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Editors

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Relationship Between Traffic Density and Pavement Deflections

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Abstract

Traffic density is one of the most important parameters to consider in road construction. The presence of different components in road construction makes it essential to know the individual layer and inter-layer behaviors. One of the physical factors that plays a major role in these layers is their displacement, which varies depending on the type and engineering properties of these layers. Road damaging is inevitable as different deformations also trigger mismatching. Due to incompatibilities between layers, the number and content of repairs are also high than they should be, which increase maintenance costs. Therefore, it is important to conduct experimental and theoretical studies on this subject. Although the effect of traffic density on a single layer has been studied, there are not many studies investigating the co-movement of different layers. Therefore, the aim of this paper is to provide a holistic approach to this subject by compiling different studies.

Keywords: Displacements, Layers, Traffic density, Pavement

Introduction

According to the European Union Road Statistics, and European Commission, 50% of the employment in companies of all transport modes lies in activities related to roads [1]. Additionally, many research show that transportation and manufacturing activities are related to mathematical methodologies [2, 3, 4]. A key component in making design, construction, maintenance, and rehabilitation decisions for pavements, consists of evaluation like, assessing and measuring surface distresses namely, cracking and rutting, or structural properties say, deflection and strain and forecasting the effect of such conditions on future performances [5]. Condition forecasts are generated with performance models, which are mathematical expressions that relate condition data to a set of explanatory variables such as material properties, pavement design characteristics, traffic loading, environmental factors and the history of maintenance activities.

Some investigations related to the mentioned properties given below: Ibrahim et al. [6] studied the evaluation of flexible pavement deformation of roads over subgrade and concluded that increase in the thickness of flexible pavement increased the number of passes which reached the same value of rutting (value of failure) and led to decrease the displacement in subgrade and subbase layers. Muttashar et al. [7] stated that the subgrade layer characterizes as one of the important fundamentals in the pavement design. The subgrade layer responses impact the whole pavement behavior. Weak subgrade layers are difficulty task to the engineers always in case of the construction of such an embankment over weak foundations soil, especially for the evacuation of; slope stability, bearing capacity, lateral pressures, differential settlement and movements. Therefore, researchers attempted to improve weak subgrade soil by pile technique.

There are also some applications that are affected by soil quality and traffic loads. Thus, some investigators [8] studied the mechanism of the interaction of soil and an underground pipeline in order to determine the load arising on the pipeline from the pressure due to the backfill soil and automobile traffic.

In another investigation, general formulae for the stresses and displacements in layered elastic systems subjected to external loads are derived [9]. On the basis of these formulae the practical formulae for calculation of the stresses and displacements in layered elastic systems under the action of vertical, centripetal-horizontal, unidirectional-horizontal and rotational-horizontal loads distributed on circular areas and compressed by rigid circular plates are derived, and the corresponding computer programs are worked out. Some researchers also worked on effect of traffic load on behavior of flexible pavements [10]. Therefore, calculations of critical stresses and strains (tensile on the bottom of asphalt and cement stabilized layer, vertical compressive load on the top of the subgrade) were performed for selected pavements by the CIRCLY software.

Methodologies and Assessments

In the light of research in the literature recently, commonly used methodologies and assessments are described as follows. Traffic density is related to the individual spacing between successive vehicles (e.g. distance measured from front bumper of a vehicle to front bumper of the next vehicle) [11]. Therefore, traffic density is defined as

$$k = \frac{n}{l} \tag{1}$$

based on traffic density in vehicles per unit distance as k, number of vehicles occupying some length of roadway at some specified time as n, length of roadway as l. The roadway length, l, can be defined as

$$l = \sum_{i=1}^{n} s_i \tag{2}$$

where s_i is spacing of the i^{th} vehicle (e.g. the distance between vehicles i and $i-1$, measured from the front bumper to front bumper), and n is number of measured vehicle spacings [11]. By substituting into traffic density equation:

$$k = \frac{n}{\sum_{i=1}^{n} s_i} \tag{3}$$

or

$$k = \frac{1}{\bar{s}} \tag{4}$$

Accordingly, Rayleigh damping is one of the most popular phenomena about deflections and the traffic density proportion [12, 13]. By using this methodology, mass proportional damping can be combined with the stiffness proportional damping on the road. The description can be seen as

$$\big[C\big] = \alpha\big[M\big] + \beta\big[K\big] \tag{5}$$

where matrix $\big[$C$\big]$ is damping matrix, α is the Rayleigh coefficient for the mass proportional damping, and β is the Rayleigh coefficient for the stiffness proportional damping [13]. The relationship between α and β can be provided by the following equation considering the circular frequency of ω with one-degree of freedom:

$$\xi = \frac{1}{2}\left(\beta\omega + \frac{\alpha}{\omega}\right) \tag{6}$$

where ξ is the fraction of damping with the circular frequency of ω. A relationship exists between damping and the load frequency in a limited range of frequency. This frequency may be cased by the traffic density at a specific region containing specific construction materials in pavement.

Conclusions

Mathematical methods and models are used to overcome diverse phenomena of infrastructures in lots of engineering subjects and operations. Traffic load such as the amount of traffic density and other factors are important parameters in the design of roads. The presence of different components in the road structure causes changes in their behavior due to the effect of these parameters. Although individual component behaviors under different influences have been examined in the literature, there is no study on the entire road structure that has been found by considering all the active parameters. Such studies need to be increased.

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