ICCES, 2025, vol.33, no.3

Tech Science Press

DOI: 10.32604/icces.2025.012221

PROCEEDINGS

SEM-FEM Co-Simulation via Substructure Coordination for Train-Track-Tunnel-Soil System Dynamics

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ABSTRACT

To address the issue of computational inefficiency arising from the large dimensionality of dynamic matrices in the train-track-tunnel-soil (TTTS) dynamic model, this study integrates the spectral element method (SEM) and finite element method (FEM) to develop a highly efficient dynamic model for the TTTS system. The model leverages the distinct vibration characteristics of the near- and far- field regions of TTTS system, employing different modelling approaches: the FEM, known for its superior shape adaptability and precise high-frequency dynamic response computation, is applied to the tunnel and near-field soil; the SEM, recognized for its rapid convergence and suitability for low-frequency dynamic response, is utilized for the far-field soil. Additionally, this paper introduces a substructure coordination technique combining the FEM and SEM, based on the elimination method. This technique establishes the near-field-far-field soil interaction matrices through the principle of displacement field equivalence at the boundaries of the near-field and far-field, thereby maximizing the advantages of both methods. Subsequently, using the aforementioned model, the dynamic response of the tunnel-soil system induced by train is analyzed. The result indicated that the maximum ground vibration does not occur directly above the tunnel but rather at a distance of 10-30 meters from the track central line. Furthermore, as the tunnel depth increases, the ground vibration becomes more uniform, with a reduction in peak vibration, particularly affecting the surface vibration within 0-15 meters from the track central line.

KEYWORDS

Train-track tunnel-soil coupled dynamics; spectral element method; substructure coordination technique; ground vibration distribution

Funding Statement: This work was supported by The Science and Technology Research and Development Program Project of China National Railway Group Co., LTD (L2022G007); National Natural Science Foundation of Hunan Province (2022JJ20071); National Natural Science Foundation of China (52378468; 52008404; U1934217; U1734208); Science and Technology Research and Development Program Project of China Railway Group Limited (2022-Major-04; Origin 2025-Major-03); China Scholarship Council (CSC) [202306370283]; National Key R&D Program 'Transportation Infrastructure' 'Reveal the list and take command' project (2022YFB2603301); Young Elite Scientists Sponsorship Program by CAST (2020-2022QNRC002).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.