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Fast prediction of vibration source intensity induced by metro trains moving on regular and floating slab tracks

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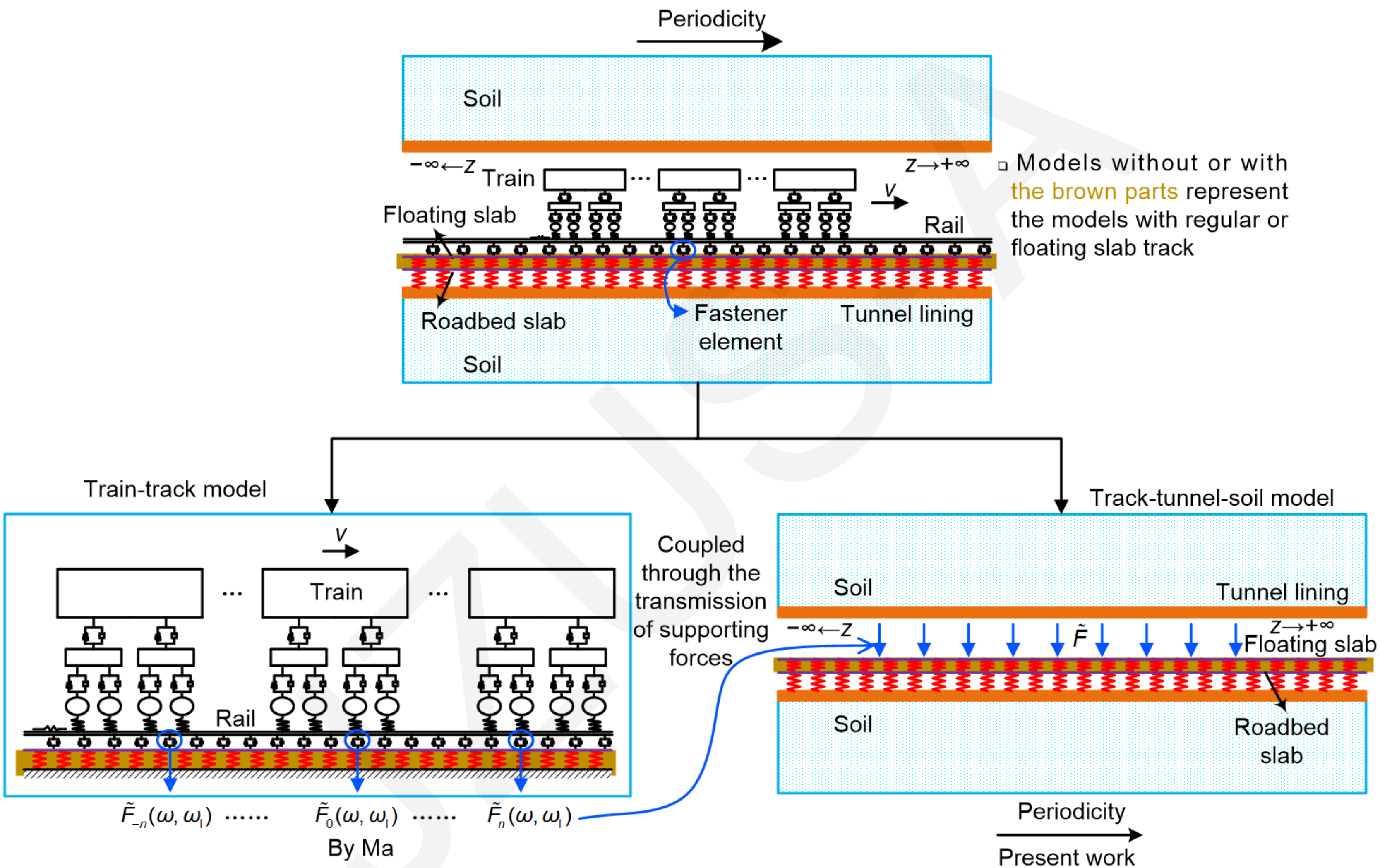
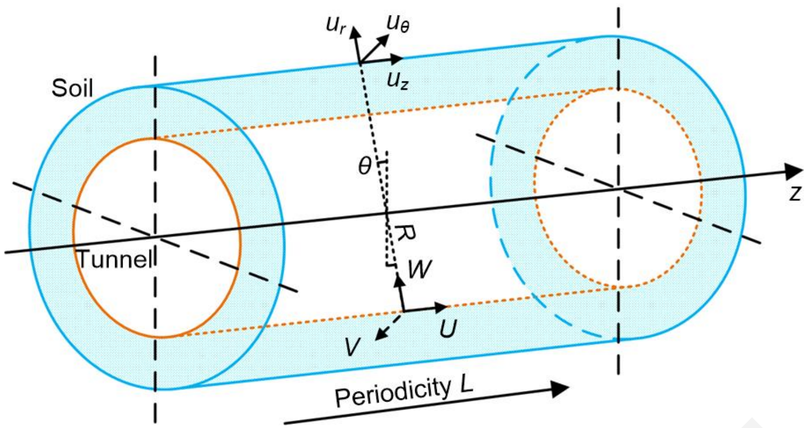
Prediction framework



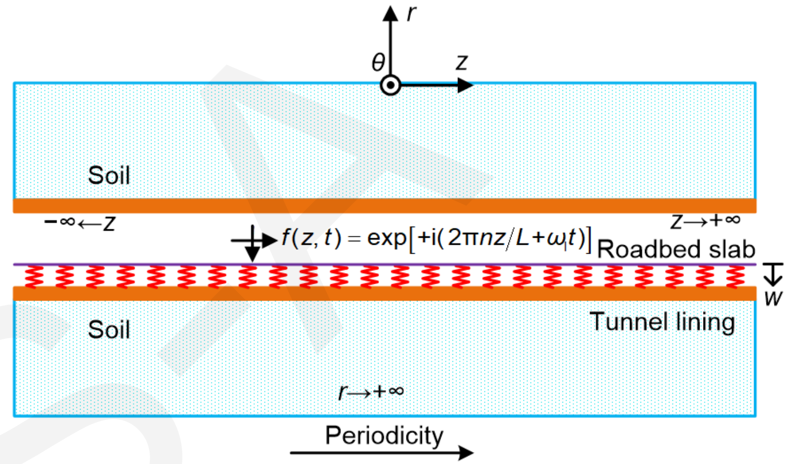
- Models without or with the brown parts represent the models with regular or floating slab track

Overview of the train-track-tunnel-soil system with a regular or floating slab track

Diagram of each part



Periodic PiP model



Regular track slab

For tunnel

$$A_{\mathrm{E}}\tilde{U}_{nm} = \tilde{Q}_{nm},$$

For slab beam

$$m_{\mathrm{s}}\frac{\partial^2 w}{\partial t^2} + EI\frac{\partial^4 w}{\partial z^4} + \left(w + W^{\dagger}\right)k_{\mathrm{eff}} = f(z,t),$$

For soil

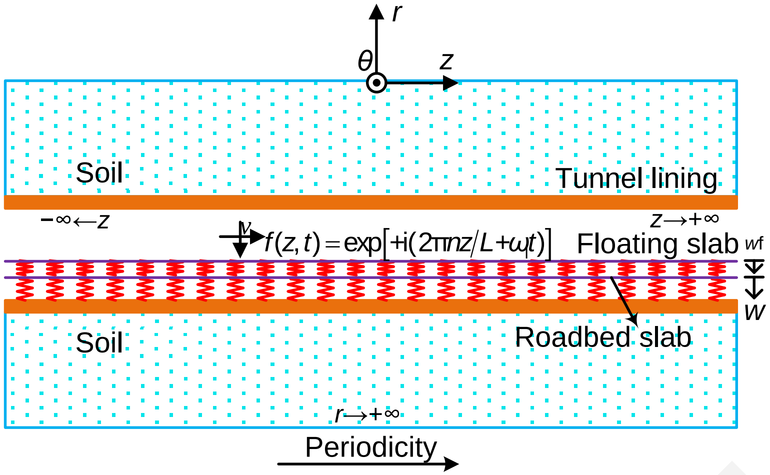
$$\tilde{u}_{nm} = \{\tilde{u}_{znm}\ \ \tilde{u}_{\theta nm}\ \ -\tilde{u}_{rnm}\} = \chi_{\mathrm{o}}(r=R)B_{\mathrm{o}nm},$$

$$\tilde{t}_{nm} = \{-\sigma_{rznm}\ \ -\sigma_{r\theta nm}\ \ \sigma_{rrnm}\} = \eta_{\mathrm{o}}(r=R)B_{\mathrm{o}nm},$$

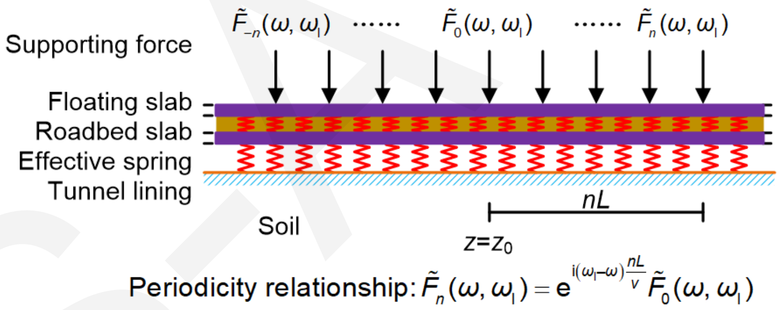
For coupled system

$$\left(K_n + k_{\mathrm{eff}}(1+\alpha)VC\right)\tilde{U}_n^B = -k_{\mathrm{eff}}\tilde{\Delta}_n V,$$

Diagram of each part



Floating slab track



Fastener forces

For slab beam

$$m_s\frac{\partial^2 w}{\partial t^2}+EI\frac{\partial^4 w}{\partial z^4}+k_{\text{eff}}\left(w+W^{\dagger}\right)+k_f\left(w-w_f\right)=0,$$

Periodicity

$$\tilde{F}_n\left(\omega,\omega_l\right)=e^{i(\omega_l-\omega)\frac{nL}{v}}\tilde{F}_0\left(\omega,\omega_l\right)$$

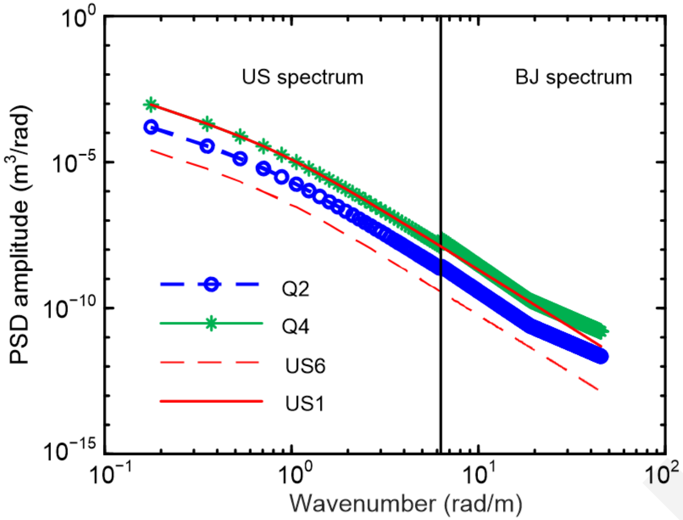
For float slab beam

$$m_f\frac{\partial^2 w_f}{\partial t^2}+EI_f\frac{\partial^4 w_f}{\partial z^4}+k_f\left(w_f-w\right)=f\left(z,t\right),$$

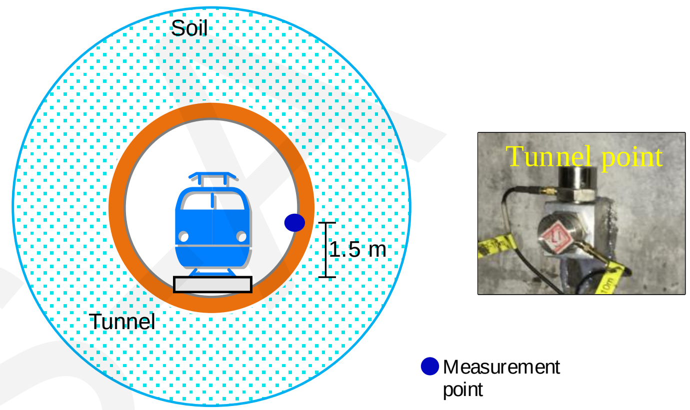
Force expression

$$\tilde{f}_n\left(\omega,\omega_l\right)=\frac{\tilde{F}_0\left(\omega,\omega_l\right)}{L}e^{-i\left(\frac{2\pi n}{L}+\frac{\omega_l-\omega}{v}\right)z_0}.$$

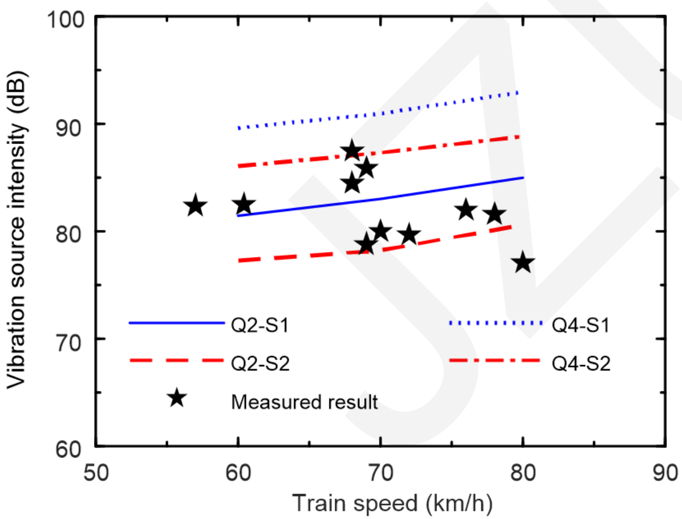
Validation and verification



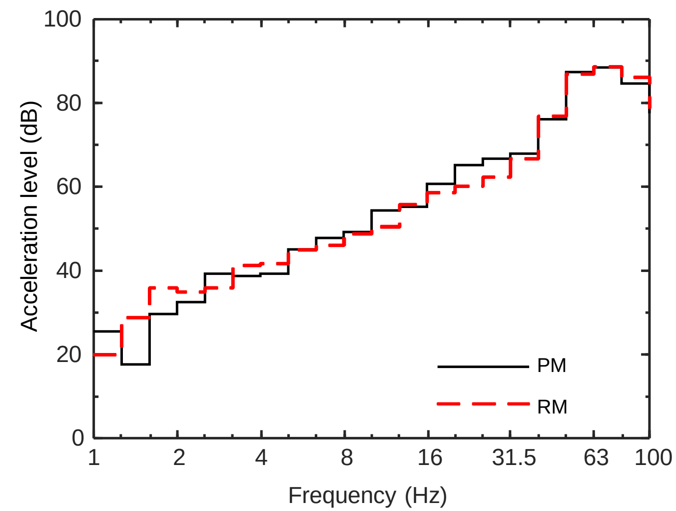
Measured irregularities



Measurement setup



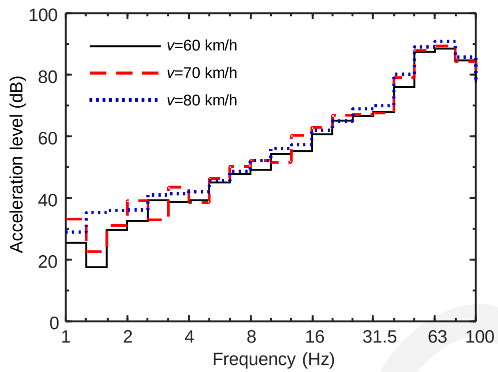
Validation against measurement



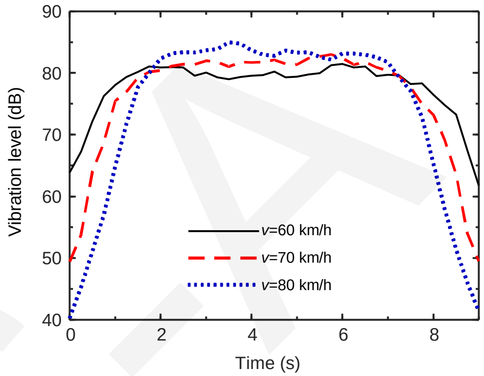
Verification against model

Regular slab track

Train speed

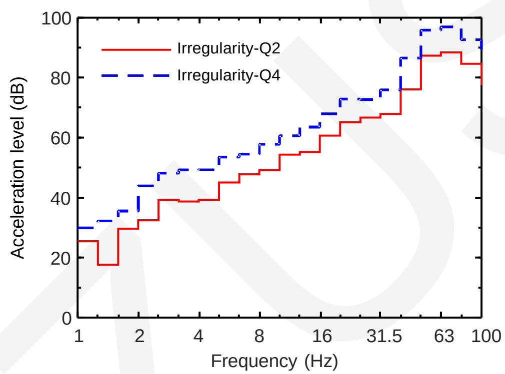


(a)

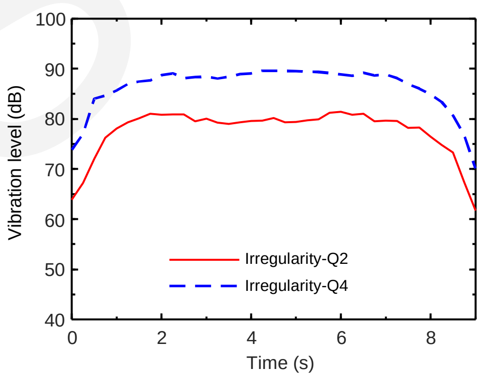


(b)

Track Irregularities

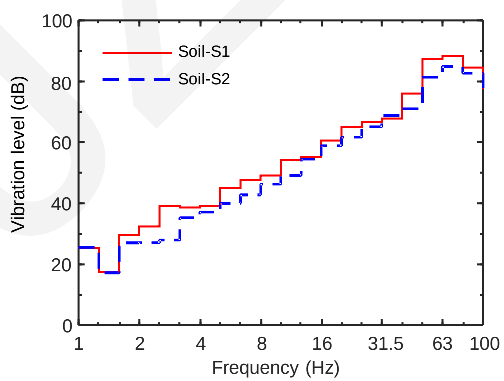


(a)

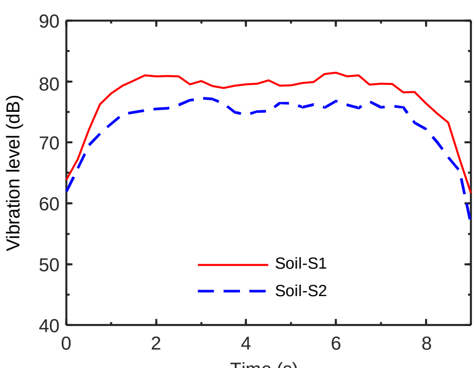


(b)

soil condition

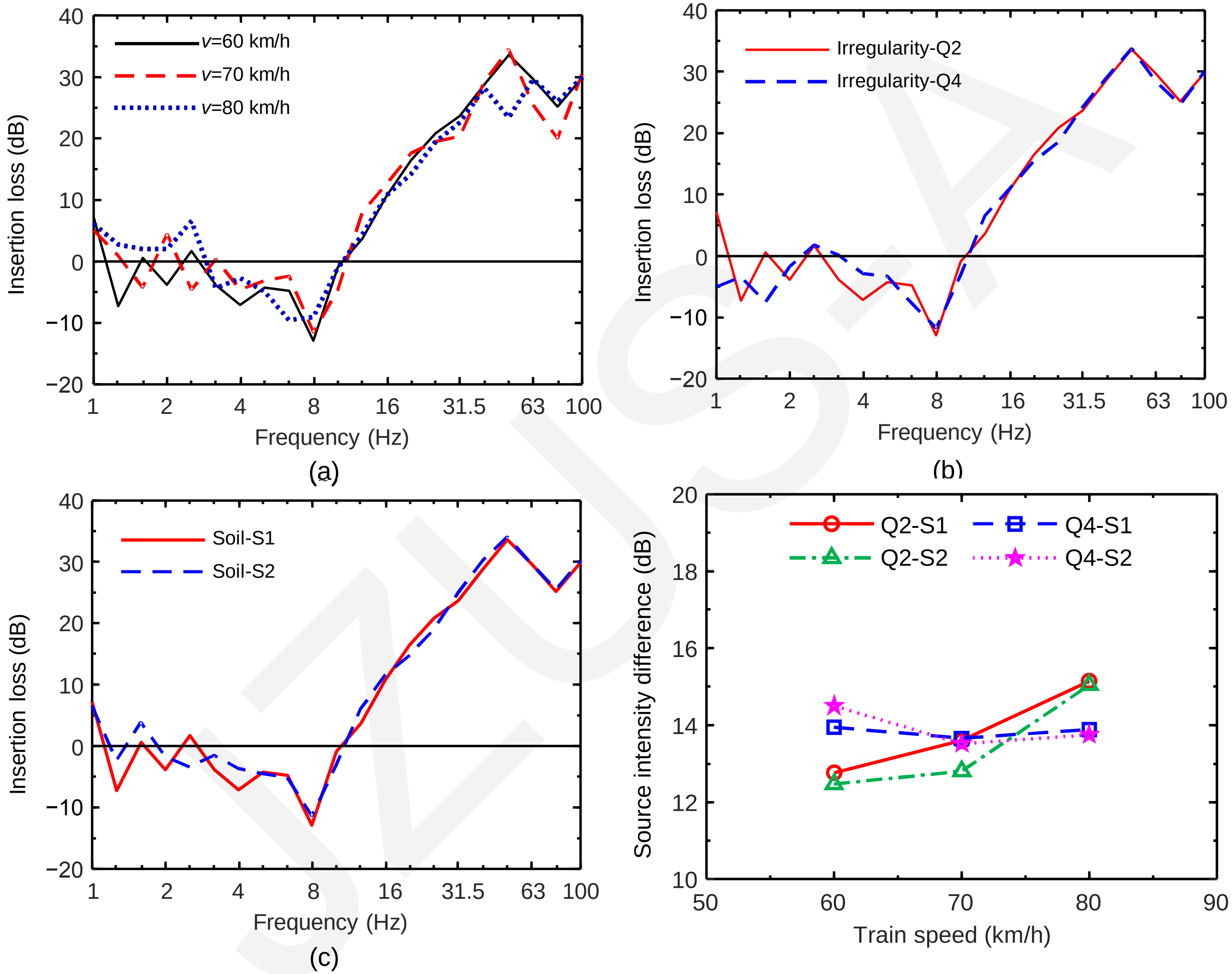


(a)



(b)

Float slab track



Insertion loss of the floating slab track

Conclusions

- (1) The proposed method is both accurate and efficient in determining the vibration source intensity. It can serve as a supplementary method in empirical prediction.
- (2) As track conditions deteriorate from class Q2 to Q4, the vibration source intensity rises by about 8 dB. Track irregularities must be considered a primary factor.
- (3) The floating slab track has a maximum vibration mitigation capacity of around 14 dB. Using a constant vibration reduction value in environmental assessments may lead to a prediction error of about 2 dB.