Static and Dynamic Investigation of Mass Spring System in Chile

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Railway Forum Napoli
6-7 November 2025

2nd International Scientific and Technical Conference
Modern Technologies in Planning, Construction and Maintenance of Slab Track Systems

Advanced solutions for railway, underground and tramway track systems

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COMPANY PRESENTATION

VCE is an internationally active engineering office with more than 350 staff members, its headquarters in Vienna and several branch offices abroad.

Fields of Activity of **VCE**:

- Bridge Engineering
- Structural Design – Buildings
- Industrial & Plant Construction
- Civil Engineering & Tunnelling
- General Consultant & Project Management
- Technical and Financial Control
- Site Supervision
- Health & Safety Engineering
- Traffic Design
- Track Design
- Structural Health Monitoring (BRIMOS®)
- Environmental Sustainability – Carbon Footprint
- LCM Life Cycle Management
- Accredited & Notified Body (BCT)
- CSM Risk Management
- Plant Data Management
- Digital Engineering . BIM
- Noise and Vibration Assessment
- Environmental Protection
- Acoustics
- Research & Development

COMPANY PRESENTATION

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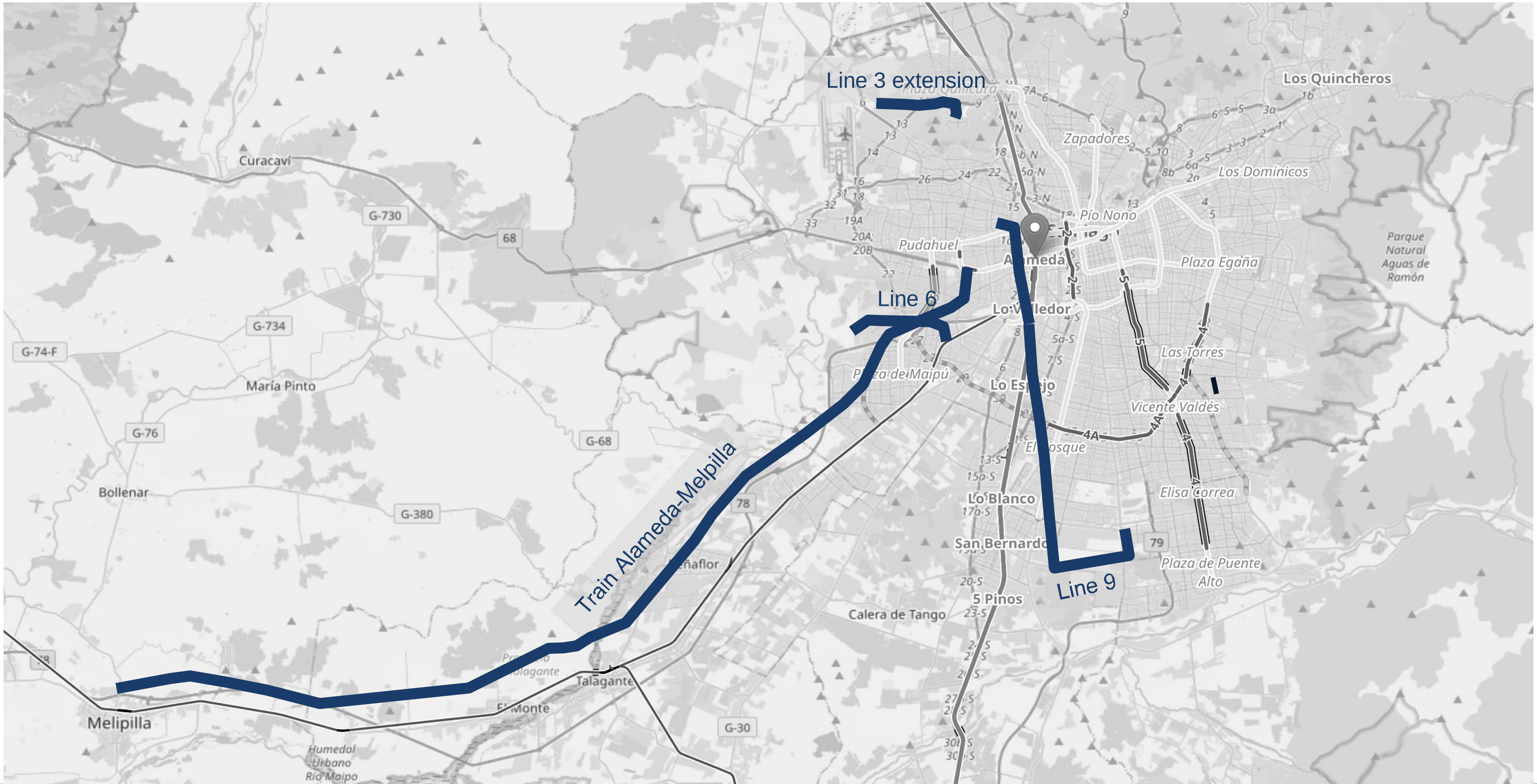
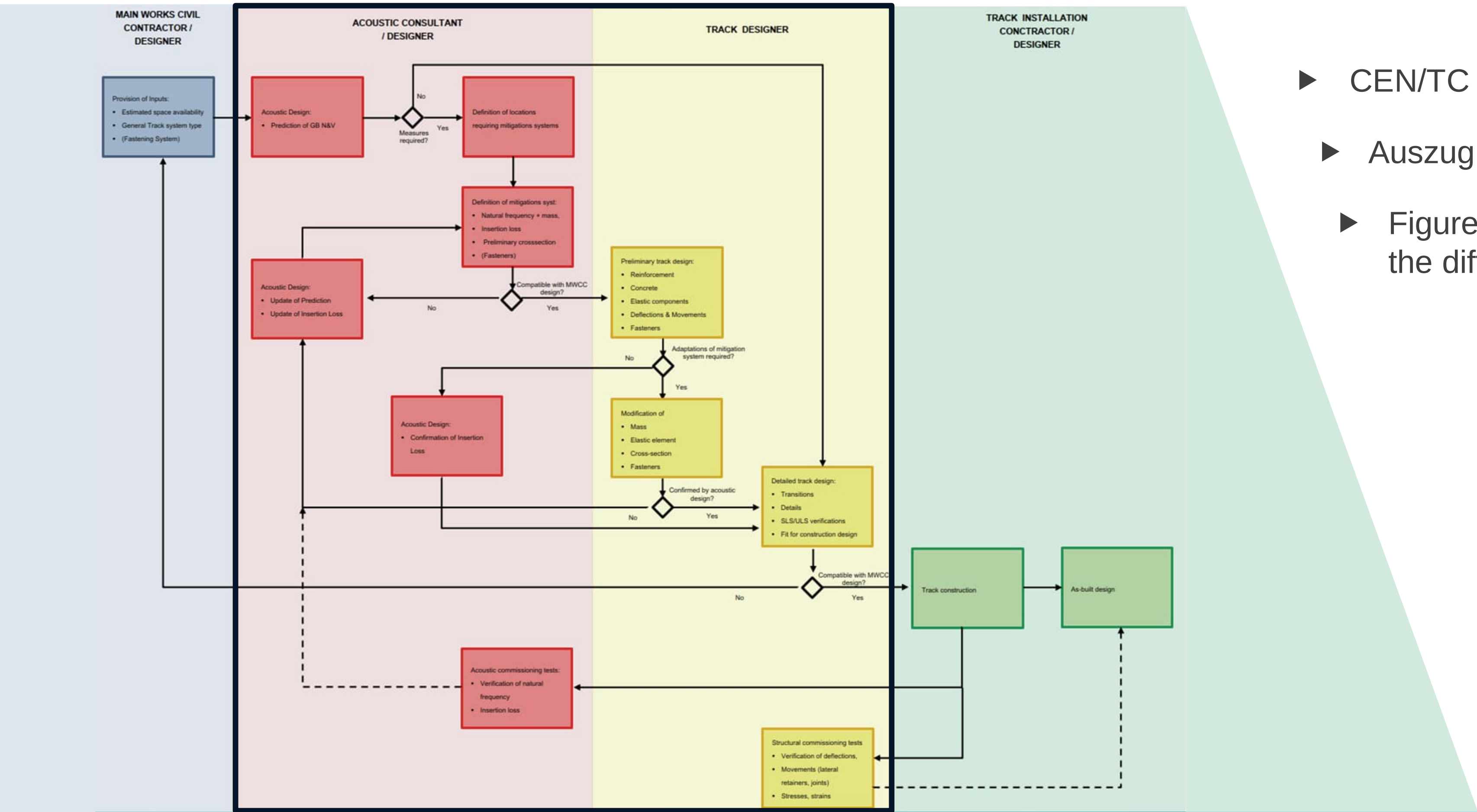
VCE Projects in Chile



Introduction



- CEN/TC 256/SC 1/WG 46 N 371
  - Auszug prEN 16432-4:2024 (E)
    - Figure A.1 — Interfaces between the different designers

Vibration Prediction

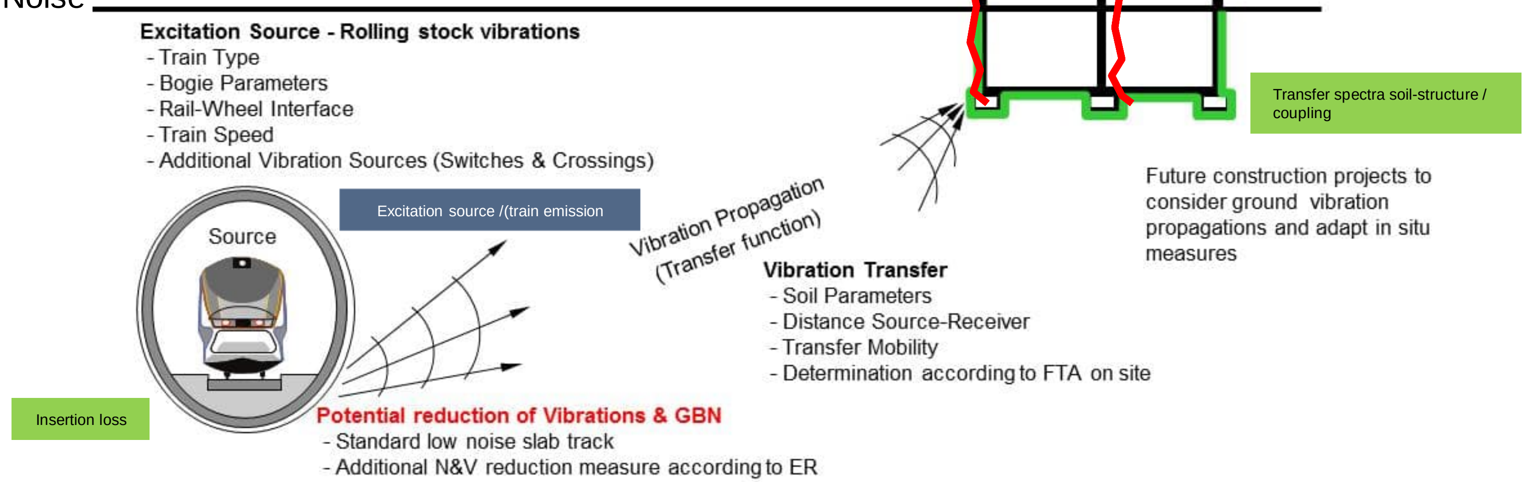
- Semi-empirical forecast model
  FTA Transit Noise and Vibration Impact Assessment Manual, 2018

$$I(f) = F[S(f), M(f), T_1(f), T_2(f), R(f)]$$

$I(f)$ … Vibration and GBN Impact as a function of frequency
$S(f)$ … Excitation source (Train Input)
$M(f)$ … Mitigation measures as a function of frequency
$T_1(f)$ … Vibration transmission through soil
$T_2(f)$ … Vibration Transfer Subsoil-Building Foundation
$R(f)$ … Amplification inside Receiver

- Train Emissions
- Insertion Loss
- Soil Transmission F.
- Coupling
- Bldg Transmission F.
- Safety Factor

Immissions
Vibration
Secondary Noise



PROCESS OF GBNV

Methodology according to FTA

1. **Early Identification of Sections without mitigation measures**
2. **Determination of Sensitive Receivers**
   - Residential buildings
   - Hospitals, schools, historic monuments
3. **Measurements of vibration emission of the excitation source**
   - Train emission data (Source spectra)
4. **Vibration transmission through track system, tunnel and soil/rock**
   - Clustering / sectioning
   - Evaluation of subsoil parameters
   - Numerical Simulations to assess vibration transfer
5. **Vibration transmission through the buildings along the track**
   - Structural / dynamic parameters of sensitive buildings (Transfer of Vibrations inside buildings)
   - Hospitals, schools, historic monuments
   - Collection of building parameters on site
6. **Prediction and verification of ground borne noise and vibration limits in the buildings**
   - Operational data, track alignment (e.g. turnout locations)
   - Verification of limit criteria for each sensitive receiver
7. **Selection and extent of mitigation measures**
   - Design of mitigation measures (structural & dynamic design, insertion loss)
   - Definition of mitigation lengths
   - Design of transition zones between standard track and upgraded track

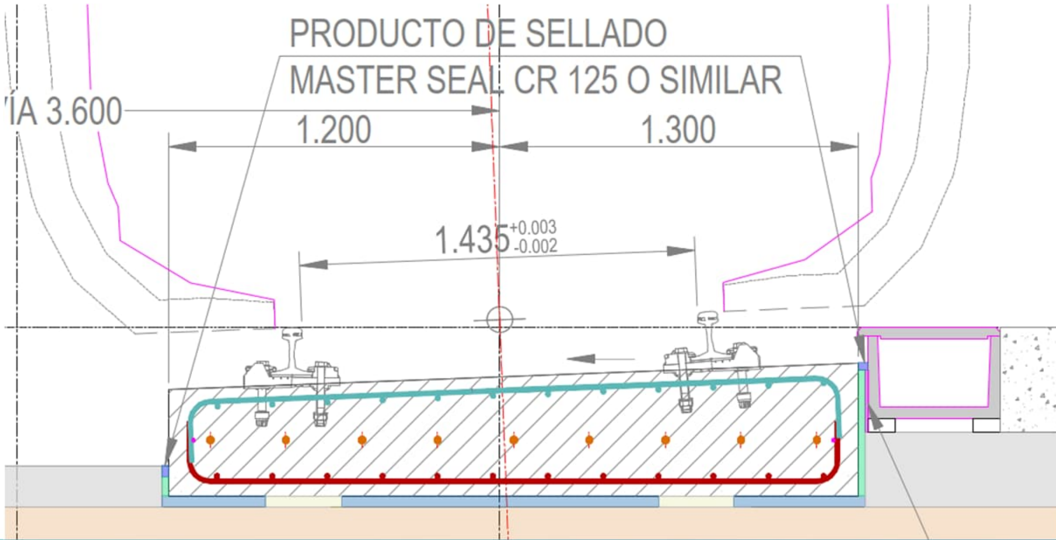
Vibration Prediction

- Requirements for

  Vibration Protection Measures:

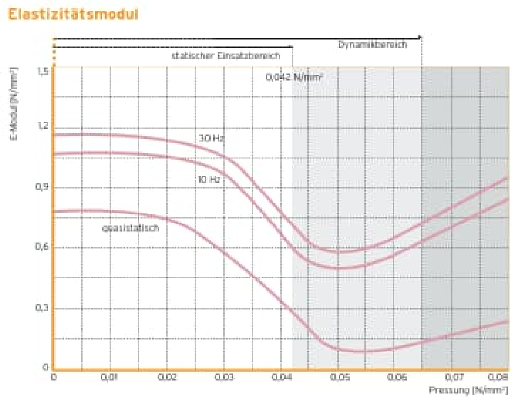
  - Slab track with rigid single support points as reference system or in areas without requirements
  - Slab track with highly elastic rail support points; resonance frequency 50 Hz < f0 < 60 Hz
  - Mass-spring system on 40 mm surface bearings, resonance frequency f0 = 15.5 Hz
  - Mass-spring system on 50 mm surface bearings, resonance frequency f0 < 13.5 Hz

  - Additional requirements for **Insertion Loss**

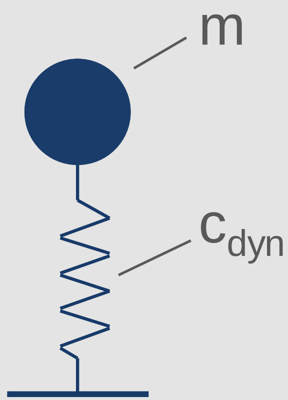


Dynamic superstructure design mass-spring systems

- Calculation of the natural frequency based on the theory of the single-mass oscillator
- Determination of the **dynamic Stiffness c_{dyn}**
  - Pressure of the elastic (surface) bearings from the calculation model
  - Dynamic bearing stiffness from the product data sheet or similar.



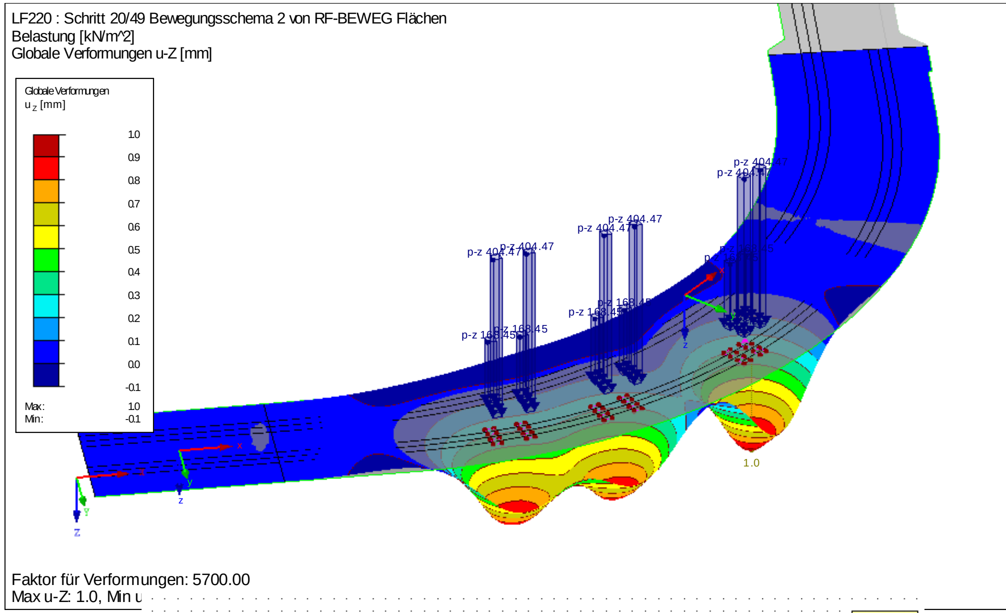
- Determination of the **effective dynamic Masses m**
  - Dead weight of track slab/rails/fastenings/track covering
  - Proportional to train mass (unsprung wheelset mass)

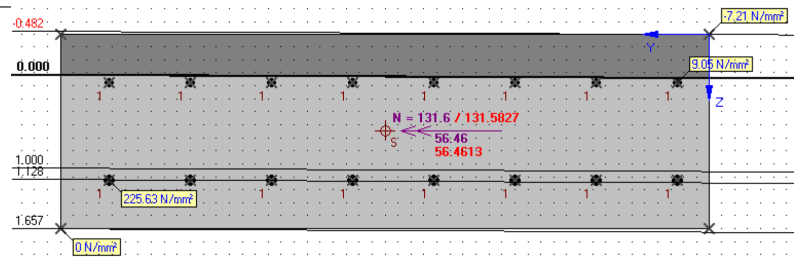


$$f_0 = \frac{1}{2\pi} \cdot \sqrt{\frac{c_{dyn}}{m}}$$

Static Calculation of the Structure

- Determination of the **internal forces** in the calculation model
- Selection of **reinforcement quantity**
- **Verification**
  - Load-bearing capacity (ULS)
  - Serviceability (SLS): Deformation & Crack Widths
  - Fatigue (FLS)
- **Standards** for structural verification
  - Actions/loads acc. EN 1991-2
  - Concrete structures acc. EN 1992-1-1, EN 1992-2
  - Properties of elastic bearings acc. EN 17682 (formerly DIN 45673-7)
  - Currently in progress: prEN 16432-4 „Bahnanwendungen Feste Fahrbahn-systeme - Teil 4: Spezielle Feste Fahrbahn-Systeme zur Vibrationsdämpfung"

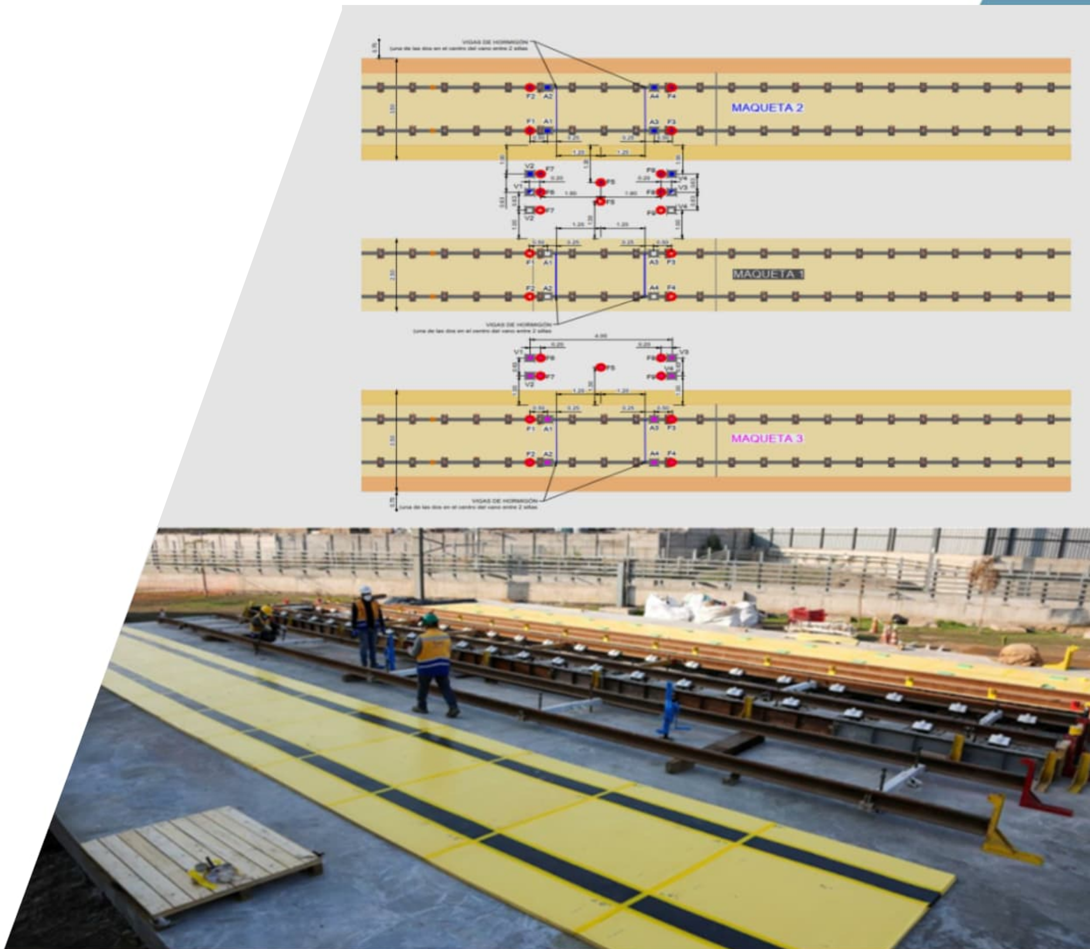




Construction and Manufacturing

- Verification before installation on specially manufactured mock-ups
- Measurement of the system natural frequencies on the loaded / unloaded system
- DIN 45673-3 Measurement of insertion loss / left/right method
- Consider transmission admittance

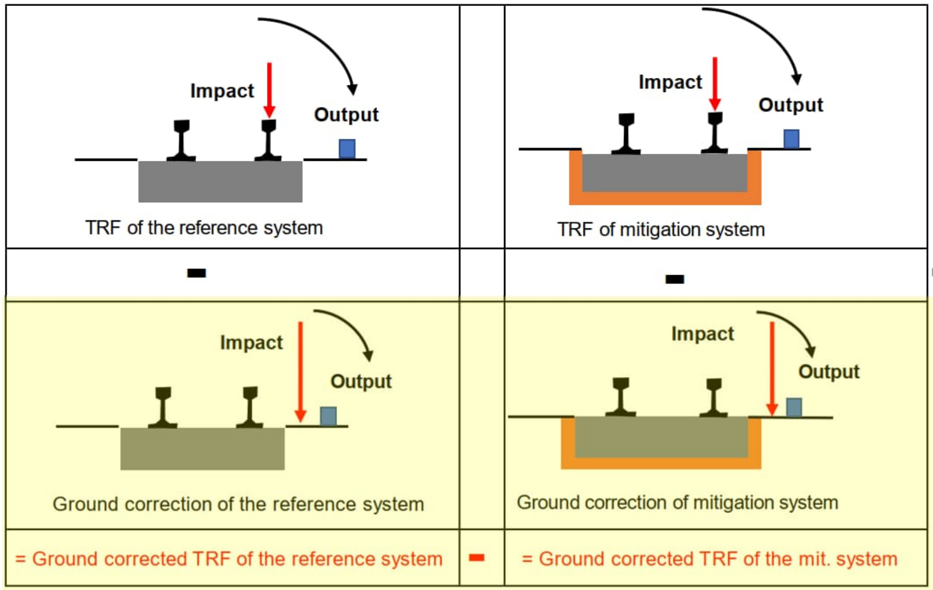
Measurment Position	Limit value	Limit value
M01	f'0<[100-160Hz]	f0<[50-60Hz]
M02	f'0<[100-160Hz]	f0<[50-60Hz]
M03	f'0<[100-160Hz]	f0<[50-60Hz]
M05	f'0<18,5 Hz	f0<15,5 Hz
M06	f'0<18,5 Hz	f0<15,5 Hz
M07	f'0<18,5 Hz	f0<15,5 Hz
M08	f'0<18,5 Hz	f0<15,5 Hz
M09	f'0<18,5 Hz	f0<15,5 Hz
M10	f'0<18,5 Hz	f0<15,5 Hz
M11	f'0<15,5 Hz	f0<13,5 Hz
M12	f'0<15,5 Hz	f0<13,5 Hz
M13	f'0<15,5 Hz	f0<13,5 Hz



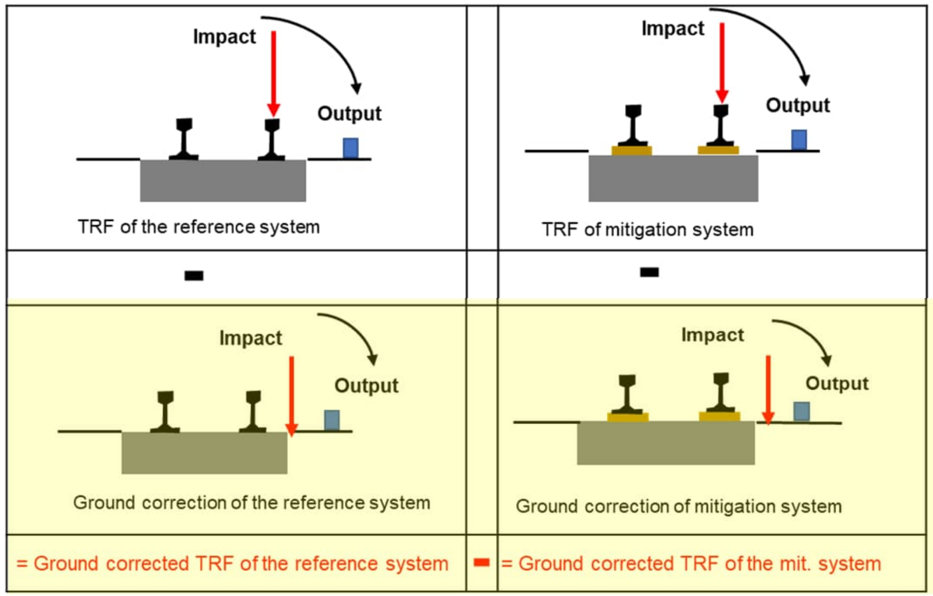
Measurement Results

Phase 3.1 – Calculation procedure of the insertion loss

Insertion loss – Track on MSS



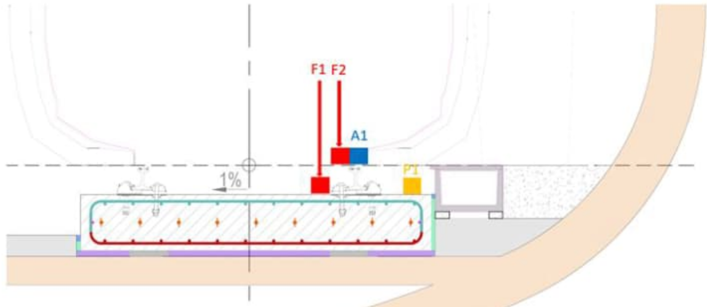
Insertion loss – Track with elastic soles

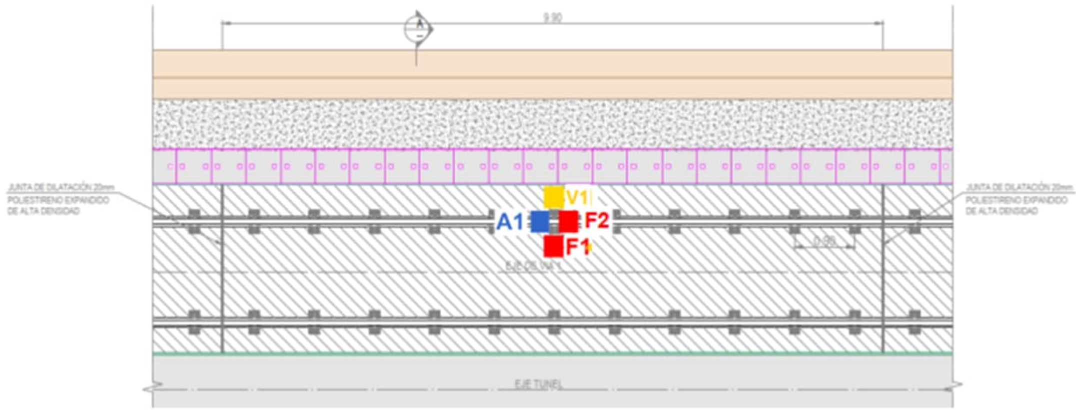


Insertion loss determined according to DIN SPEC 45673-3 (Left-Right approach)

TRF – transfer function
MSS – mass spring system
– concrete block
– Sensor on Sideway
– spring (elastic element)
– railpad (elastic element)
– Rail

In Situ Measurements: Unloaded System

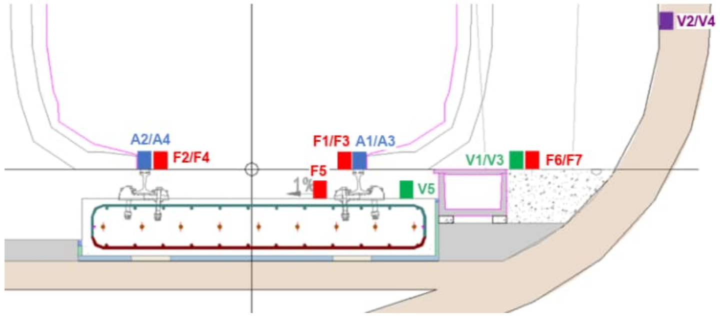




Measurement Position	natural frequency [all signals]	natural frequency [signals removed]	Limit value
M01	214,2	214,2	f0<[50-60Hz]
M02	172,9	172,9	f0<[50-60Hz]
M03	214,8	214,8	f0<[50-60Hz]
M05	12,5	12,5	f0<15,5 Hz
M06	14,6	14,6	f0<15,5 Hz
M07	14,3	14,3	f0<15,5 Hz
M08	12,7	12,7	f0<15,5 Hz
M09	12,6	12,5	f0<15,5 Hz
M10	13,2	13,4	f0<15,5 Hz
M11	11,7	11,7	f0<13,5 Hz
M12	12,7	12,7	f0<13,5 Hz
M13	11,7	11,7	f0<13,5 Hz

- Natural frequency
- Direct track with elastic soles shows unclear f_0
- MSS with 40mm fulfill the requirements
- MSS with 50mm fulfill the requirements

In Situ Measurements: Static Loaded System



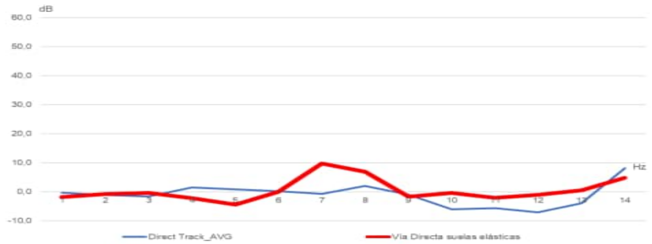
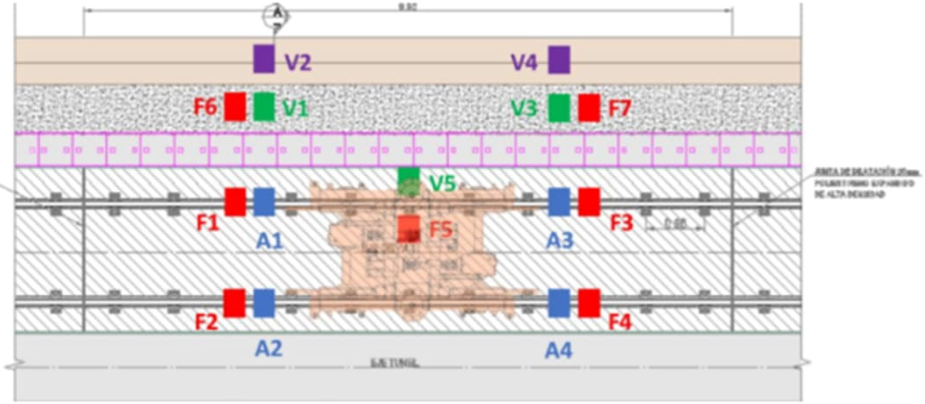


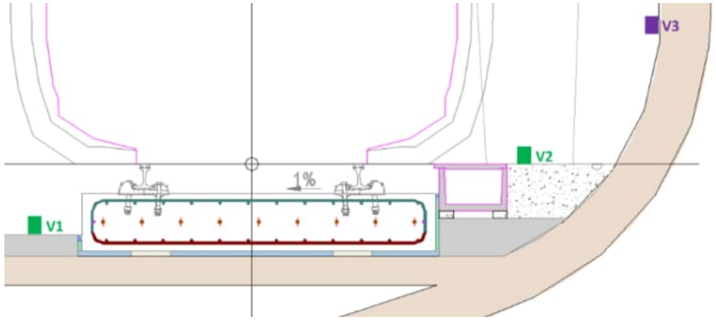
Figure 81: IL summary over all direct track elastic soles sections.

Figure 82: IL summary over all MSS sections (excl. sections with 50 Hz issues [1]



- Results improve when averaged
- Small spread among section of same type
- Ground correction was considered

In Situ Measurements: Trains Passings



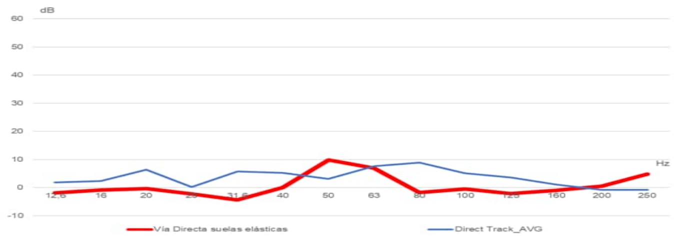


Figure 103: IL summary over all direct track elastic soles sections.

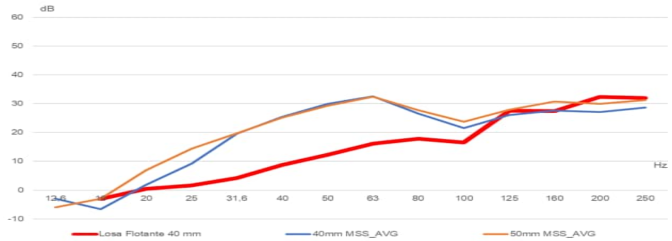
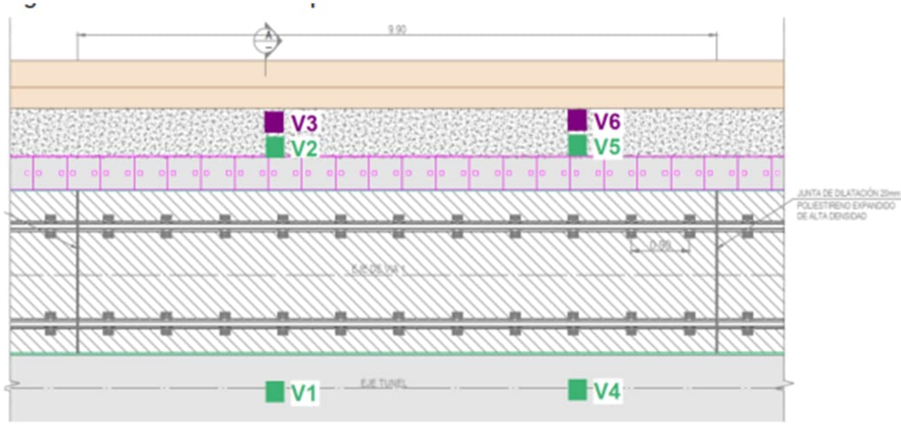


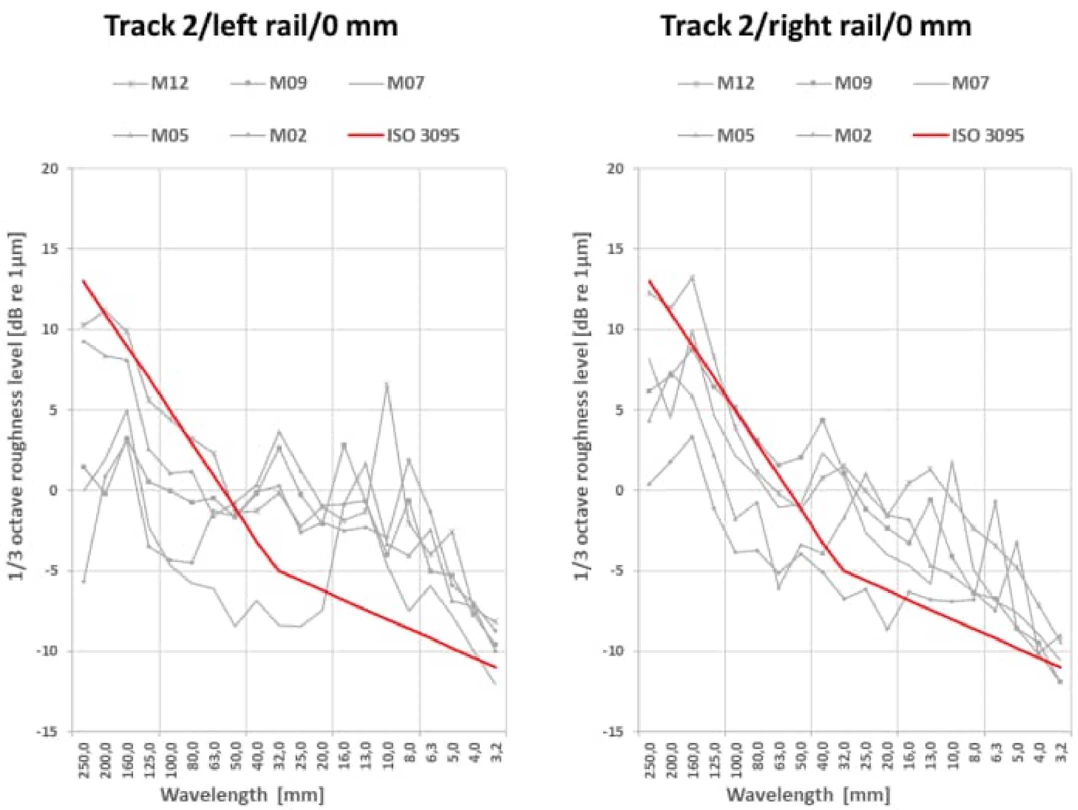
Figure 105: IL summary over all MSS sections.



- Results improve when averaged
- Small spread among section of same type
- Ground correction was considered

Measurement Results

Phase 3.3 – Rail Roughness



- ISO Requirement is generally fullfilled for wavelength < 40 mm
- Most roughness values are in a bandwidth ± 5 dB with a max diffrence of 10 dB
- Vibration due to rolling wheel is comparable and reliable

Findings

1 Vibration engineering and track construction planning are usually carried out by different planners.

2 Early involvement of the civil engineering planners, vibration engineers, track construction planners and exchange of information between all parties involved is required.

3 Interfaces must be defined and the planning process is iterative.

4 During the mock-up tests and during the measurements on the unloaded and statically loaded system, the effect could not be proven due to a lack of pre-pressing.

5 During the on-site measurements, it was demonstrated that all basic requirements were met.

6 However, particularly in the case of highly elastic rail support points, it has been found that these only exert their protective effect when trains pass by.

Thank you for your attention!

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