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NUMERICAL MODELLING OF GROUND-BORNE VIBRATION AND RE-RADIATED NOISE IN BUILDINGS DUE TO UNDERGROUND RAILWAYS

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ABSTRACT

This paper presents a numerical model for the prediction of ground-borne vibrations and re-radiated noise in buildings due to underground railway traffic. The three-dimensional deterministic coupled numerical model covers the whole vibration chain starting with vibration generation by a moving metro train and ending with the re-radiated noise in the building's rooms. The problem can be classified into the following subproblems: the dynamic vehicle-track-tunnel-soil interaction problem, the dynamic soil-structure interaction problem, and finally the prediction of primary re-radiated noise in the structures.

The three-dimensional dynamic tunnel-soil interaction problem is solved with a subdomain formulation, using a finite element method for the tunnel and boundary element method for the soil [1,2]. The periodicity of the tunnel and the soil in the longitudinal direction is exploited using the Floquet transformation, limiting the discretization effort to a single bounded reference cell [1,2]. The track is efficiently incorporated in the model using the Craig-Bampton substructuring [2]. The track-tunnel-soil interaction problem is solved in the frequency-wavenumber domain and the wave field radiated into the soil is computed. A general analytical formulation is used to compute the response of three-dimensional invariant or periodic media that are excited by moving loads [3,4].

A weak coupling between the incident wave field and the structure is assumed if the distance between the source and the receiver is much larger than the dominant wavelengths in the soil. The free field displacements are applied as an excitation on the coupled soil-structure system and vibrations in the building are calculated using the coupled finite element-boundary element method [5]. Subsequently, the computed structural displacements are used as a vibration input for the computation of ground-borne noise. The noise radiation in the building enclosures is computed using three dimensional spectral finite element method [5].

To demonstrate the efficiency of the approach, an invariant concrete tunnel embedded in a layered half space is modelled using the coupled periodic finite element-boundary element approach. The response in the free field due to a moving train is predicted in the frequency range 1-150 Hz, and subsequently the re-radiated noise in a multi-story portal frame office building is estimated. The proposed methodology is used to investigate the efficiency of various vibration countermeasures such as a floating slab track in the tunnel, base-isolation of the building and a box-within-box arrangement in a room. Advantages and limitations of various countermeasures on the source as well the receiver side are discussed. It has been shown that the track isolation is the most effective measure to counter the vibrations and re-radiated noise in buildings close to metro lines.

This papers demonstrates the use of the state-of-the art three-dimensional numerical model to study the vibration isolation efficiency of various vibration countermeasures.

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