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THE EFFECT OF TYPE OF TIRE HEAVY VEHICLES ON THE ROAD PAVEMENT PERFORMANCE

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ABSTRACT

Road pavements have been designed to support the traffic defined in the project which is composed by different type of vehicles with different axle configurations, load magnitudes, wheel types and tire inflation pressures. Heavy traffic overloads is the major source of pavement damage by causing fatigue, which leads to cracking and permanent deformation. Heavy vehicles do not cause equal damage because the differences in wheel loads, number and location of axles, types of suspensions and tires. Furthermore, the damage is specific to the pavement properties, operating conditions and environmental factors.

This proposal presents a research program to improve the knowledge on the effect of heavy traffic overloads in the pavement performance, aiming to characterize traffic severity and to improve the definition of traffic characteristics to be considered in pavement design.

STATE OF THE ART

The traditional approach to predict flexible pavement response to traffic loading, when using mechanistic pavement design methods, is usually made by multi-layer elastic theory. This method, which was originally developed by Burmister (1943) for a pavement with two layers composed of materials with linear elastic behaviour, has been successfully extended to a variety of pavements and is now considered the most popular approach to calculate pavement responses to the traffic loads.

The Burmister method, generalized to at least five layers, has also been incorporated into a large number of computer softwares for calculating stresses, strains, and pavement deflections. Although this approach involves several assumptions that may be questionable, the simplicity of the multi-layer analysis is usually thought to justify the uncertainty of the results (Al Qadi et al., 2004).

Due to the limitations of the multi-layer elastic theory, pavement engineers have paid considerable attention to the use of finite element techniques for simulating different pavement problems that could not be modeled using the traditional layered theory (Huang et al., 2001).

The repeated loads applied by heavy vehicles are one of the main causes of the differences between these two approaches for pavement modeling. The analysis of the interaction between pavement and vehicle is not easy because trucks do not damage the pavement in the same way in each pass, due to the vehicle heterogeneity, axle load, frequency and number of load applications, axle type, suspension type, wheel type, tire type, tire inflation pressure, speed (loading time) and traffic loading path. There is also the influence of the properties of pavement materials, operational condition of traffic and environmental factors (Leomar et al., 2006).

Accelerated pavement testing, defined as the controlled application of wheel loading to pavement structures for the purpose of simulating the effects of long-term in-service loading conditions in a compressed time period, is the best method to acquire the solution for these questions (Hugo and Martin, 2004). The in situ testing, where a trial section is constructed in service roads, can also be an important tool to evaluate the pavement performance when subjected to real traffic conditions.

OBJECTIVE

The objective of the research presented in this report is to propose a model for predicting the mechanical behavior and performance life of Portuguese road pavements subjected to various tire configurations.

This study will be supported by the monitoring of a trial section constructed and instrumented in a road subjected to real traffic. The trial section will represent the typical pavement structures for Portuguese road pavements. Furthermore, a numeric simulation, using 3D dynamic finite element modeling will be performed to simulate the effect of different tire configurations. The calibration of the finite element models will be performed using the results of the trial section and laboratory testing applying the visco-elasto-plastic model.

The testing program requires the developing of a visco-elasto-plastic model that consists of complex modulus, repetitive creep and relaxation testing for visco-elasto-plastic modeling of the asphalt mixtures.

The analysis of the information obtained in situ and in laboratory with this research will be used to accomplish a more reliable modeling of the traffic loads for pavement design, especially in terms of different tire configurations and to minimize the effect of overloads in the pavement performance.

PROGRESS TO DATE

The commercial software DIANA has been used for finite element (FE) modeling of the pavement structure and tire loads. In general, a finer mesh is recommended for more detailed results. Therefore, to reduce the number of elements for a 3D model without compromising the analysis, a symmetrical geometry about the x-axis (perpendicular to the wheel path) has been used. To minimize the effect of boundary conditions, the model dimensions have been used 5000 mm length by 2000 mm in width. A 3D element with 8 nodes has been used as the element type (Figure1). A relatively coarser mesh has been used at the boundaries. Fixed support has been used along the z-axis at the bottom of the sub-grade layer and the x-axis along the model boundary. The modeled pavement structure has been based on the dense-graded surfaced section. Material properties were determined through nondestructive deflection and seismic testing that consists of complex modulus, repetitive creep and relaxation testing as well as laboratory analysis.

Among the main variables that define the traffic load and overload the following has been defined: load levels for normal loads and overloads, frequency (speed for laboratory testing) and number of load applications, wheel type, tire type, tire inflation pressure, wander amplitude and traffic loading path.

FUTURE WORK

The trial sections, which will be built (by specialized contractors in road construction) for in situ testing, subjected to real traffic, and for laboratory testing in the accelerated loading testing facility, will be instrumented with sensors to measure displacements, both in the asphalt and granular layers, compressive stresses in the granular layers, temperature in the asphalt layers and moisture in the granular layers. These variables, together with the properties of the tested structures, will be used as input in the 3D finite element simulations to define the effect of overloads in the pavement performance.

During the trial sections layers construction, the thicknesses will be controlled by topography to have exact values as input in the finite element modeling.

The quality of the materials of the pavement layers of all trial sections (in situ and in laboratory) will be evaluated during this task to be used in the pavement modeling.

For the in situ testing, some vehicles will be characterized, especially their load level, footprint, inflation pressure and dimensions. To complement these variables and to develop a model to define traffic for pavement design, a 3D finite element modeling will be developed and calibrated with the in situ and laboratory test results.

REFERENCES

Burmister, D.M. 1943. The Theory of Stresses and Displacements in Layered Systems and Applications to the Design of Airport Runways. Highway Research Board, Vol. 23, pp. 126-144.

Al-Qadi, I., Mostafa E., Pyeong J.Y. 2004. In-Situ Validation of Mechanistic Pavement Finite Element Modeling. Proceeding of the Second International Conference on Accelerated Pavement Testing, Minneapolis, Minnesota, USA.

Huang, B., L.N. Mohammad, and M. Rasoulian. 2001. Three-Dimensional Numerical Simulation of Asphalt Pavement at Louisiana Accelerated Loading Facility. In Journal of the Transportation Research Board 1764, TRB, Washington, D.C., pp. 44-58.

Hugo, F., Martin, A.L.E. 2004. Significant Findings from Full-Scale Accelerated Pavement Testing - A Synthesis of Highway Practice, NCHRP Synthesis 325, Transportation Research Board, Washington, D.C.

Leomar, J.F.J., Pais, J.C., Pereira, P.A.A. 2006. Effect of Traffic Loading on Portuguese and Brazilian Pavement Performance. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

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