Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

Effect of softening of cement asphalt mortar on vehicle operation safety and track dynamics

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Cite this as: Jian Han, Guo-tang Zhao, Xin-biao Xiao, Ze-feng Wen, Qing-hua Guan, Xue-song Jin, 2015. Effect of softening of cement asphalt mortar on vehicle operation safety and track dynamics. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 16(12):976-986. [doi:10.1631/jzus.A1500080]

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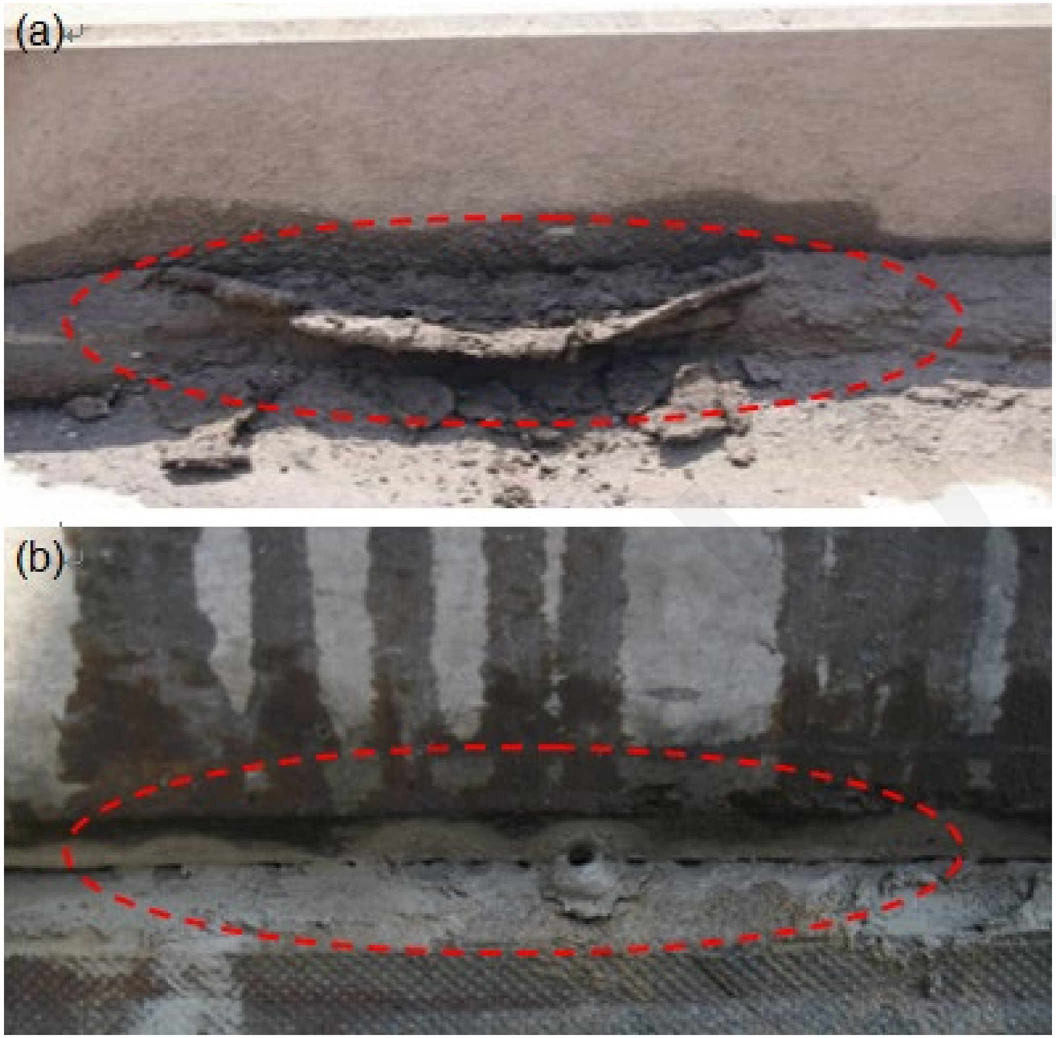
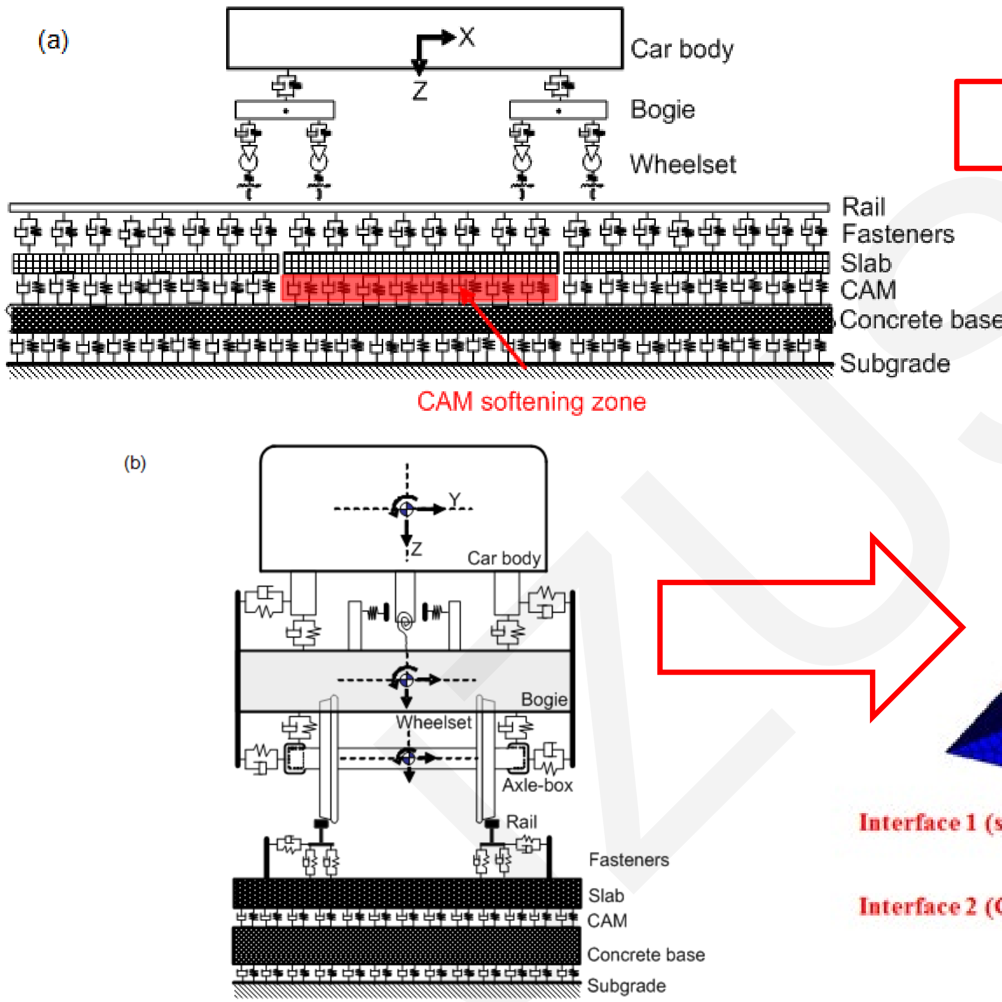
Background (CAM damage)

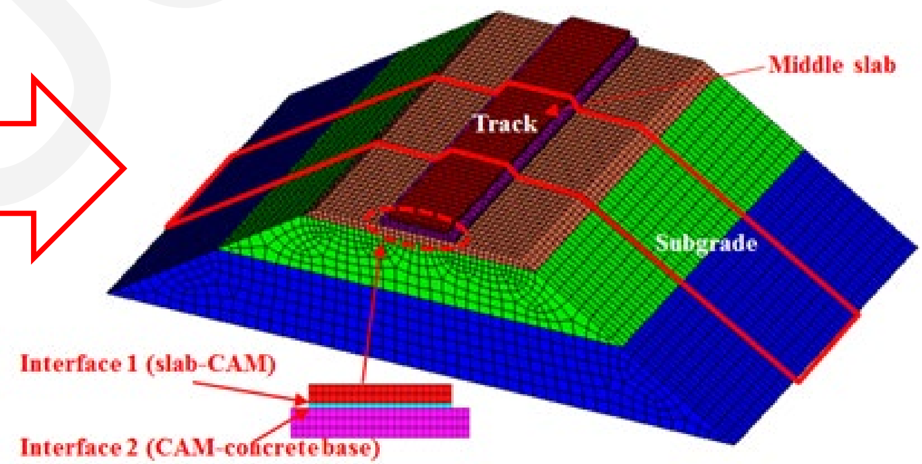


CAM damage (softening). Fig (a) Reprinted from (Zhu, 2014), Copyright 2014, with permission from Elsevier

Analysis model

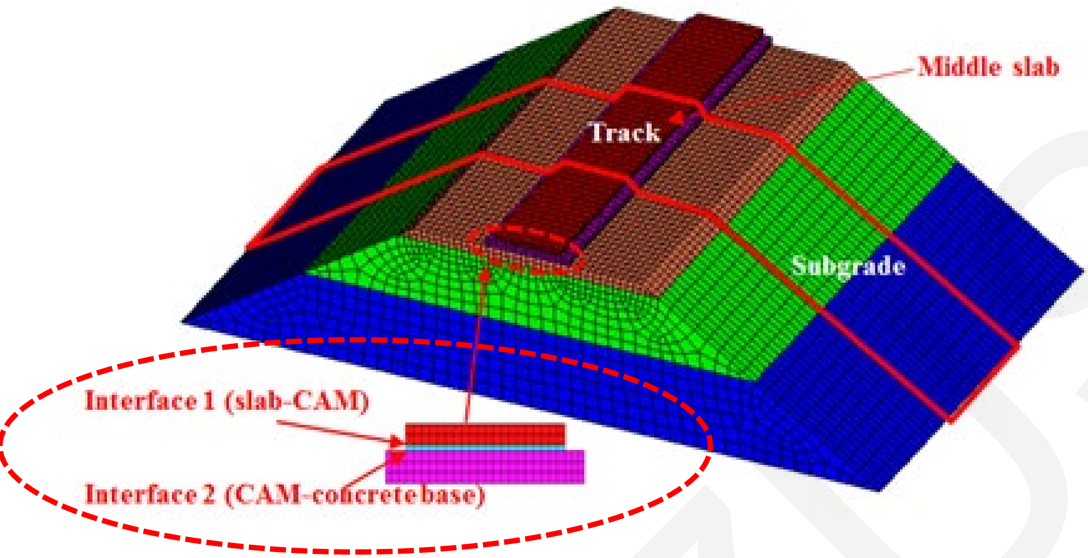


Vehicle-track coupling dynamic model



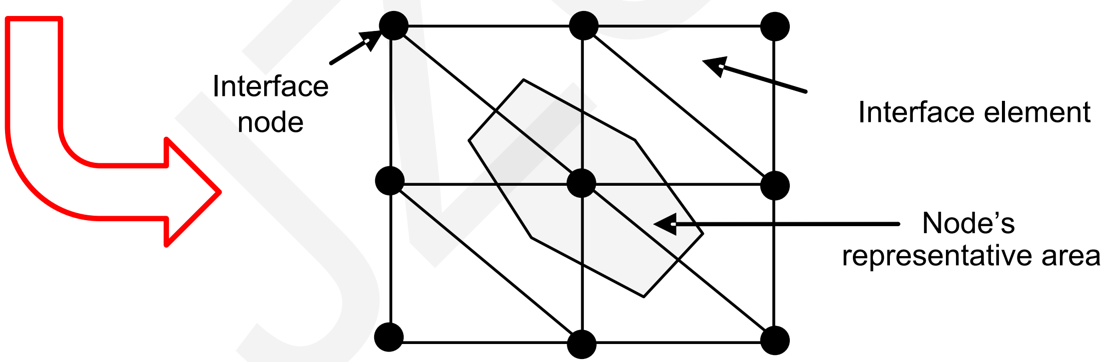
3D model of a CRTS-I slab track and its subgrade

Contact model of CAM



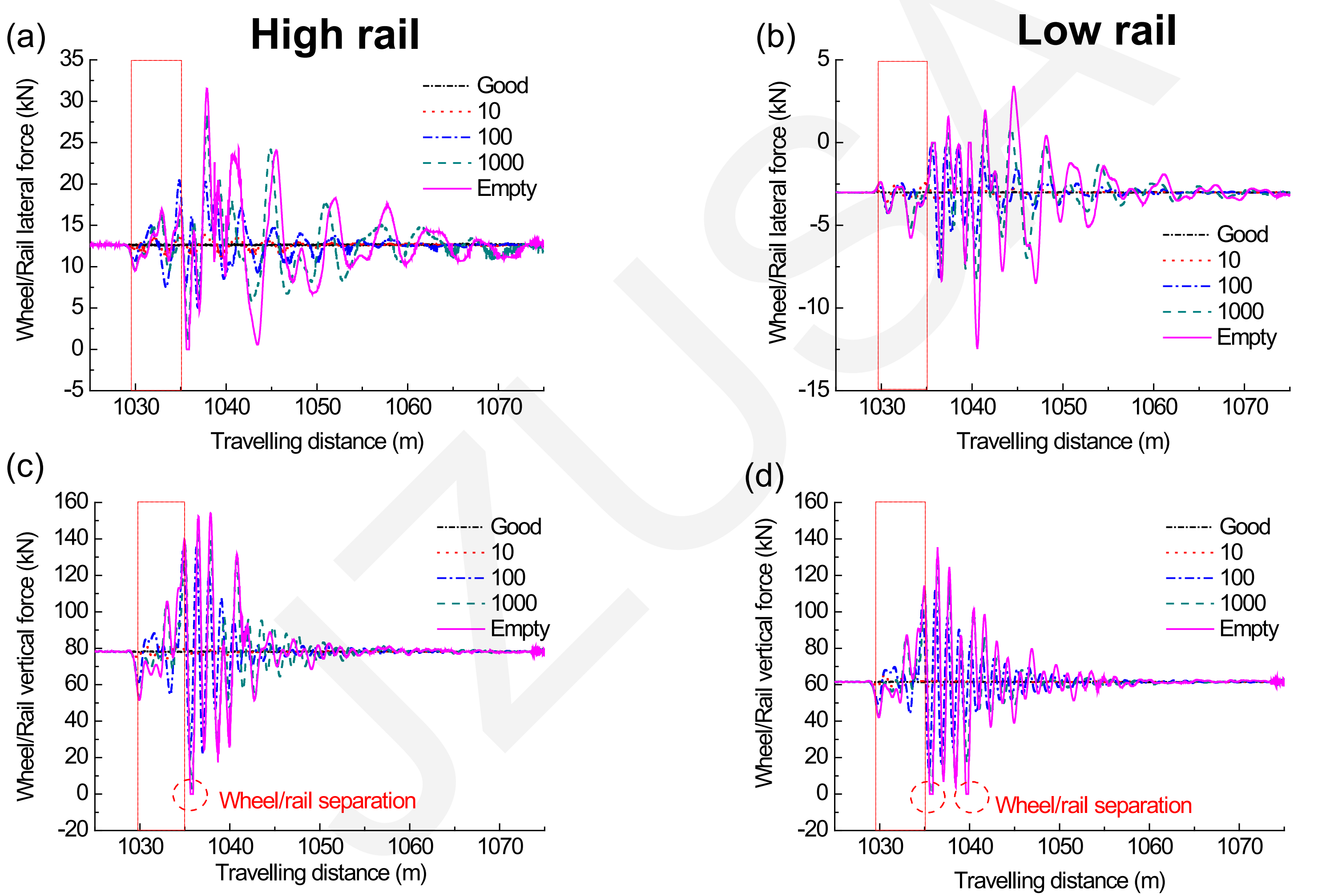
$$\begin{cases} F_{\mathrm{n}}^{(t+\Delta t)} = k_{\mathrm{n}} u_{\mathrm{n}} A + \sigma_{\mathrm{n}} A, \\ F_{\mathrm{si}}^{(t+\Delta t)} = F_{\mathrm{si}}^{(t)} + k_{\mathrm{s}} \Delta u_{\mathrm{si}}^{(t+0.5\Delta t)} A + \sigma_{\mathrm{si}} A, \end{cases}$$

$$F_{\mathrm{smax}} = cA + \tan\phi F_{\mathrm{n}},$$



Distribution of representative areas in relation to interface nodes (Han, 2015)

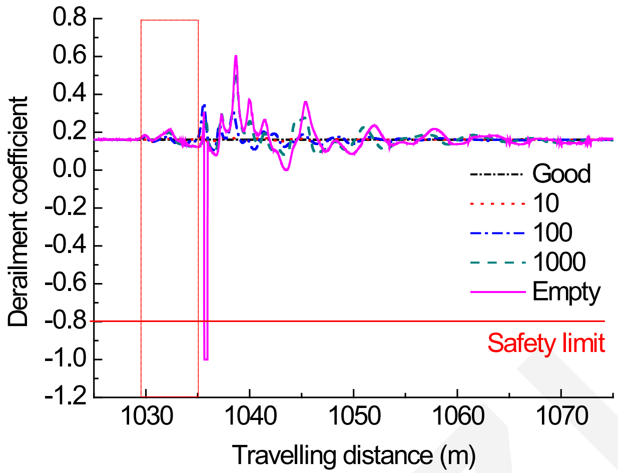
Effect of CAM softening on high-speed vehicle operation safety



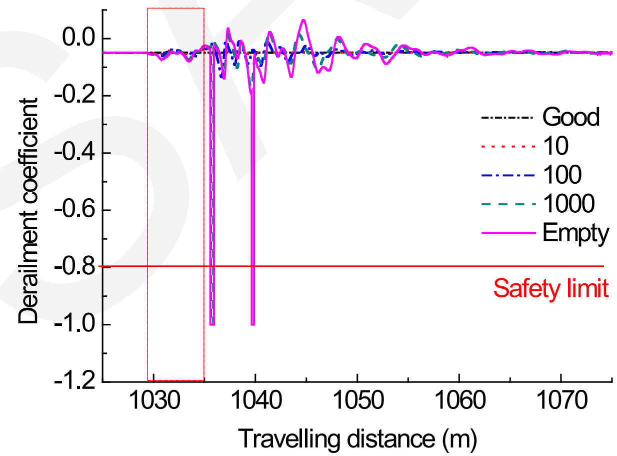
Wheel/Rail forces with different degrees of CAM softening

Effect of CAM softening on high-speed vehicle operation safety

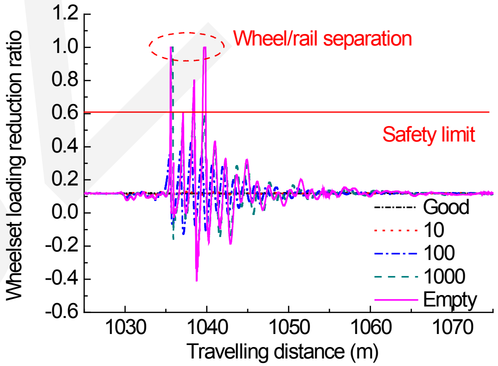
(a) **High rail**



(b) **Low rail**



Derailment coefficient (*L*/*V*)



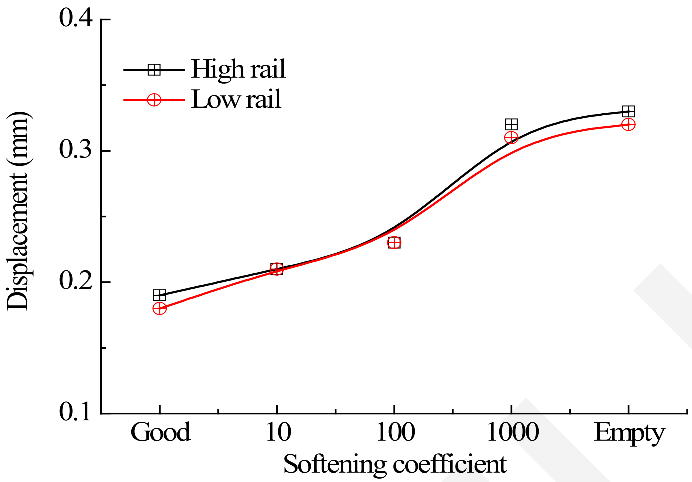
Wheelset loading reduction ratio (Δ*V*/*V*)

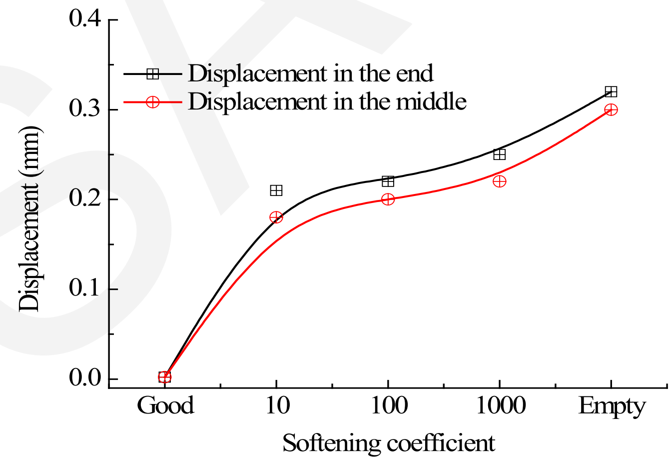
Track Dynamics

Rail displacement

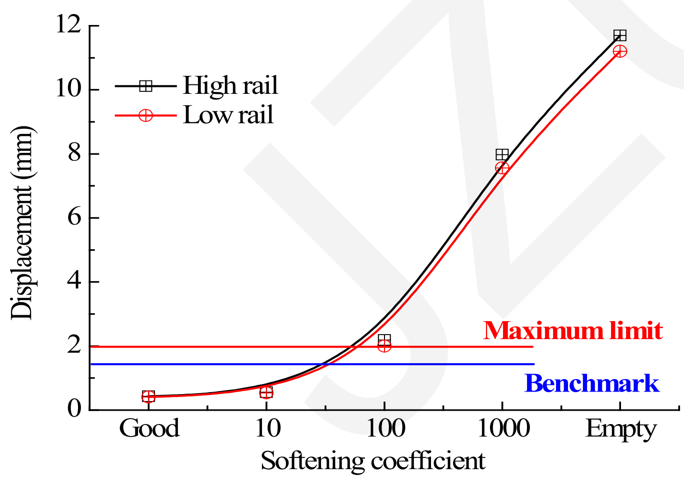
Slab displacement

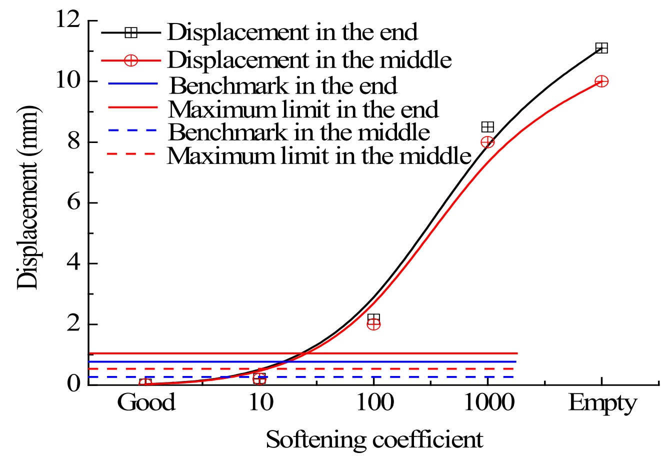
Lateral



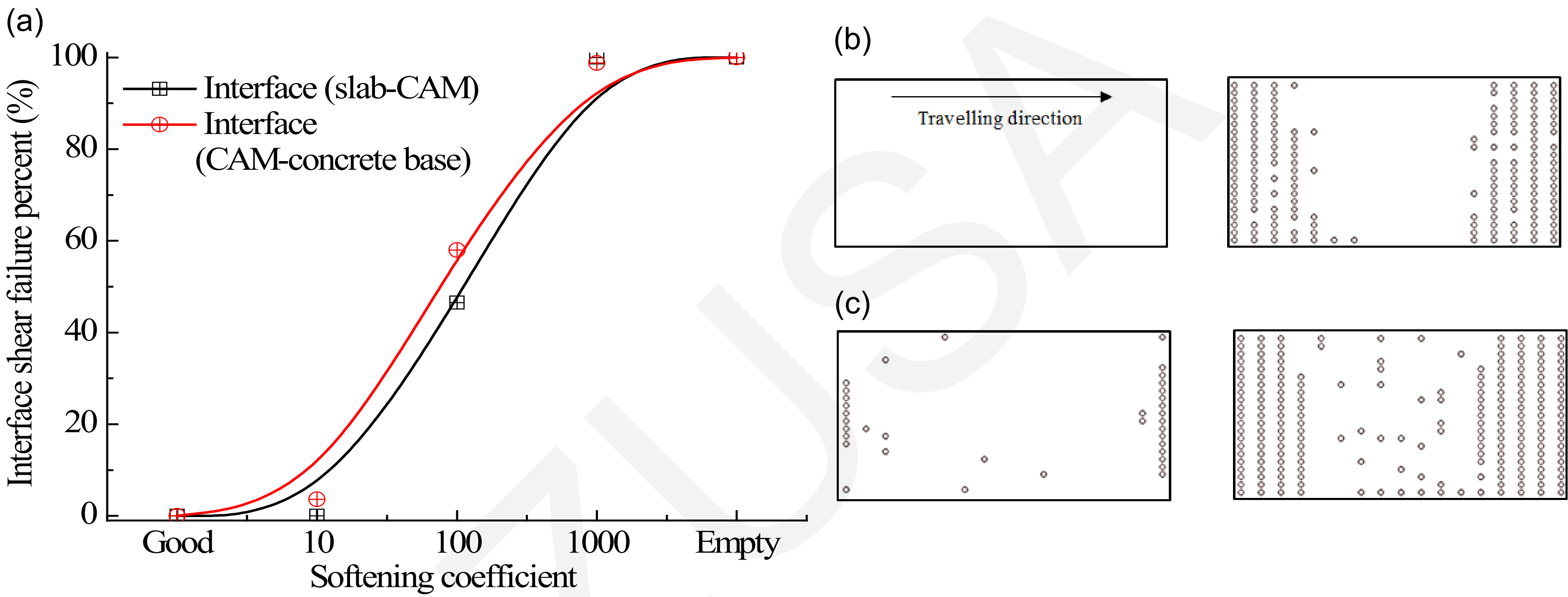


Vertical





Interface shear failure



(a) Interface shear failure percent vs CAM softening coefficient;
(b) Interface shear failure distribution (slab-CAM) (left: 10; right: 100);
(c) Interface shear failure distribution (CAM-concrete base) (left: 10; right: 100)

Conclusions

In this paper, a 3D coupling dynamic model of a vehicle and a CRTS-I slab track is developed. Using the proposed model, the wheel-rail contact forces, derailment coefficient, wheelset loading reduction ratio, and the track displacements are calculated to study the influence of CAM softening on the dynamic characteristics of the vehicle-track system. A track-subgrade finite difference model is developed to study effect of CAM softening on track damage. The following conclusions can be drawn:

- 1. Wheel-rail contact forces fluctuate dramatically when a high-speed train runs over the curved track with CAM softening. When the CAM softening coefficient is larger than 1000, wheel/rail separation occurs, and the derailment coefficient and wheelset loading reduction ratio both exceed their safety limits.
- 2. As CAM softening increases, slab displacement more easily exceeds its geometric limit than rail displacement. When the CAM softening coefficient is larger than 10, slab vertical displacement in the middle exceeds the corresponding benchmark. When the softening coefficient is larger than 100, the vertical displacements of both the rail and slab exceed their corresponding maximum limits.
- 3. CAM softening cannot lead to slab damage based on a simple strength analysis. When the CAM softening coefficient reaches 10, a small partial slip occurs between the CAM and the concrete base. When the CAM softening coefficient is larger than 100, at both the slab-CAM interface and the CAM-concrete base interface, serious damage occurs due to slippage.

According to these conclusions, when the CAM softening coefficients reach 10-100, track interface shear failure develops. The CAM softening coefficient should not be less than 1000, otherwise a high-speed running vehicle may risk derailment.