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Parameter sensitive analysis of flexible pavement

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Abstract

This paper describes the usefulness of FEM for exploring the parameter sensitive analysis. Using 2D axisymmetric analysis, the critical performance parameters are examined by varying the thickness and material properties of different layers of flexible pavement. Hypothetical pavement sections are also analyzed with a view to check the sensitivity of horizontal axisymmetric extent and refinement of mesh. The developed computer program after validation is used to calculate the horizontal tensile strain at the bottom of the bituminous layer (BL) and the vertical compressive strain at the top of the subgrade. These computed strains are incorporated in the fatigue and rutting criteria recommended in Indian Road Congress (IRC: 37-2012) to estimate the pavement life for various hypothetical conditions. Tensile strain at the bottom of BL and compressive strain on top of the subgrade decreases with an increase in the thickness of BL, which results in increase of fatigue and rutting lives. An increase in thickness of the base layer and the increase in its elastic modulus reduces the damage due to rutting, while it has less effect on damage due to fatigue. Such type of analysis proves beneficial for designing a pavement, keeping equilibrium between fatigue and rutting lives.

Keywords: Flexible pavement; Parametric study; Finite element method

1. Introduction

The application of direct or indirect empirical approach in the current design procedures, results either in premature failure of the pavement or building up of uneconomical pavement sections. The relationship between design inputs and pavement failure is applied through experience, experimentation or a combination of both, which is limited to a certain set of environmental and material conditions [1,2]. A good pavement design is one that provides the expected performance with appropriate economic consideration, so, here the need arises to find an economical alternative in the form of analytical tool which can accommodate the details of the complex pavement system [3].

Application of such enhanced analytical tool can prove to be beneficial to predict the performance of pavement without actual construction or even by surpassing the expensive and time consuming laboratory or in situ tests, for various thicknesses and material properties of different component layers instead of relying on CBR values. In this connection, the application of the versatile finite element method (FEM) towards the design of flexible pavement holds a perfect assurance. As FEM is not constrained to two dimensional axisymmetric conditions, if required FEA can be easily used for two-dimensional plane stress/strain as well as more rigorous three dimensional finite element analysis for further extension of work [4]. Axisymmetric modeling predicts pavement behavior using a 2D mesh revolving around a symmetric axis by assuming identical stress states exist in every radial direction; therefore, loading is circular [5].

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Figs. 1 and 2 summarizes many of the finite element parameters and should be referenced throughout the paper. Fatigue and rutting are generally assumed as two independent modes of distresses which can be analytically evaluated [6]. If the horizontal tensile strain at the bottom of the bituminous layer (Point P as shown in Fig. 1) is excessive, cracking of the surface layer will occur, and the pavement distresses due to fatigue. If the vertical compressive strain on top of the subgrade (Point Q as shown in Fig. 1) is excessive, permanent deformation occurs on the surface in the pavement structure, and the pavement distresses due to rutting.

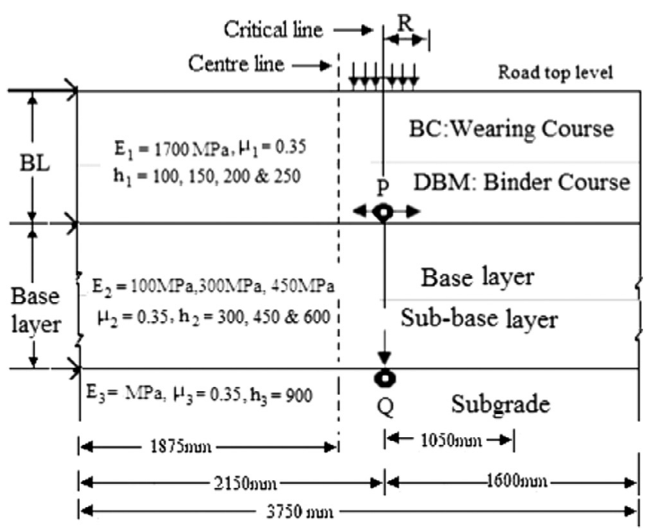

Fig. 1. Flexible pavement composition showing critical line and its material properties.

Present analysis is performed considering the tyre pavement interaction as an axisymmetric solid to mechanistically solve the layered pavement response to variation in material properties of different component layers, variation in thickness, considering any point on the critical line as a center[7]. The obtained results are then incorporated as input to estimate the pavement life in terms of rutting and fatigue lives in number of standard axles.

The major objective of the paper is to illustrate the usefulness of finite element analysis for examining the effect of variation in thickness and material properties of critical parameters, especially on rutting and fatigue lives, with a view to develop a design chart for particular condition which correlates with actual field condition. If such type of analysis is validated, it will prove to be beneficial to derive useful design charts for any combinations of thicknesses, material properties and field conditions without relying on theoretical/empirical design procedures. The hypothetical thicknesses and material properties which are considered for analysis are generally used in practice as per IRC: 37-2012 [8]; hence it is an attempt to correlate the present study with actual field conditions. An equilibrium between fatigue and rutting lives can be achieved from such type of analysis.

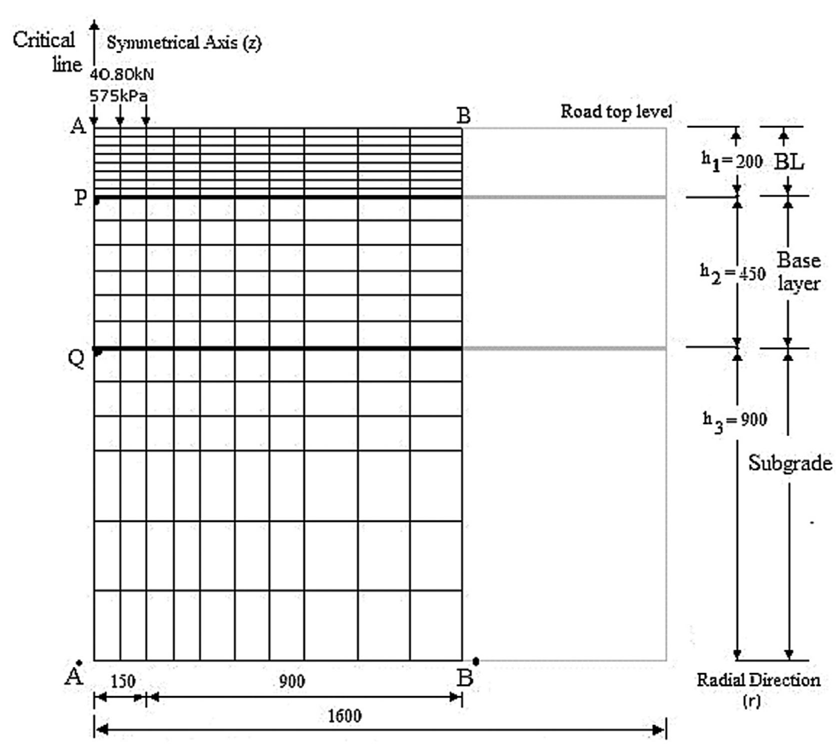

Fig. 2. Pavement section showing critical line and hypothetical idealization.