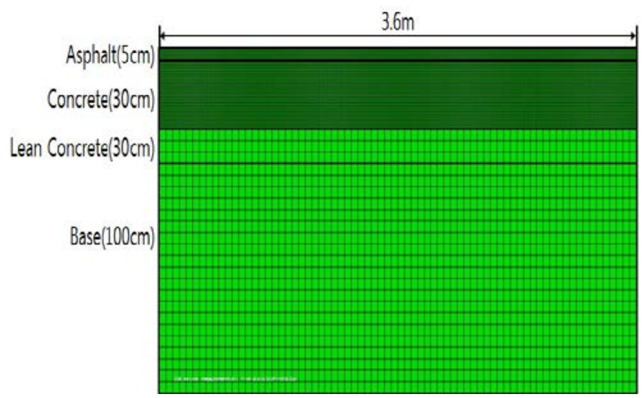

Figure 1. Modeling of Pavement Structure

2.2 Result of Structure Analysis

In order to identify the effect of strength of asphalt, modified Young’s modulus was simulated in Abacus 6.10. Weight was applied to simulated pavement and stress variation to asphalt, concrete, lean concrete and base is as follows. As shown in figure 2, we could find a stress variation by variation of Young’s modulus in Abacus. The higher the Young’s modulus the less the strain in asphalt layer and stress variation in sub-base appeared to be insignificant.

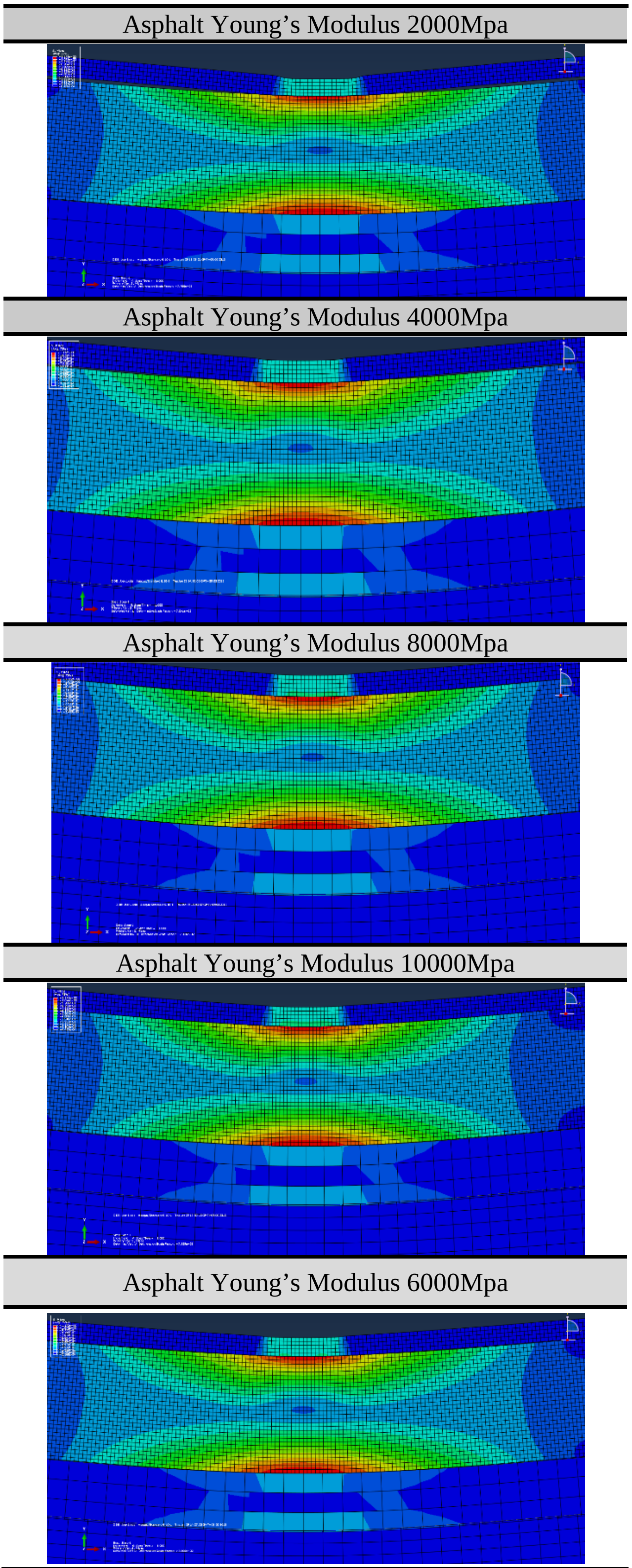

Figure 2. Stress Distribution by Asphalt Young's Modulus

3. Development of Regression Equation

A multiple regression analysis was conducted to identify the relationship between variation of Young’s modulus of each layer of composite pavement and strain of each layer. A regression equation was obtained and was statistically significant.

A multiple regression analysis was conducted using SPSS. Young’s modulus of asphalt was set as independent variable and maximum horizontal tensile strain of asphalt layer was set as dependent variable. Regression analysis result of asphalt layer is as Table 4 and regression equation was obtained as Equation (1) accordingly. VIF(Variance Influence Factor) of model equation was 1.00 which was smaller than reference value 10. Thus this equation has no multicollinearity. All equations must be typed or written neatly in black. They should be numbered consecutively throughout the text. Equation numbers should be enclosed in parentheses and flushed right. Equations should be referred to as Eq. (X) in the text where X is the equation number. In multiple-line equations, the number should be given on the last line.

Table 4. The Result of Regression Equation

Model	Non-Standardized Path Coefficients	
	B	Standard Error
a constant	7.870×10^{-5}	0.000
Asphalt	6.199×10^{-9}	0.000
Model	t	Significance Probability
a constant	46.461	0.000
Asphalt	-24.273	0.000
Standardized Path Coefficients		
Beta		
-0.910		
Multicollinearity Statistics		
A tolerance	VIF	
1.000	1.000	

$$S_a = 7.870 \times 10^{-5} + 6.199 \times 10^{-9} A_y$$
(1)

Where,

S_a: maximum horizontal tensile strain of asphalt layer

A_y: Young’s modulus of asphalt layer

Anova test result of this regression equation is as Table 5. Significance probability was 0.000 which was less than 0.05, indicating the existence of linear regression model.

Table 5. The result of Variance Analysis

Model	Sum of Squares	The Degree of Freedom	Mean Square
Regression Model	0.000	1	0.000
Residual	0.000	123	0.000
Sum	0.000	124	
F			Significance Probability
589.166			0.000

4. Conclusions

In this study, modeling of maximum horizontal tensile strain of asphalt layer depending on variation of Young's modulus of asphalt, concrete and lean concrete of composite pavement was conducted. Abaqus 6.10 which has been commonly used for structure analysis was used. Parameters to be used for structure analysis were selected through literature review and Young's modulus were applied to each layer. As a result of structure analysis, the higher the Young's modulus the greater the stress occurred.

And, regression analysis of maximum horizontal tensile strain was conducted by asphalt variation of Young's modulus. This research developed regression equation, and it had statistical significance.

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