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DESIGN AND PERFORMANCE OF A STIFF WAVE BARRIER IN THE SOIL USING 2.5D AND 3D FE–BE MODELS

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Railway induced vibrations are an important source of annoyance in the built environment, causing malfunctioning of sensitive equipment and nuisance to people. Within the frame of the EU FP7 project RIVAS [1], mitigation measures on the transmission path between source (railway track) and receiver (surrounding buildings) are investigated. This paper reports on the design of a stiff wave barrier as an efficient vibration reduction measure using state–of–the–art numerical techniques.

Numerical simulations are performed using a coupled finite element – boundary element (FE–BE) methodology accounting for dynamic soil–structure interaction (SSI). In a first approach, the geometry of the barrier is assumed to be invariant in the longitudinal direction, allowing for computationally efficient two–and–a–half–dimensional (2.5D) calculations in the wavenumber domain. It is demonstrated that the barrier hinders the transmission of plane waves in the soil with a longitudinal wavelength smaller than its bending wavelength. This leads to a critical frequency from which this mitigation measure starts to be effective, depending on the stiffness contrast between the surrounding soil and the barrier. The existence of a critical angle delimiting an area where vibration levels are reduced for the case of harmonic excitation on the rail is also demonstrated [2].

The assumption of longitudinal invariance is in practice not fulfilled, however, as the length of the barrier is limited and comparable to the wavelength in the soil in the frequency range of interest [3]. Rigorously accounting for the finite length requires the solution of a full three–dimensional (3D) dynamic SSI problem, which is computationally very demanding. An innovative spatial windowing technique that allows accounting for the finite length of the barrier while still maintaining the computational efficiency of a 2.5D formulation is therefore employed [4]. This technique accounts for the diffraction occurring at the barrier's edges, but not for its modal behaviour resulting from reflections of waves at its boundaries. Complementary full 3D computations are subsequently performed as well; these calculations rely on a fast BE method based on hierarchical matrices ($\mathscr{H}$–matrices) [5] and an appropriate FE–$\mathscr{H}$-BE coupling algorithm [6].

Findings from the numerical studies are verified by means of a field test at El Realengo (Spain), where a continuous barrier has been created close to an existing railway track using overlapping jet grout columns. Geophysical tests have been carried out prior to the installation of these columns for the determination of the dynamic soil characteristics. Furthermore, results of a track receptance test have been employed for an updating of the track parameters. Measurements of track – free field transfer functions and train passages before and after installation of the barrier are compared to numerical simulations in order to assess the vibration reduction efficiency of the proposed mitigation measure.

REFERENCES

[1] http://www.rivas-project.eu, 2011.

[2] P. Coulier, S. François, G. Degrande, and G. Lombaert. Subgrade stiffening next to the track as a wave impeding barrier for railway induced vibrations. *Soil Dynamics and Earthquake Engineering*, 48:119–131, 2013.

[3] P.K. Banerjee, S. Ahmad, and K. Chen. Advanced application of BEM to wave barriers in multi-layered three-dimensional soil media. *Earthquake Engineering and Structural Dynamics*, 16: 1041–1060, 1988.

[4] M. Villot, C. Guigou, and L. Gagliardini. Predicting the acoustical radiation of finite size multi-layered structures by applying spatial windowing on infinite structures. *Journal of Sound and Vibration*, 245(3):433–455, 2001.

[5] M. Bebendorf. *Hierarchical Matrices: A Means to Efficiently Solve Elliptic Boundary Value Problems.* Springer Publishing Company, 1st edition, 2008.

[6] P. Coulier, S. François, G. Lombaert, and G. Degrande. Coupled finite element – hierarchical boundary element methods for dynamic soil–structure interaction in the frequency domain. *International Journal for Numerical Methods in Engineering*, DOI: 10.1002/nme.4597.