Semana de Engenharia 2010
Guimarães, 11 a 15 de Outubro

MODELING OF WAVE PROPAGATION IN SOILS USING THE FINITE ELEMENT METHOD

José Cunha[1,2], A. Gomes Correia[1] and Geert Degrande[2]
[1]C-TAC, Department of Civil Engineering, University of Minho, Portugal
[2] Department of Civil Engineering, Katholieke Universiteit Leuven, Belgium
E-mail: jpcunha@civil.uminho.pt

KEYWORDS
High speed trains, numerical models, soil behavior.

EXTENDED ABSTRACT

The development of tools and methodologies that can accurately predict the behavior of high-speed lines when subjected to traffic loads, along with the development and study of mitigation countermeasures, has become one of the main issues of research in the past few decades.

The work herein presented was done in the scope of the PhD thesis of the first author, entitled "*Modeling of ballasted railway tracks for high speed trains*". The objective of this thesis is to provide insight into the different approaches for modeling railway tracks for high speed trains. The prediction of the soil structure interaction in such tracks presents specific challenges. In order to overcome these challenges, several numerical models are available. Most of them present one great advantage despite of making assumptions that can also compromise the predictions. Because of this, it is pertinent to evaluate the different approaches available, to discuss the advantages and short comes of each, and also suggest further developments.

The purpose of this study was to understand if simple numerical elements can accurately simulate the soil response to a unitary point load at the surface. For this purpose, several axissymmetric models with different numerical meshes were created in order to simulate a defined soil (Cunha et al., 2010). These were loaded by a point load at the surface and the responses were observed at a frequency range of 0-150Hz at several points on the surface. In order to determine the accuracy of the soil response, Green Functions of the soil were calculated using the validated numerical tool EDT (Schevenels et al., 2009).

A case study was defined using an experimental trench in Lincent, Belgium, along the high-speed line Brussels-Cologne. In this trench experimental procedures were used in order to determine the soil dynamic characteristics (Pyl and Degrande 2001; Haegeman 2001). It was found that the soil has an upper layer 3m thick with shear wave velocity between 150m/s and 160m/s and a lower layer considered infinite with shear wave velocity between 250m/s and 280m/s.

The finite element models were created with the commercial software TNO Diana. A peak soil response at 2m from the load and at 22Hz calculated with EDT was used as reference for a calibration of the hysteretic soil damping in the FEM model. The soil response in the FEM models at the considered frequency spectrum is compared with the EDT Green's Functions in figure 1.

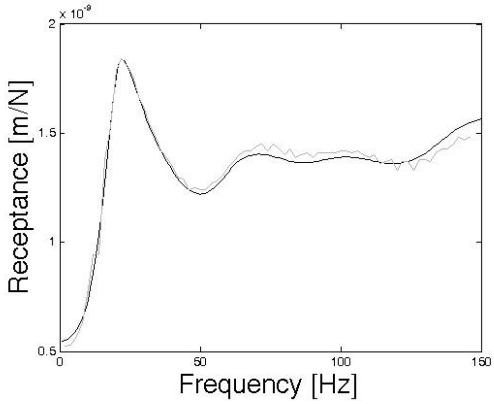

Figure 1 – Comparison between the responses of the soil computed using EDT (black) and Diana (gray) at the soil surface 2m from the load.

The calibrated FEM model simulates the response in an accurate manner since the response that is obtained practically overlaps the EDT calculation. Small discrepancies only appear at high frequencies, although the approximation is still very satisfactory. This is explained by the element size of the FEM mesh. Since a minimum number of 6 to 8 elements per wavelength are advisable to properly simulate wave propagation in FEM, a higher element size would mainly affect the response at low wavelengths (i.e. high frequencies). However, in the scope of this work, the results were considered satisfactory.

Following this FEM model calibration, it was decided to progressively simplify the FEM mesh and to study how this affects the model results. The first property that was studied was the depth of the mesh. In the calibrated FEM model the depth was 50m. Then the study consisted in decreasing this value and comparing the new response with the original response. These comparisons are shown in figure 2.

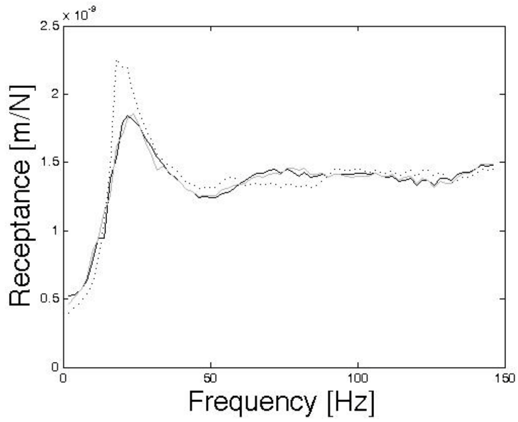

Figure 2 – Comparison of the soil response of the FEM models with 50m (black), 10m (gray) and 5m (dotted) of mesh depth, at the soil surface 2m from the load.

The reduction from 50m to 10m of depth is accompanied with some changes in the model response observable at low frequencies. This is explained by the fact that the long wavelengths of the low frequencies cannot be accurately represented with the smaller mesh size. Even though, the lack of accuracy is not so pronounced, considering that the mesh was reduced to 1/5 of the original size. The reduction to only 5m of depth produces higher response inaccuracies, mainly the peak response. However, the accuracy response at most of the frequency spectrum is still appreciable.

The next simplification involved the mesh length. The calibrated model had a length of 75m. Similarly to what was done before for the mesh depth, the length was consecutively reduced. The comparison of the model receptance for the different lengths is shown in figure 3.

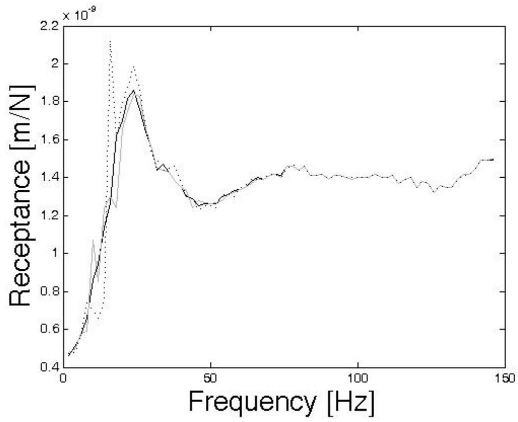

Figure 3 – Comparison of the soil response of the FEM models with 75m (black), 45m (gray) and 35m (dotted) of mesh length, at the soil surface 2m from the load.

As expected, the changes affected mainly the low frequencies. For frequencies higher than 50Hz there are basically no noticeable differences in the response of the FEM models. Although the response of the model with 35m of length shows great inaccuracies, the reduction of the length from 75m to 45m does not severely affect the results.

Thus, this study shows that not only the soil elastic response can be simulated with simple FEM models but also that these models can provide a good indication on the ideal FEM mesh size of models more computationally expensive (i.e. 3D models). It was shown that the size of the mesh affects mainly the response at low frequencies. Equally, in order to obtain very good simulations at high frequencies, the size of the elements should be optimized.

REFERENCES

Cunha, J.; G. Degrande; and A. Gomes Correia. 2010. "Modeling of wave propagation in soils using the Finite Element Method" (in Portuguese) , *12º Congresso Nacional de Geotecnia*, Guimarães, Portugal.

Haegeman, W. 2001. "In situ tests Retie-Waremme-Lincent." Report RUG IV.1.16.3, Soil Mechanics Laboratory, Ghent University.

Pyl, L., and G. Degrande. 2001. "Determination of the dynamic soil characteristics with the SASW method at a site in Lincent." Report BWM-2001-02, Department of Civil Engineering, K.U.Leuven.

Schevenels, M., S. François, and G. Degrande. 2009. "EDT: An ElastoDynamics Toolbox for MATLAB". *Computers & geosciences*, 35(8), 1752-1754.

AKNOWLEDGEMENT

The authors acknowledge the financial support for this research from the Foundation for Science and Technology (FCT) given through the individual doctoral grant SFRH / BD / 46850 / 2008

AUTHORS BIOGRAPHIES

JOSÉ CUNHA was born in Braga, Portugal in 1983. In 2006, he obtained his degree in Civil Engineering (5-years graduation) at University of Minho, Portugal. His e-mail address is: `jpcunha@civil.uminho.pt`

ANTÓNIO GOMES CORREIA is Professor at University of Minho and Director of Centre for Territory, Environment and Construction. He is supervisor of the PhD thesis. E-mail address: `agc@civil.uminho.pt`

GEERT DEGRANDE is Professor at the Katholieke Universiteit Leuven, Belgium and is the head of the Civil Engineering Department. He is co-supervisor of the PhD thesis. E-mail address: `Geert.Degrande@bwk.kuleuven.ac.be`