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Fracture Fatigue and Wear

Elastic wave propagation characteristics of a periodic track structure in rail transit

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Peicheng Li[1,2], Zhiping Zeng[1], Magd Abdel Wahab[2]
[1]School of Civil Engineering, Central South University, China
[2]Faculty of Engineering and Architecture, Ghent University, Belgium

Introduction

Rails and fasteners form a periodic track structure; guided elastic waves can propagate over long distances but are strongly affected by periodic constraints.

Reliable dispersion-curve analysis is a prerequisite for rail nondestructive evaluation, vibration mitigation, and bandgap design.

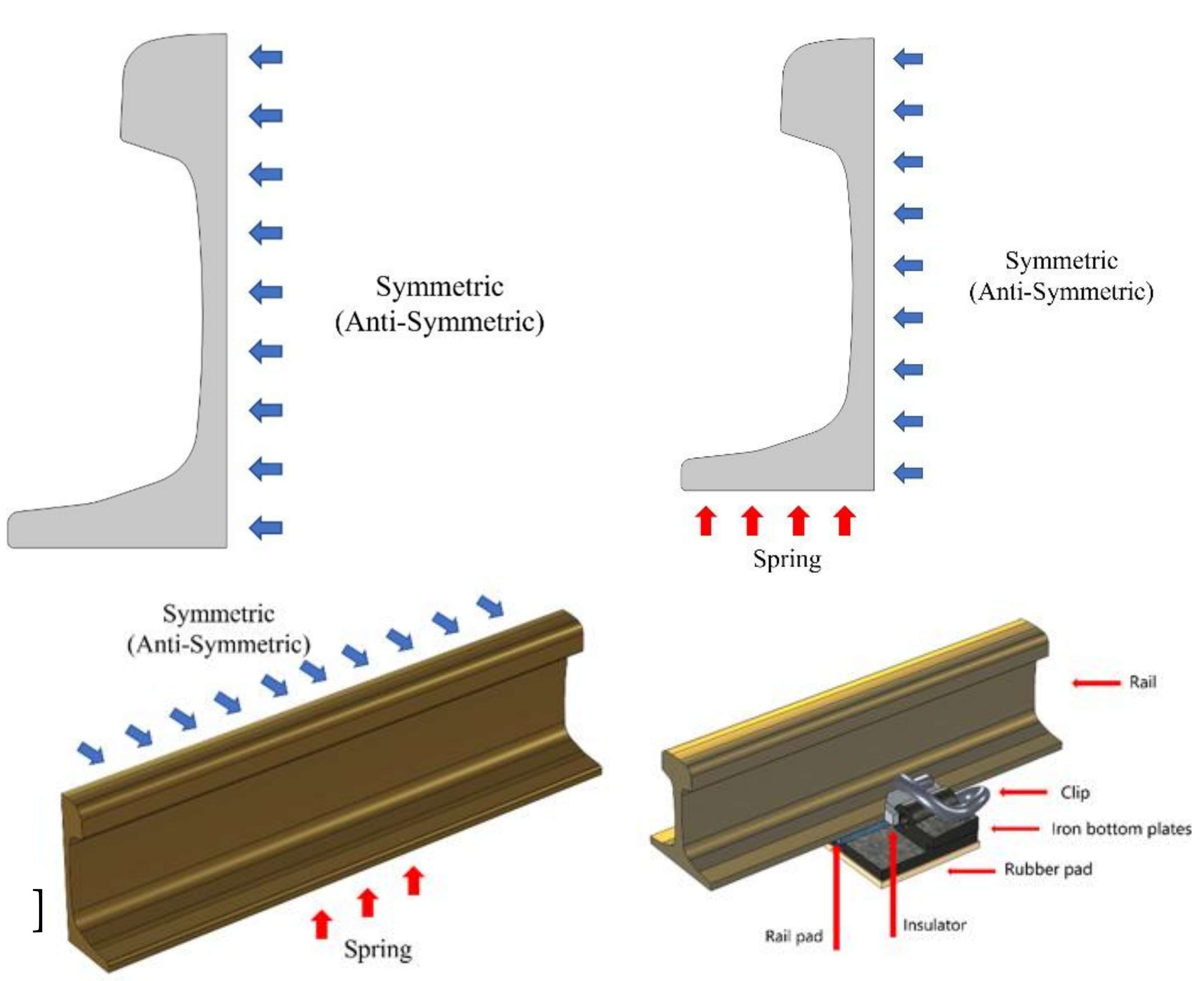
Challenge: simplified spring-boundary models cannot fully capture local mass-stiffness coupling from detailed fastener components.

Aim: compare four modeling strategies and propose a reduced fastener model validated by field impact tests.

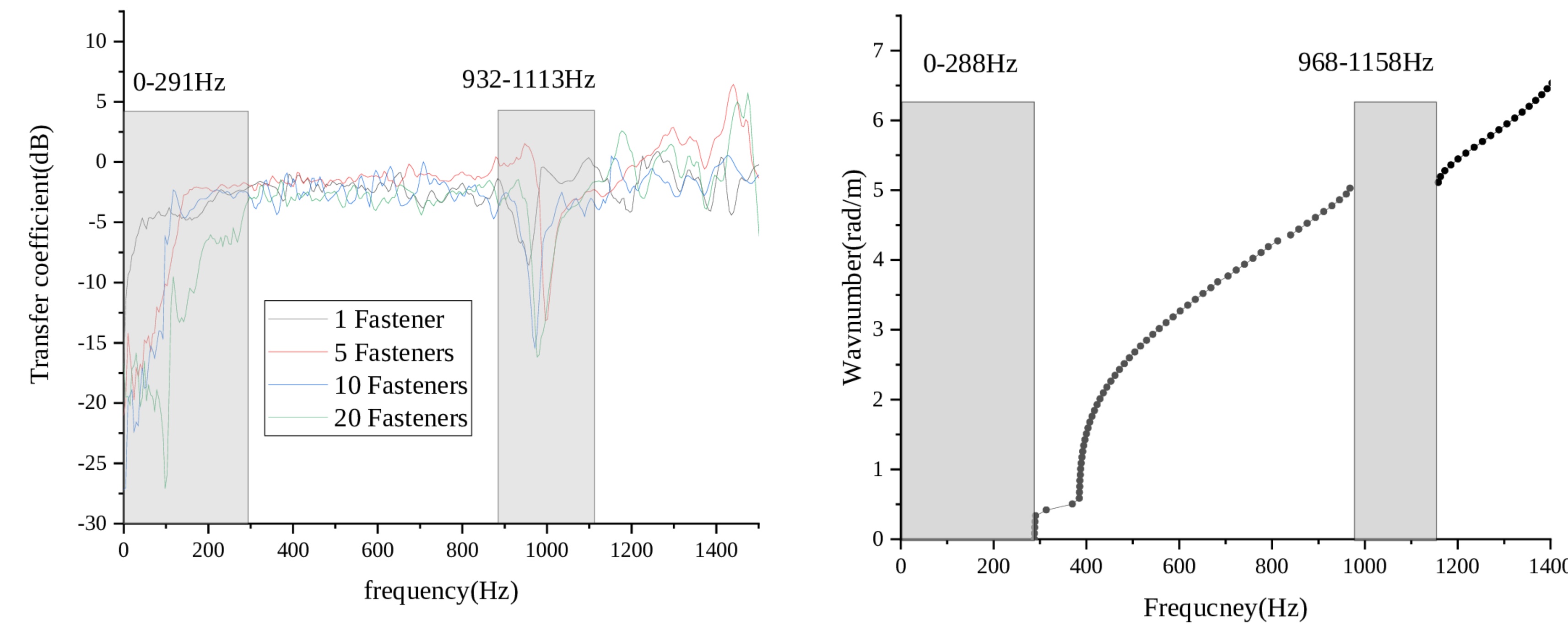
Methods

- Free rail and Continuous spring rail models established by semi-analytical finite element (SAFE) method
- Discrete spring rail model established by finite element and Bloch boundary conditions

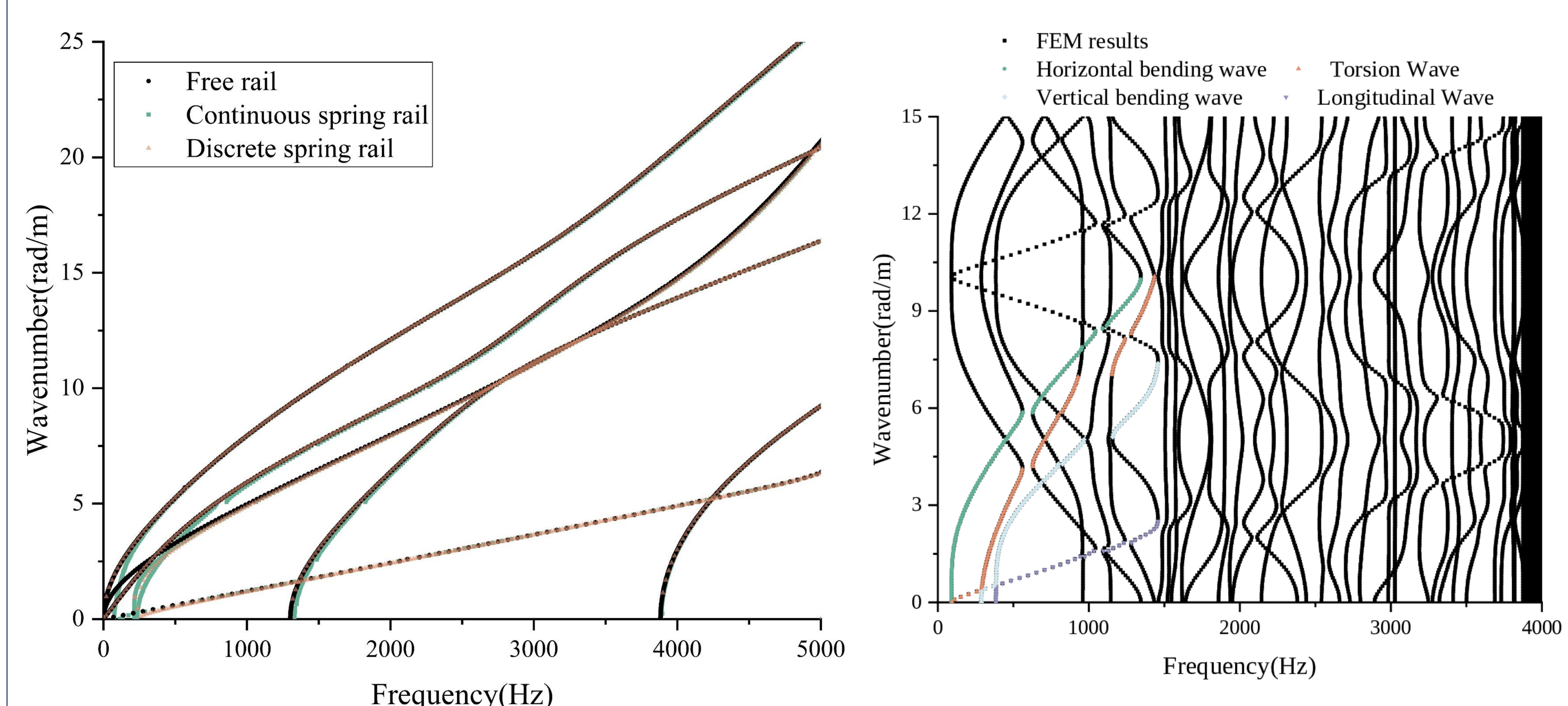
Graphics



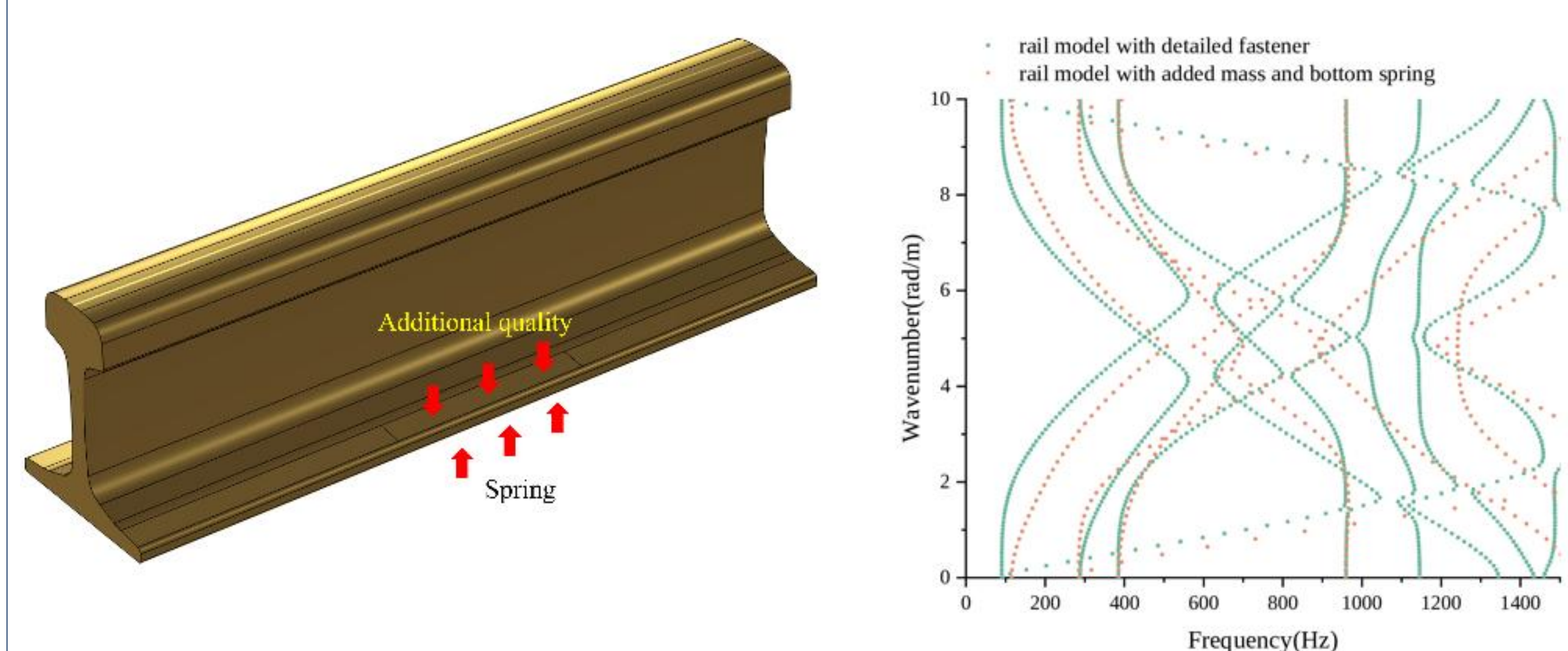
Numerical model



Experimental verification



Dispersion curve



Simplified model

Conclusions

Fasteners significantly influence low-frequency guided wave propagation in rails.

Spring-only boundary conditions show limited influence, while discrete supports create bandgaps.

Detailed fastener modeling reveals wavelength reduction, additional bandgaps and local-mode hybridization.

The proposed equivalent mass-spring fastener model offers a practical balance between accuracy and efficiency.

Future work will consider nonlinear fastener stiffness and hyperelastic rubber behavior