Which Load Model do We Use for Rail Track Design?

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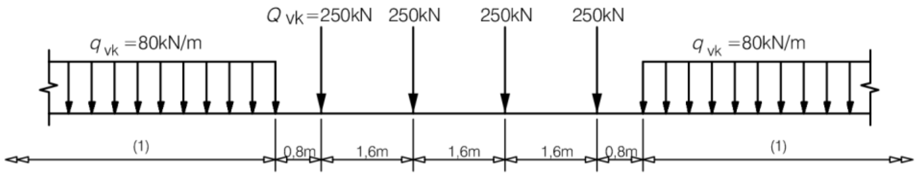
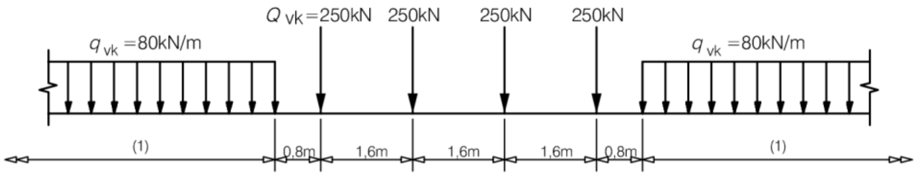
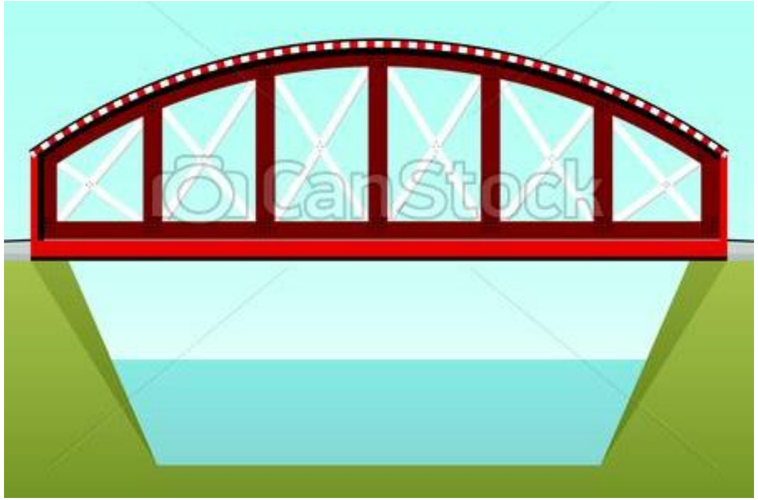
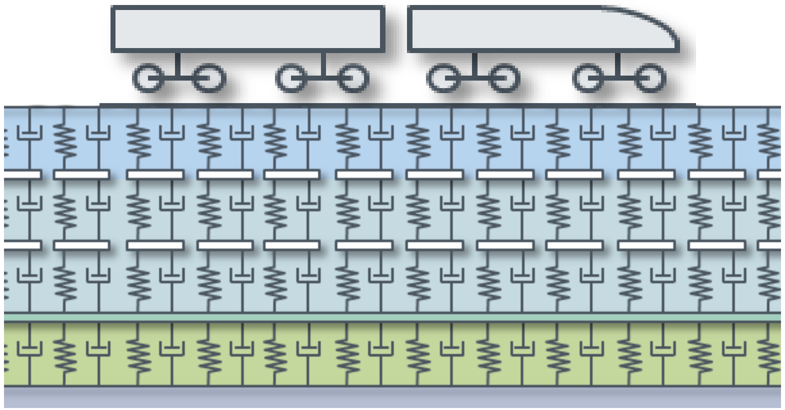
Review of Load Model 71









Analysis Options for Track Designers

I. Multi-Body Dynamic Simulation

Pros: Currently Most “Exact” Method
Allows Addressing Reliability (or risk etc.)

Cons: Stiffness-, Damping-, Mass- Properties of Train not always available, Challenging Computation (Soil Dynamics, Rolling Contact), Experienced of Engineers Required.

II. Dynamic Moving Load Analysis

Pros: Very Simple & Accurate, Relatively Short Computation Since no Vehicle-Track Interaction and no Irregularities

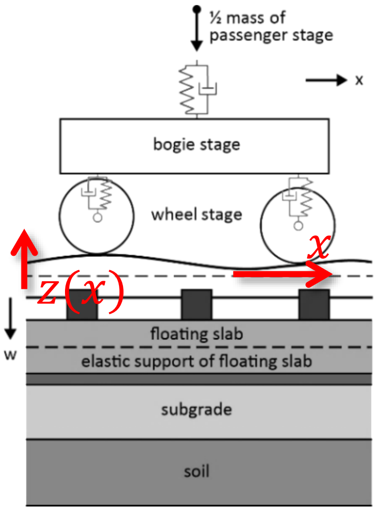
Cons: Software Requires “Dynamic Moving Load Module”, Simplified Reliability-Analysis.

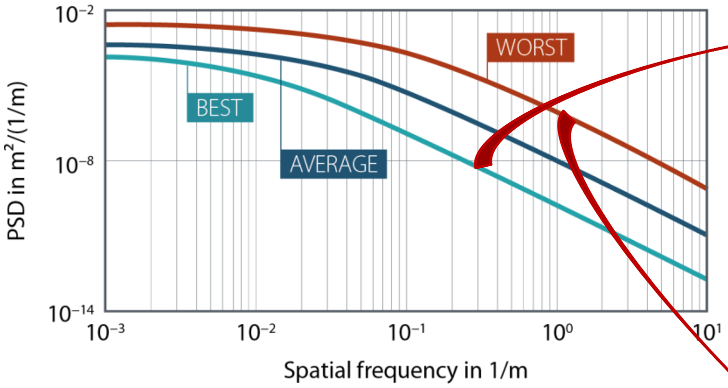
III. Static Moving Load Analysis

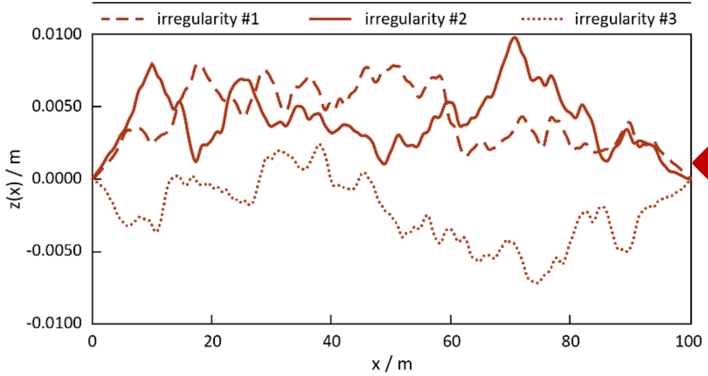
Pros: Relatively Simple & Accurate “Spectrum of Static-to-Dynamic Conversion Factors”, Very Short Computation, no Vehicle-Track Interaction and no Irregularities,
Static Analysis only.

Cons: Does Reliability-Analysis make sense based on static analysis?

Influence of Track Irregularities



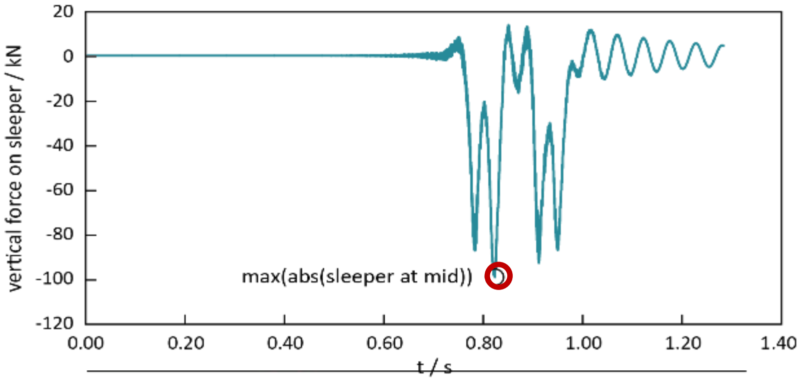


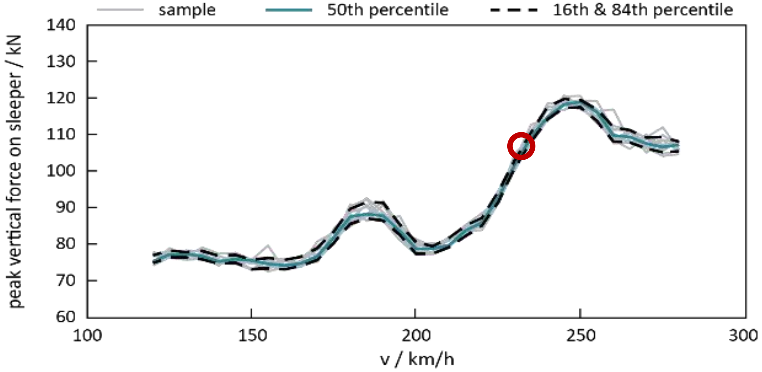


Example:

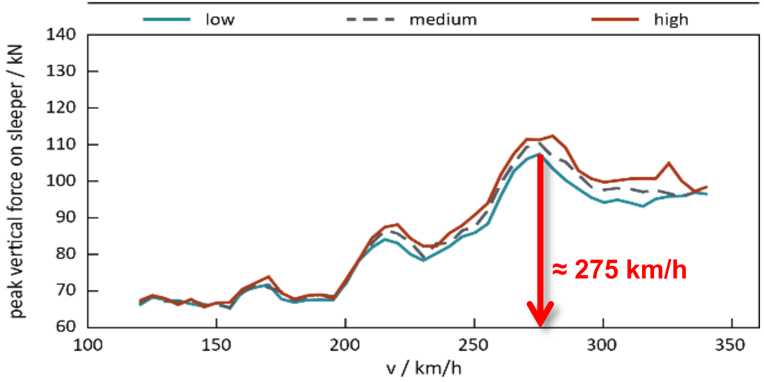
- Vehicle: ICE2
- Track: Ballastless
- Soil: Winkler Model
- > 10 Irregularities!

Influence of Track Irregularities



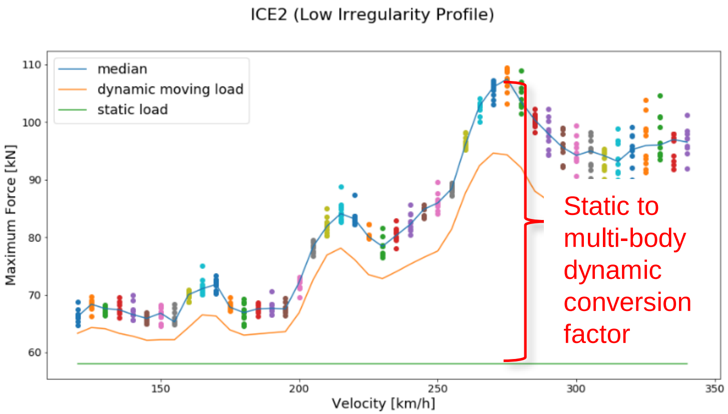


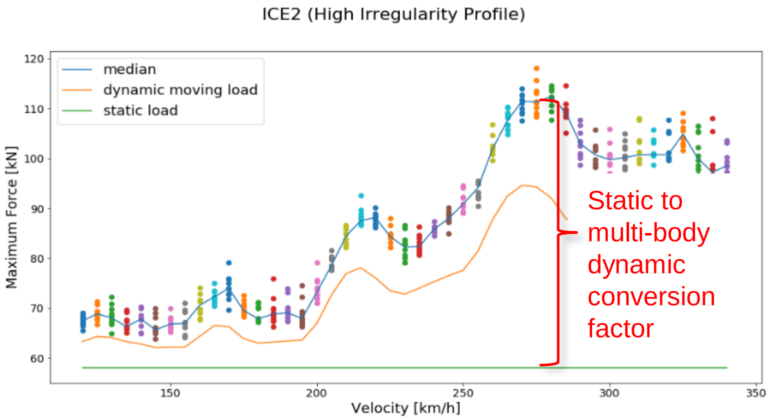
Variation of track quality and statics



Variation of velocity and Irregularity

Dynamic Amplification Factor and Influence of Soil Model





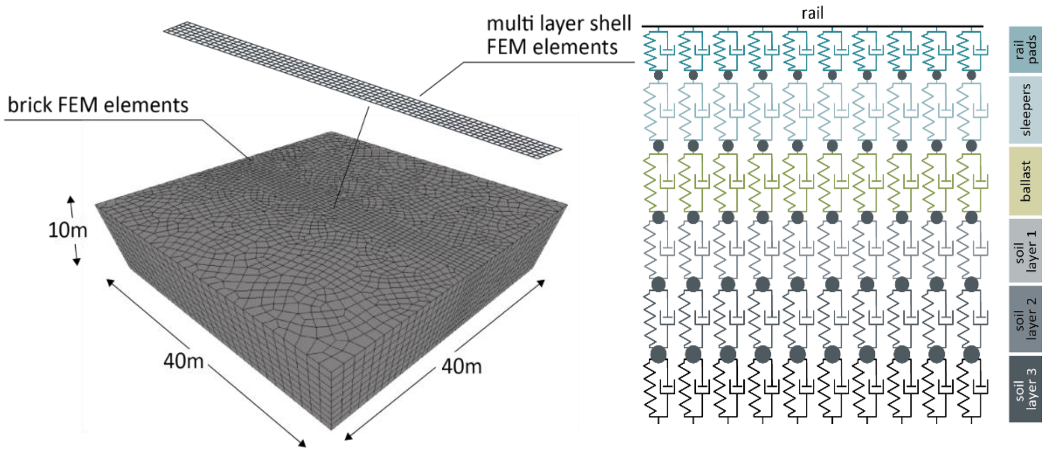
- Dynamic Amplification Factor

$$\beta = \frac{F_{\text{dynamic}}}{F_{\text{static}}}$$

- Weighted Dynamic Amplification Factor

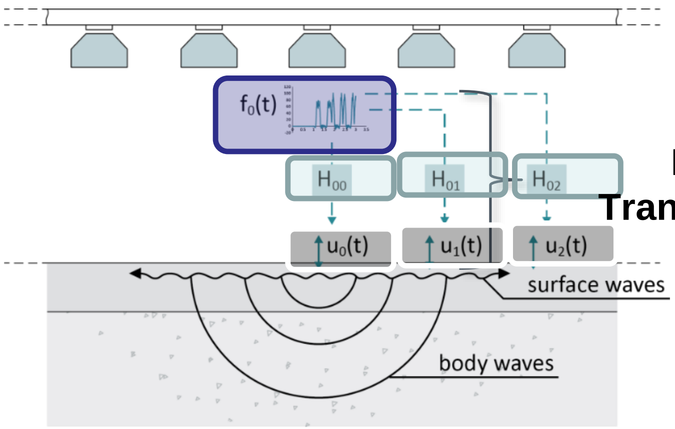
$$\alpha = \frac{F_{\text{dynamic}}}{F_{\text{static}}} \cdot \frac{F_{\text{axle}}}{250\ \text{kN}}$$

Dynamic Amplification Factor and Influence of Soil Model

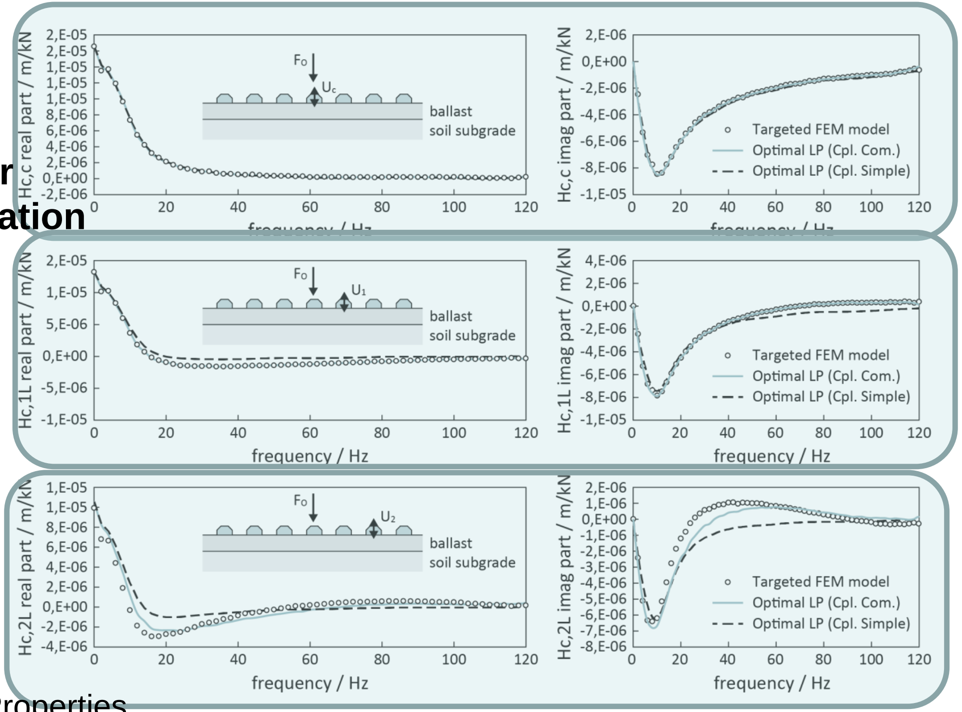


Is the Winkler Model an Accurate Representation of the Semi-Infinite Elastic Half Space?

Dynamic Amplification Factor and Extended Winkler Model



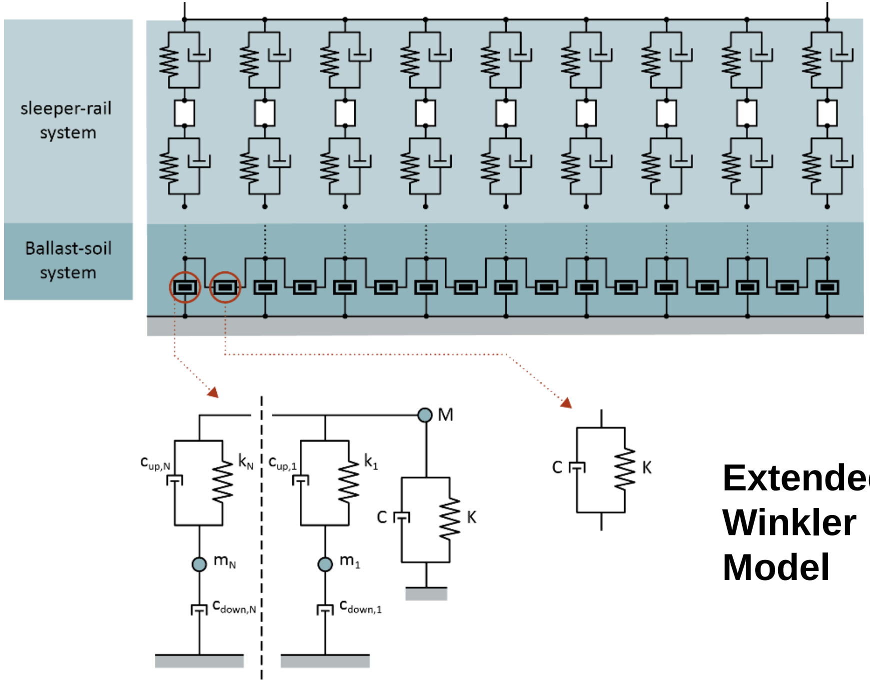
Fourier Transformation



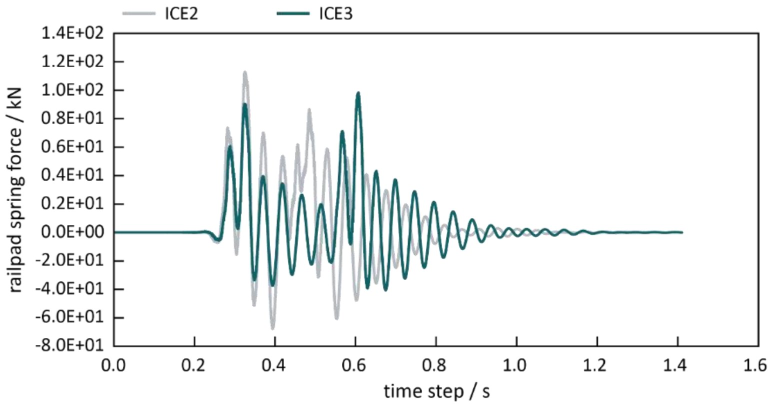
$$\begin{bmatrix} H_{0,0}(\omega) & H_{0,1}(\omega) & H_{0,2}(\omega) & \cdots \\ H_{1,0}(\omega) & H_{1,1}(\omega) & H_{1,2}(\omega) & \\ H_{2,0}(\omega) & H_{2,1}(\omega) & H_{2,2}(\omega) & \\ \vdots & & & \ddots \end{bmatrix} \cdot \begin{bmatrix} F_0 \\ F_1 \\ F_2 \\ \vdots \end{bmatrix} = \begin{bmatrix} U_0 \\ U_1 \\ U_2 \\ \vdots \end{bmatrix}$$

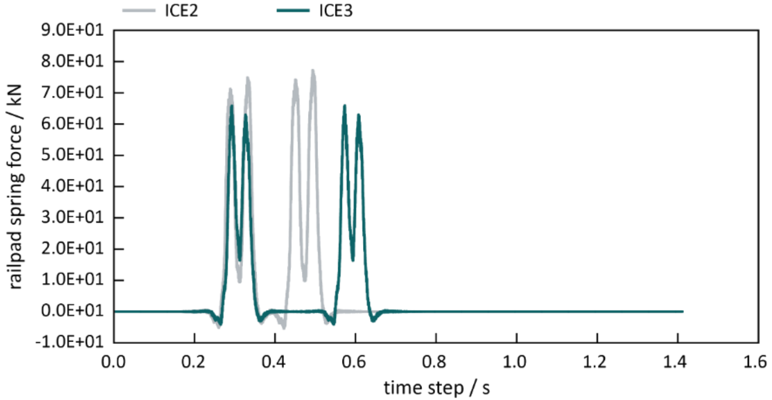
✓Approximation of Frequency Dependent Soil Properties
✓Consideration of Rayleigh Wave Propagation
✓**Less of Degrees-of-Freedom for Dynamic Analysis**

Dynamic Amplification Factor and Extended Winkler Model



Extended Winkler Model





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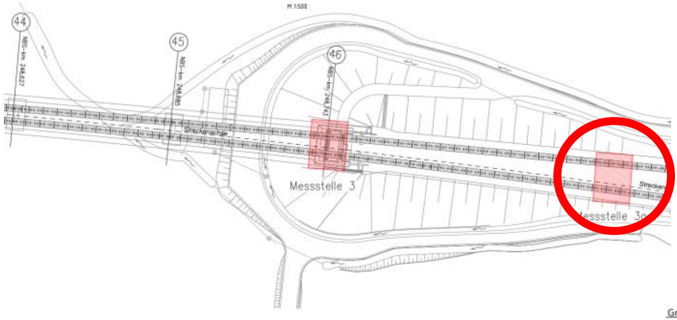
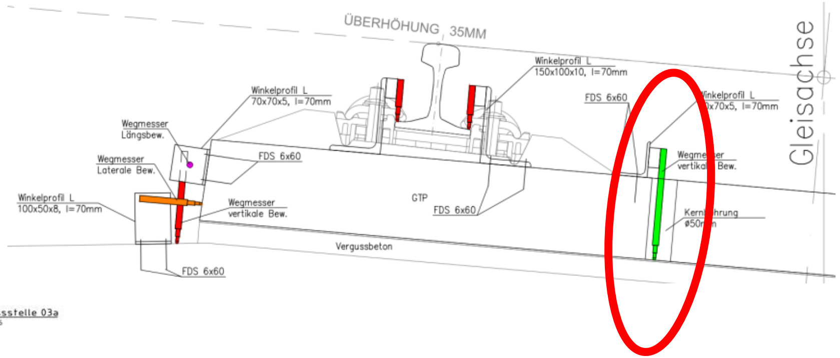
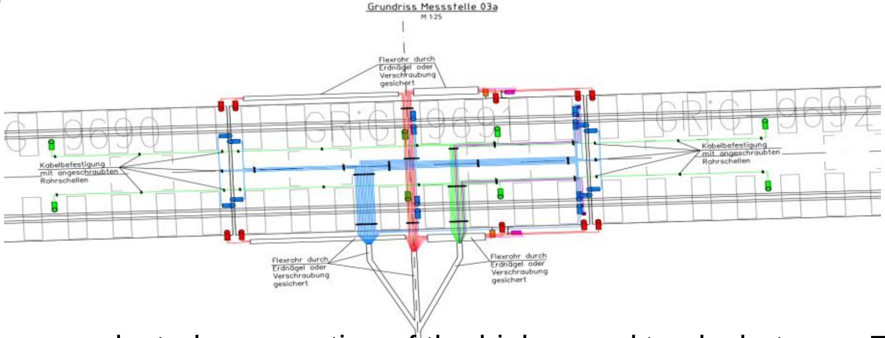
Validation: Comparison with Recorded Data ICE2 at v = 160 km/h

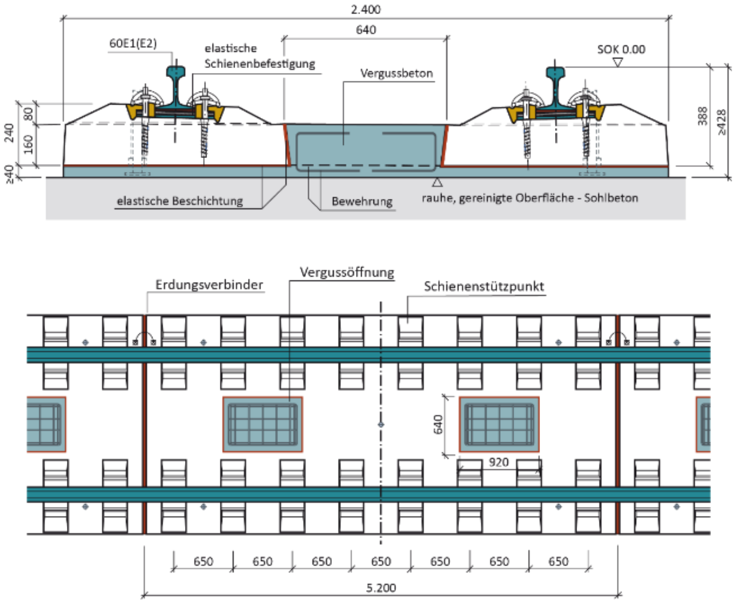




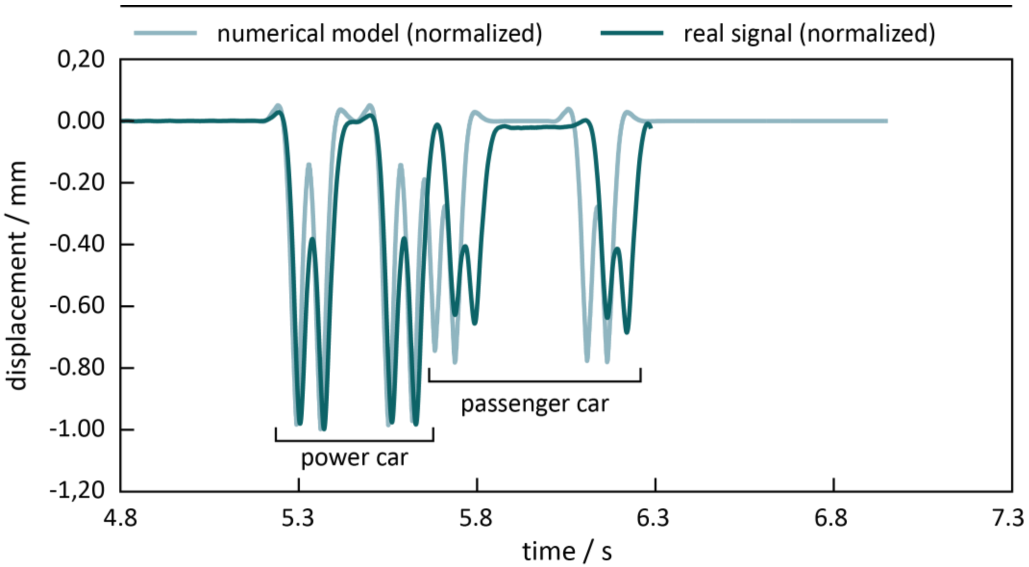


The measurements were conducted on a section of the high-speed tracks between Erfurt-Leipzig in 2014 by FCP in the context of the project entitled ‘VDE 8.2, New Line Erfurt-Leipzig / Halle’ (a part of the new German High-speed Track Network).

Validation: Comparison with Recorded Data ICE2 at v = 160 km/h

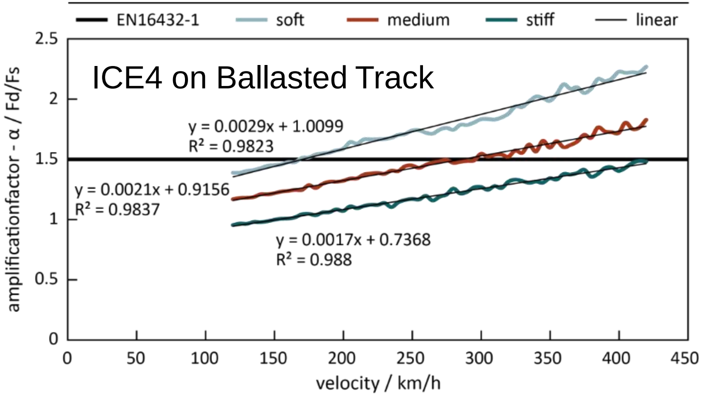


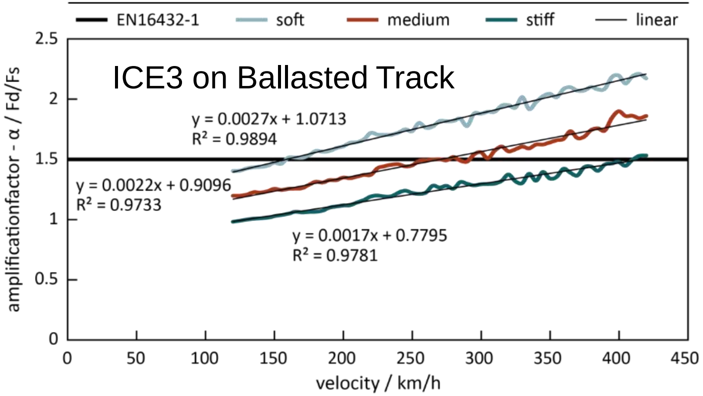
Typical PORR system

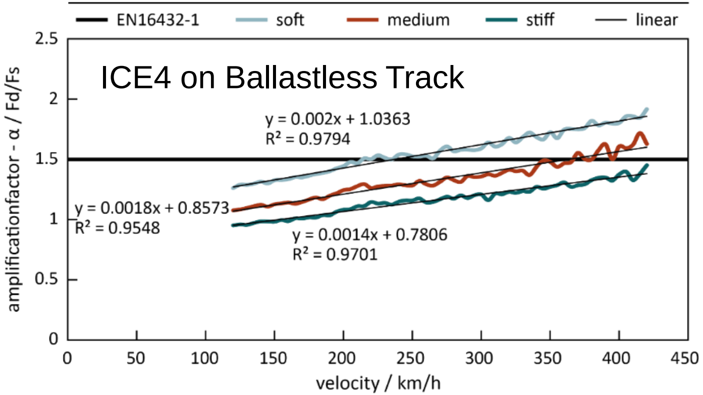


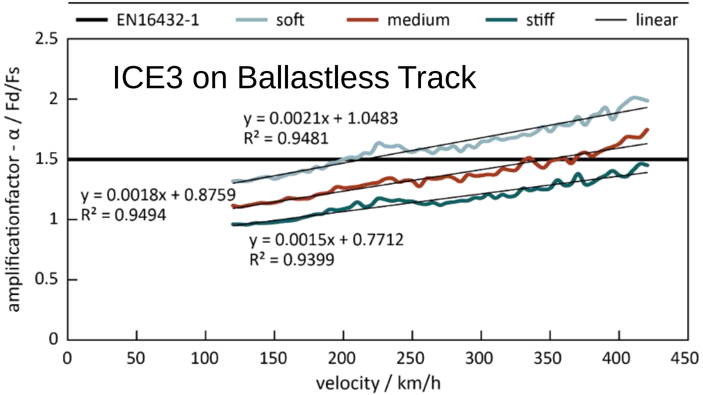
Results of validation

Dynamic Amplification Factor and Extended Winkler Model

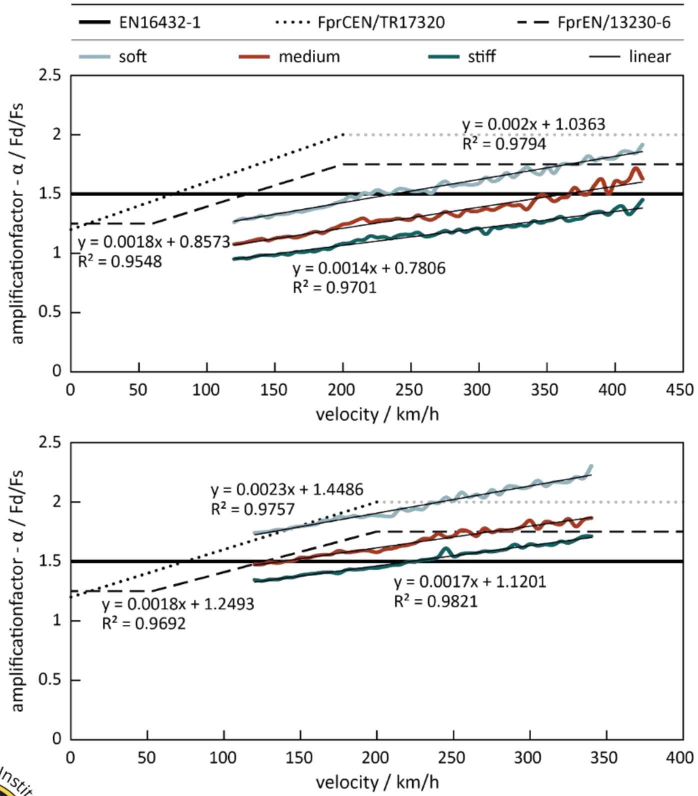








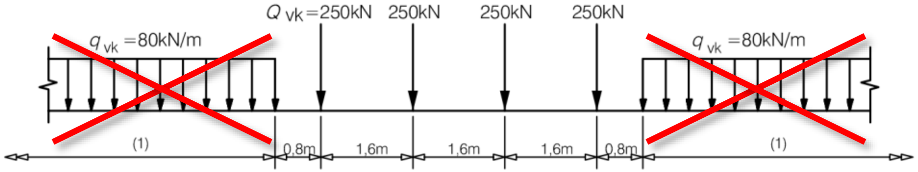
Dynamic Amplification Factor and Extended Winkler Model

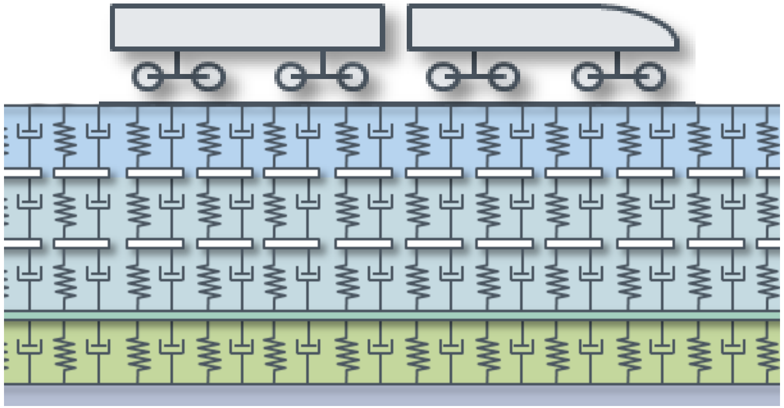


- ✓ **Good Agreement** with FprCEN/TR17320: “Railway Applications - Infrastructure - Determination of Laboratory Test Parameters for Assessing the Mechanical Durability of Rail Fastening Systems - Complementary Element”
- ✓ **Good Agreement** with FpEN/13230-6: “Railway Applications - Track - Concrete Sleepers and Bearers - Part 6: Design”
- ✓ Proposed Tables for “Early Design Phase”: Maximum Speed to Meet EN16432-1 Dynamic Amplification Factor of 1.50:

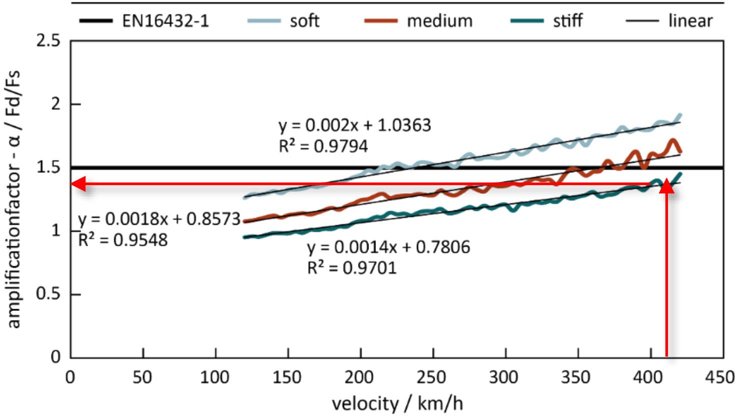
Track System	**Subgrade Conditions E_{V2} in MPa**		
	40	80	120
Ballastless	330	395	-
Ballasted	255	320	370

Novel Procedure to Design Rail Tracks on Earthworks



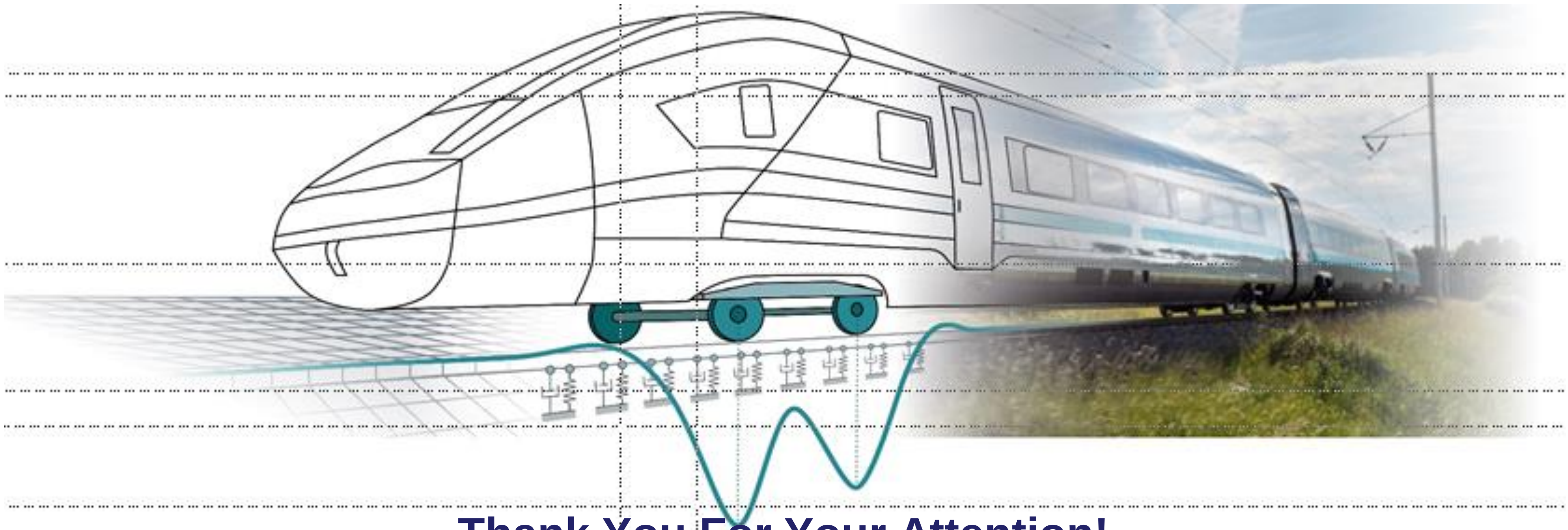


1. Classification of Train (New/Old HS Train, Commuter Train, Freight Train)
2. Classify Soil using E_{V2}
3. Get Expected Top Speed
4. Estimate Velocity Dependent Dynamic Amplification Factor from Diagram
5. Assign Modified LM71 to Your Model
6. **Perform Static Analysis**



Further Research Activities

- Quantification of Vehicle Irregularities (e.g. Flat Wheels) on Track Response
- Sophisticated Multi-Body-Dynamic Simulation to Simulate Rolling Contact
- Application to Lateral and Longitudinal Direction, and Curved Sections
- Stochastic Simulation and Sensitivity Analysis using Extended Winkler Model
- **What is the Impact on Life Cycle Assessment?**
- **Harmonization with EN1990**



Thank You For Your Attention!

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