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Study on Effect of Surface Course Thickness and Modulus of Elasticity on Performance of Flexible Pavement using a Software Tool

Srikanth M R
Civil Engineering,
Sri Jayachamarajendra College of Engineering
Mysore, India

***Abstract*— Transportation is a catalyst for development of any society. Road transportation is considered as veins and arteries of a nation, thus roads are constructed with variety of materials & specifications to mitigate the connectivity problems. Utmost care is taken in designing & developing the road ways, may it be in designing the network of roads or designing components of roads or in considering materials for construction. Hence it is very much essential to analyse a flexible pavement for its responses on application of vehicular loads. In the present study the pavement responses are analysed using Kenlayer and Michigan flexible pavement design software tools. An attempt has been made to analyse the effect and side effects of varying surface layer thickness and Modulus of elasticity with linear and nonlinear material in the granular base course on the performance of pavement.**

***Keywords*— Flexible Pavement; Pavement response; Pavement failure; Kenlayer; Linear; non-linear analysis; Multi-layer theory.**

I. INTRODUCTION

Flexible pavements are pavements constructed with bituminous and granular materials these pavement structure deflects/bends under traffic loading. Flexible pavements are layered systems that can be analyzed with Burmister's layer theory (Burmister, 1943). Flexible pavements structure may be composed of several layers of material with great thickness for transmitting load to the subgrade. It is composed of several layers of material with high quality material like bitumen at top and lower quality material at bottom where the stress concentration is low.

The primary objective of providing the pavement is to have a surface that have strength to bare the deteriorating effects of the vehicles and also the environmental effects over the service life of the pavement, and also serve the purpose of its construction e.g. provide acceptable level of the service for the users. A well designed, constructed and maintained pavement contributes to the economy of the country and also provides comfort for the users of these pavements.

It will be essential to predict the performance of pavements before construction since the estimate and cost before and after construction of pavements may vary, hence design can be finalized only after analyzing the pavement for its responses on load application. In order to view the responses and its impact on pavement with linear and nonlinear materials in base course the pavement is analysed using KENPAVE software tool.

The sensitivity of the changes in pavement parameters are observed from results by performing sensitivity analysis.

II. BACKGROUND AND OBJECTIVES OF STUDY

A. *Flexible Pavement Structure*

Flexible pavements structure may be composed of several layers of material with varying thickness for transmitting load to the subgrade. The materials used in various layers may vary i.e., high quality material like bitumen at top and lower quality material at bottom where the stress concentration is low. Fig – 1 represents the cross sectional view of flexible pavement with the critical locations for analyzing a pavement [IRC 37-2012]

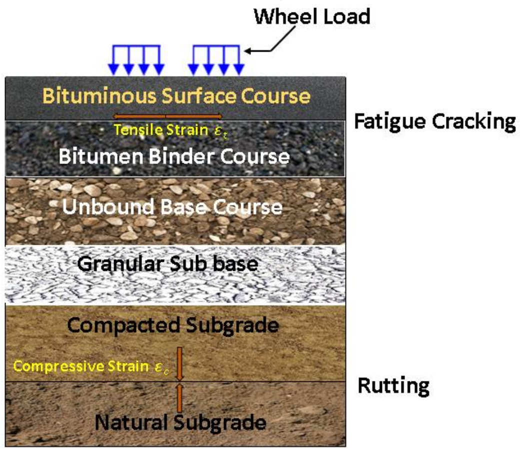


Fig -1: Typical cross section of pavement with critical locations.

B. *Software tool used*

Kenpave software was developed by Dr. Yang and Huang in the year 1993 [1] to analyze the pavements and its response to the load application; in 2004 Huang revised the software tool to predict the pavement performance under varied conditions and pavement parameters. It is a Microsoft windows based version that combines Kenlayer and Kenslab which are used in analysis of flexible and rigid pavements respectively.

KENLAYER program is applicable only for analyzing flexible pavements. In this software damage ratio can be calculated using the distress models. It is actually provides us the answers to the problems regarding elastic multilayer system when there is a circular load which is implied by using multiple wheels on viscoelastic layers. In Kenlayer the distress models that are used they evaluate fatigue cracking and show permanent deformation on rutting.

The most problem causing factors in designing the flexible pavements is strain which is caused by rutting and it is caused by the horizontal tensile strain at the bottom of the asphalt layer while the permanent deformation is caused by the compressive strain at the subgrade surface.

The inputs for the tool may be categorized into i) Wheel Load, ii) Layer thickness, iii) Material characteristics. By providing the input details we can obtain the output in terms of tensile and compressive strains which helps us in predicting the performance of a pavement.

C. *Sensitivity Analysis*

In a broader sense sensitivity analysis gives an overview of how the output from a model attributes to the input parameters. The prime aim of the analysis is to determine how the changes in output may affect the clarity of decisions made based on the results obtained from a model.

Sensitivity analysis is used to increase the confidence of user in the model and its predictions, by providing detailed understanding of how the model responds to the variables or changes in input. Sensitivity analysis is preferred in case of pavements so as to identify how sensitive is the output with reference to the input parameters and it is of severe importance for pavements because the estimate and cost and pre bidding of pavements can be done after this sensitivity analysis.

Objective of the present study is more concentrated on the influence of surface layer thickness (h1) and elastic modulus (E1) on horizontal tensile and vertical compressive micro strains which are the main cause for pavement failures.

III. Methodology Of The Present Study

Methodology involves the collection of data, method of analysis and results. Data for the present study are obtained from IRC 37-2012.

The data obtained are analyzed using the KENLAYER software tool and the micro strains are tabulated. Local sensitivity analysis is adopted for analyzing the data.

h1 is varied from its minimum value up to its maximum, keeping the rest of the input parameters constant and similarly E1 is varied treating remaining parameters constant. General input and output pavement parameters are as shown in TABLE.1

TABLE 1. Input parameters and output obtained

Input Parameters	
h1, h2 in mm	Thickness of surface course, base course
E1,E2 & E3 in MPa	Young's modulus of Surface , base and Subgrade
μ1, μ2 & μ3	Poisson ratio of Surface , base and Subgrade
Output Obtained	
ϵ_t & ϵ_c	Tensile and compressive micro strains

The material properties for the pavement structure is considered from IRC 37-2012 [2] as given in the TABLE. 2

TABLE 2. Material properties adopted for analysis

SAL	80 KN
Contact Pressure CP	550 KPa
Contact radius CR	107.70 mm
Axle spacing XW	1250 mm
Tire spacing YW	350 mm
BC, E1	1000 to 9000 MPa
Granular base, E2	Calculated from CBR (10%)
Subgrade, E3	Calculated from CBR (10%)
μ1	0.35
μ2	0.35
μ3	0.4
K1	12.4 to 55.2 MPa
K2	0.32 to 0.7
γ1	22.8 KN/m3
γ2	21.2 KN/m3
γ3	17.17 KN/m3

Also consider base course thickness h2=300mm, from CBR10% young's modulus of Subgrade is 77MPa and Base course is 200MPa respectively are calculated. K1 value is obtained from Allen's table, 1973.

This value can be obtained by varying K1 value suitably with respect to the micro strains obtained for linear analysis in kenlayer.

After analyzing the above data for linear and nonlinear base course material with varied surface thickness and modulus of elasticity using kenlayer, the tensile and compressive micro strains (εt & εc) are obtained and tabulated as in the TABLE. 3

Table 3: Output micro strains with varied h1

h1	Linear		Nonlinear	
	εt	**εc**	**εt**	**εc**
50	-3.94E-04	7.06E-04	-2.88E-04	6.48E-04
75	-4.27E-04	6.19E-04	-3.72E-04	5.90E-04
100	-3.94E-04	5.46E-04	-3.75E-04	5.36E-04
125	-3.47E-04	4.83E-04	-3.47E-04	4.83E-04
150	-3.01E-04	4.31E-04	-3.12E-04	4.36E-04
175	-2.61E-04	3.86E-04	-2.79E-04	3.94E-04
200	-2.27E-04	3.48E-04	-2.49E-04	3.57E-04
225	-1.99E-04	3.14E-04	-2.21E-04	3.24E-04

The tensile and compressive micro strains are obtained by varying the modulus of elasticity of surface course from 1000 to 10000 with a constant surface thickness of 300mm, base course of 450mm, from CBR10% young's modulus of Subgrade is 77MPa and Base course is 200MPa respectively are calculated. Table 4 consists of the tabulated micro strains with varied surface modulus of elasticity.

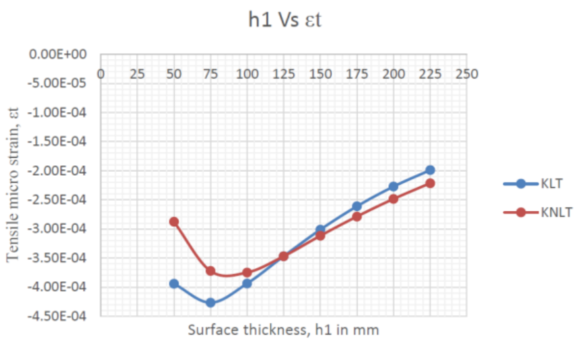
Table 4: Output micro strains with varied E1

E1	Linear		Nonlinear	
	εt	εc	εt	εc
1000	-1.21E-04	1.73E-04	-1.21E-04	1.73E-04
2000	-8.77E-05	1.43E-04	-9.03E-05	1.44E-04
3000	-6.98E-05	1.25E-04	-7.25E-05	1.27E-04
4000	-5.85E-05	1.13E-04	-6.10E-05	1.14E-04
5000	-5.06E-05	1.03E-04	-5.29E-05	1.04E-04
6000	-4.48E-05	9.58E-05	-4.68E-05	9.66E-05
7000	-4.03E-05	8.97E-05	-4.21E-05	9.02E-05
8000	-3.67E-05	8.46E-05	-3.83E-05	8.49E-05
9000	-3.38E-05	8.02E-05	-3.52E-05	8.02E-05
10000	-3.13E-05	7.63E-05	-3.26E-05	7.62E-05

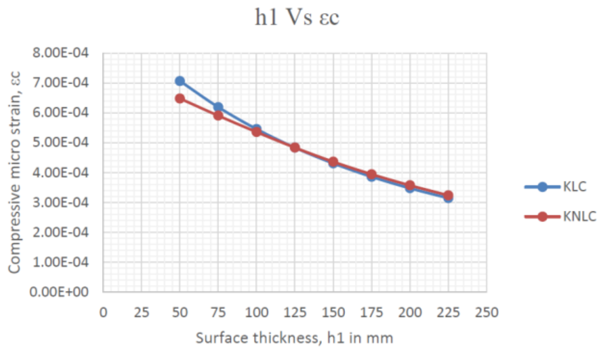
Plots for the above obtained values from table 3 and table 4 helps us in identifying the sensitivity of the pavement response with reference to the variation in thickness of surface course (h1) and Surface modulus (E1).

Plot 1 and Plot 2 represents tensile and compressive micro strains obtained with linear and nonlinear base course for varied h1, Plot 3 and plot 4 represents tensile and compressive micro strains obtained with linear and nonlinear base course for varied E1 respectively.

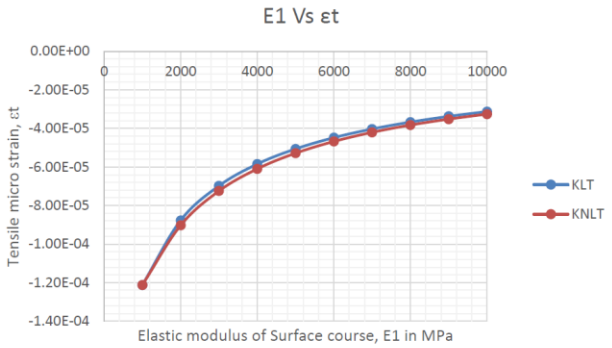
(KLT: Kenlayer linear tensile micro strain, KNLT: Kenlayer nonlinear tensile micro strain, KLC: Kenlayer linear compressive micro strain, KNLT: Kenlayer nonlinear compressive micro strain)



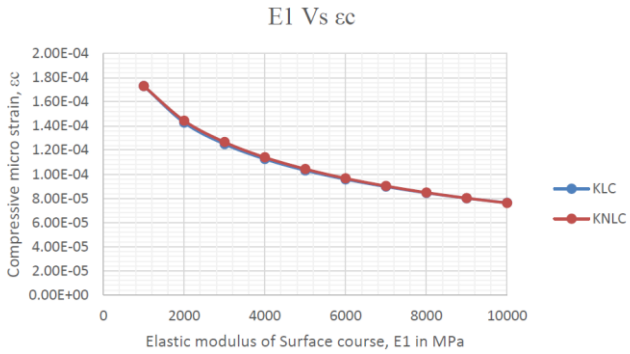
Plot 1: Comparison of linear and nonlinear tensile micro strains with varied h1



Plot 2: Comparison of linear and nonlinear compressive micro strains with varied h1



Plot 3: Comparison of linear and nonlinear tensile micro strains with varied E1



Plot 4: Comparison of linear and nonlinear compressive micro strains with varied E1

The plot 1 shows the relationship between tensile micro strains at the bottom of surface course obtained for linear and nonlinear base course versus varied h1, from the plot we can comment that with the increase in thickness; tensile strain increases till 80mm and then decreases i.e., 80mm thickness acts as critical thickness with the increase in thickness of surface course tensile strain decreases and by decreasing the thickness below 80mm the tensile strain decreases.

The plot 2 shows the relationship between compressive strains at the top of subgrade course versus varied h1, from the plot we can comment that with the increase in thickness compressive strain decreases linearly.

The plot 3 shows the relationship between tensile micro strains at the bottom of surface course obtained for linear and nonlinear base course versus varied E1, from the plot we can comment that the tensile micro strain decreases with the increase in E1 value, also the εt values obtained for both linear and nonlinear base course are almost same.

The plot 4 shows the relationship between compressive micro strains at the top of subgrade course obtained for linear and nonlinear base course versus varied E1, from the plot we can comment that the compressive micro strain also decreases with the increase in E1 value, also the εc values obtained for both linear and nonlinear base course are almost same.

IV. CONCLUSION

From the results obtained and the plots we arrive at few conclusions.

1) With increase in surface thickness the tensile and compressive microstrains decrease. While selecting Minimum surface thickness care must be taken.

2) Too thin flexible pavement may cause the total pavement structure deteriorate before the design period is reached.

3) Layer thickness plays an important role in determining the cost to construct new pavement.

4) With increase in modulus of the surface course, the tensile strain and compressive strain decreases. But increase in elastic modulus of surface results in brittlenesss of the surface hence care must be taken while selecting material for surface.

5) From this study, it is observed that the distresses on flexible pavement structures are considerably reduced by varying surface thickness and elastic modulus suitably, leading to the reduction in operating and maintenance cost which benefits the user to a greater extent.

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