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Transfer relation between subgrade frost heave and slab track deformation and vehicle dynamic response in seasonally frozen ground

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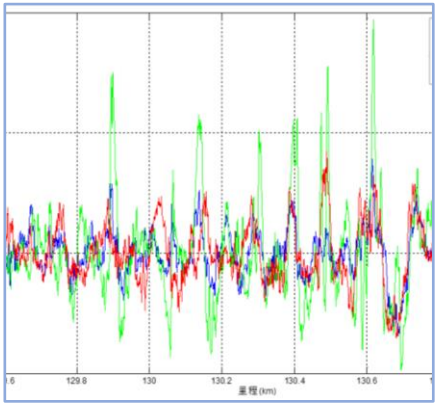
1. Research background

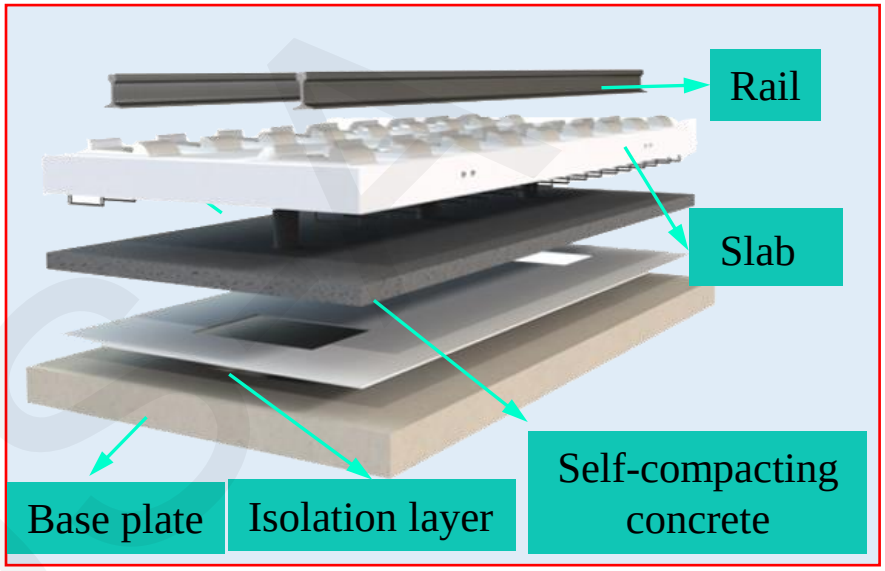
Negative influence



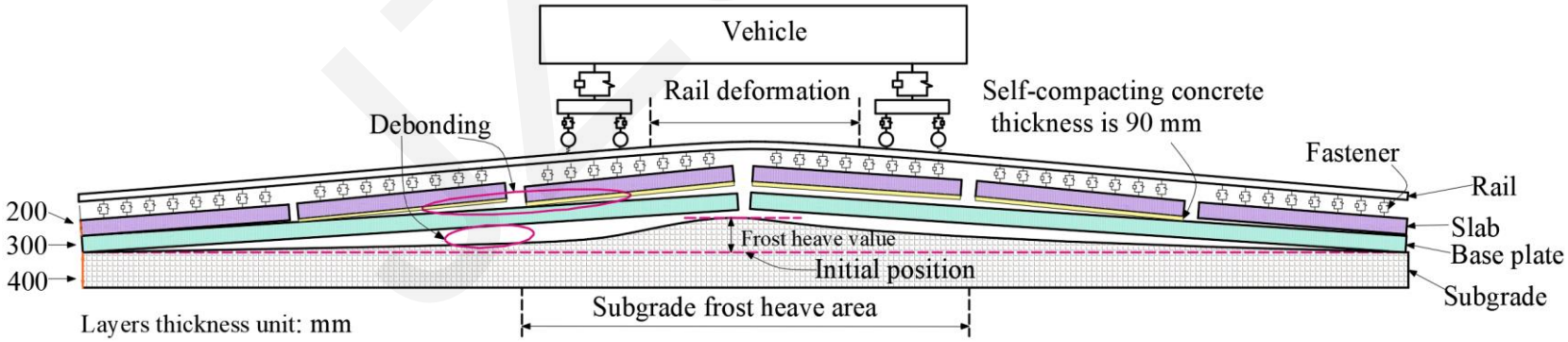
Interlayer debonding between the track slab and SCC

Track irregularity increases

2. Research subjects

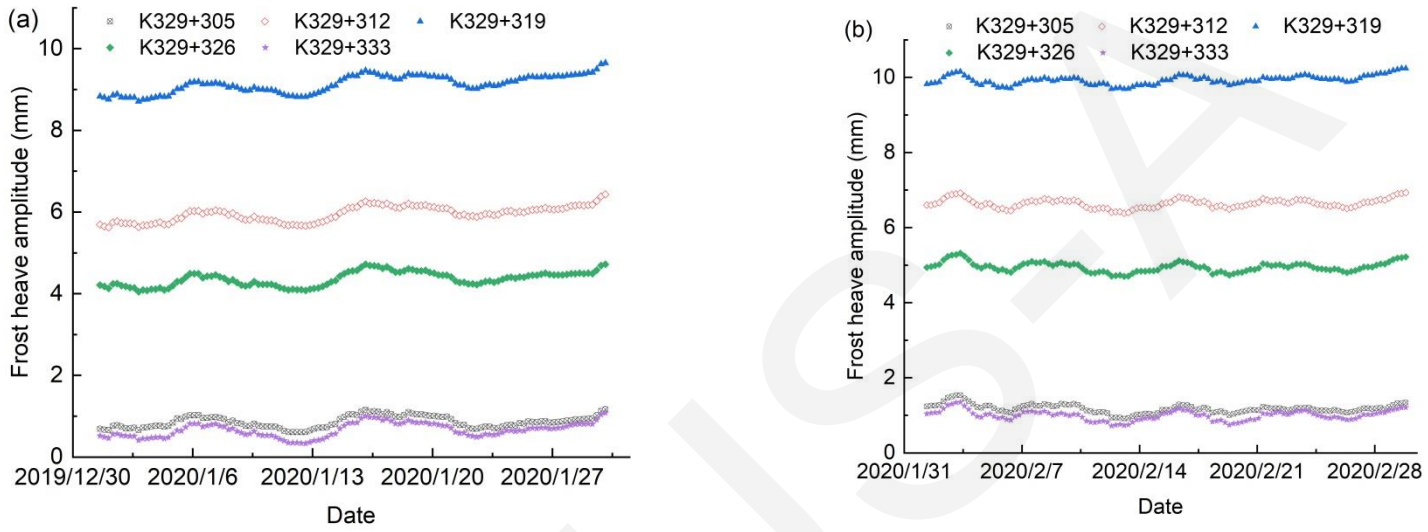


Structural composition of CRTS III prefabricated slab track

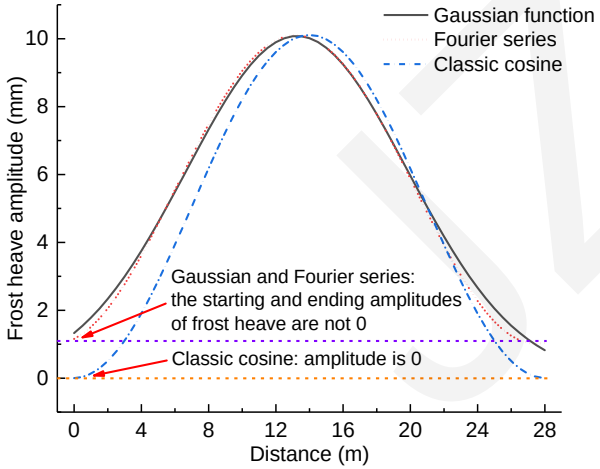


Schematic diagram of subgrade frost heave deformation

3. Research method



Subgrade frost heave amplitude monitored on field



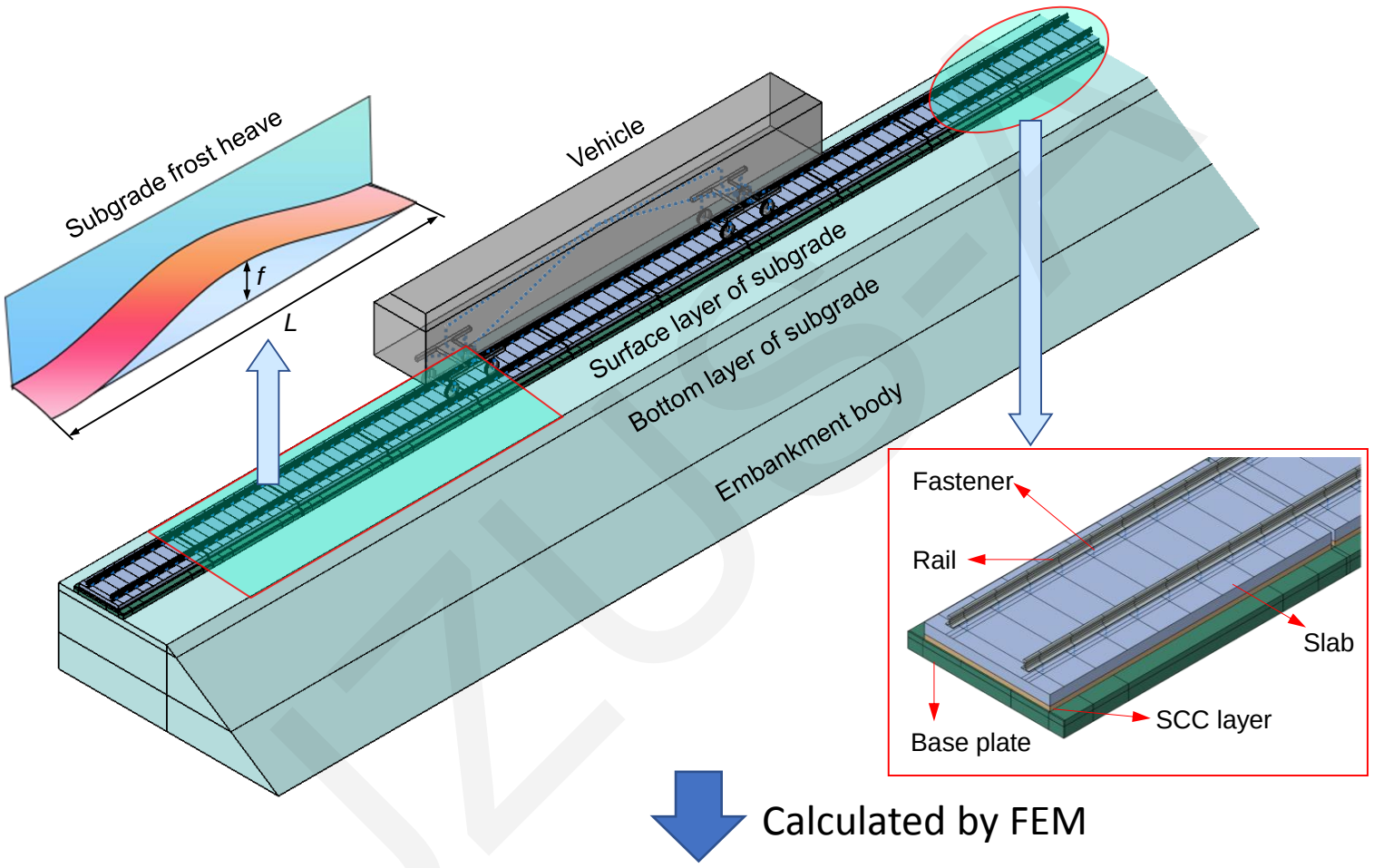
Subgrade frost heave curves

Fourier series curve

The analytical field equation of frost heave excitation was as follows:

$$f(x)=5.559-4.406\cos(0.2196x)+1.125\sin(0.2196x).$$

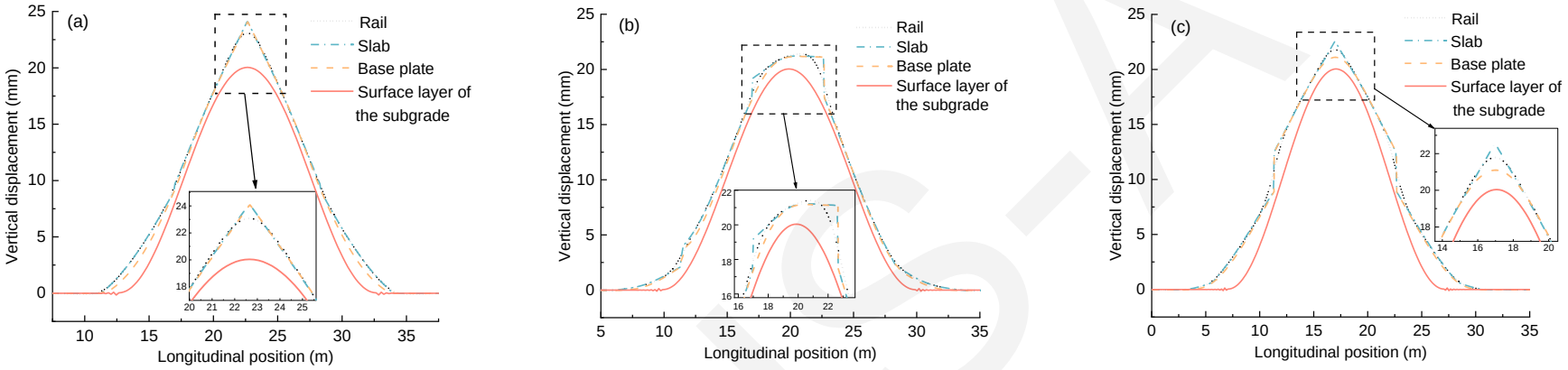
4. Research method



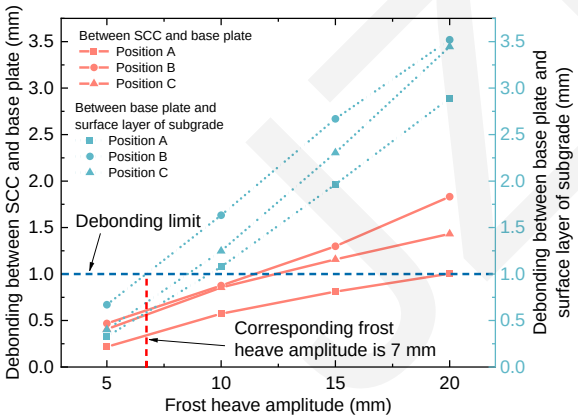
Calculated by FEM

- vertical displacements of track structure
- vertical wheel–rail force
- Debonding between track structure layers
- vertical acceleration of the vehicle body

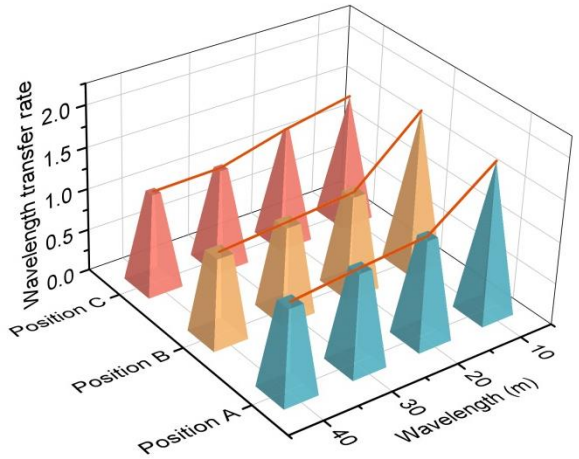
5. Results of static model calculation



Transfer of subgrade–base plate–slab–rail deformation at different frost heave positions: (a) position A; (b) position B; (c) position C

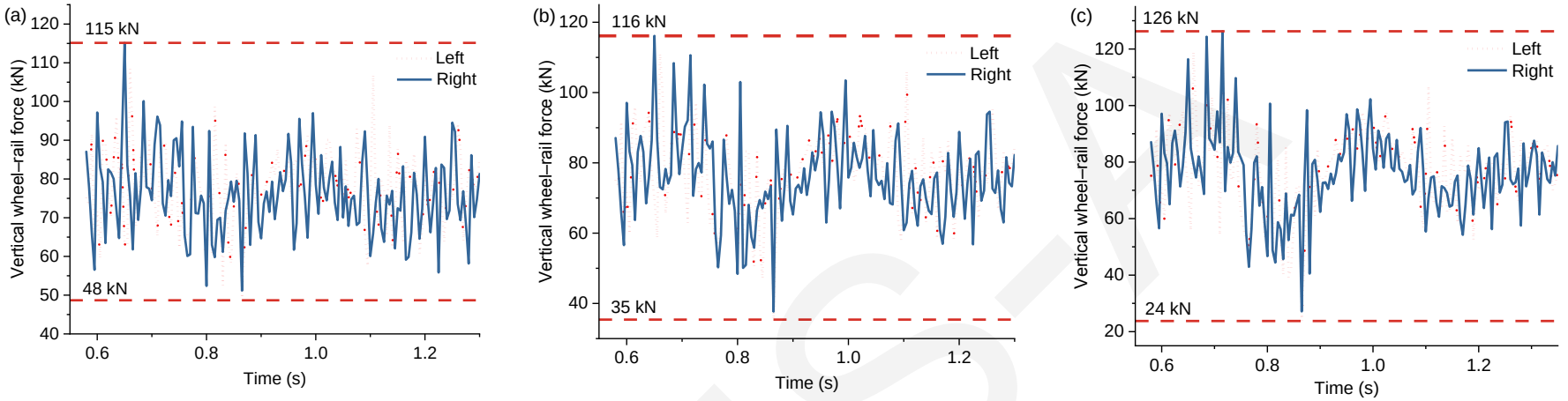


Debonding between track structure layers

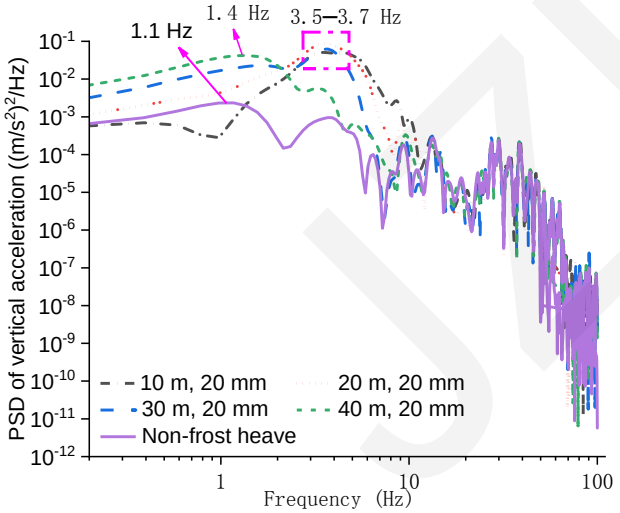


Rail–subgrade wavelength transfer rate

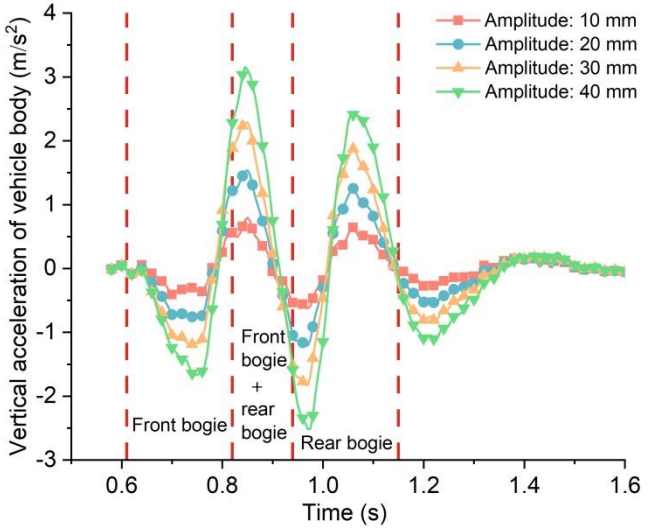
6. Dynamic model calculation results



Time-history curves of vertical wheel–rail force with different frost heave amplitudes: (a) amplitude of 10 mm; (b) amplitude of 20 mm; (c) amplitude of 30 mm



PSD curves of vertical acceleration at different frost heave wavelengths



Time-history curves of vertical acceleration with different frost heave amplitudes

7. Conclusions

- The position of frost heave significantly affects the transfer of deformation to a slab track. The largest deformation of the track slab, with the amplitude transfer ratio reaching 20%, was recorded when the frost heave occurred near the joint of the base plate.

- In the wavelength range of 10–30 m, the main frequency of the acceleration spectral density was concentrated between 3.5 and 3.7 Hz, with larger frost heave wavelengths producing smaller superposition on the vertical acceleration of the vehicle.

- The peak value of the wheel–rail force increases as the frost heave amplitude increases from 10 to 40 mm, and the maximum increase (16.5%) is recorded at a frost heave wavelength of 20 m.

- In frost heave areas with wavelengths less than 20 m and amplitudes greater than 20 mm, the running speed of trains should be limited and daily maintenance should be strengthened.