INTERNATIONAL UNION
OF RAILWAYS

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Vibration State of the Art Report 1

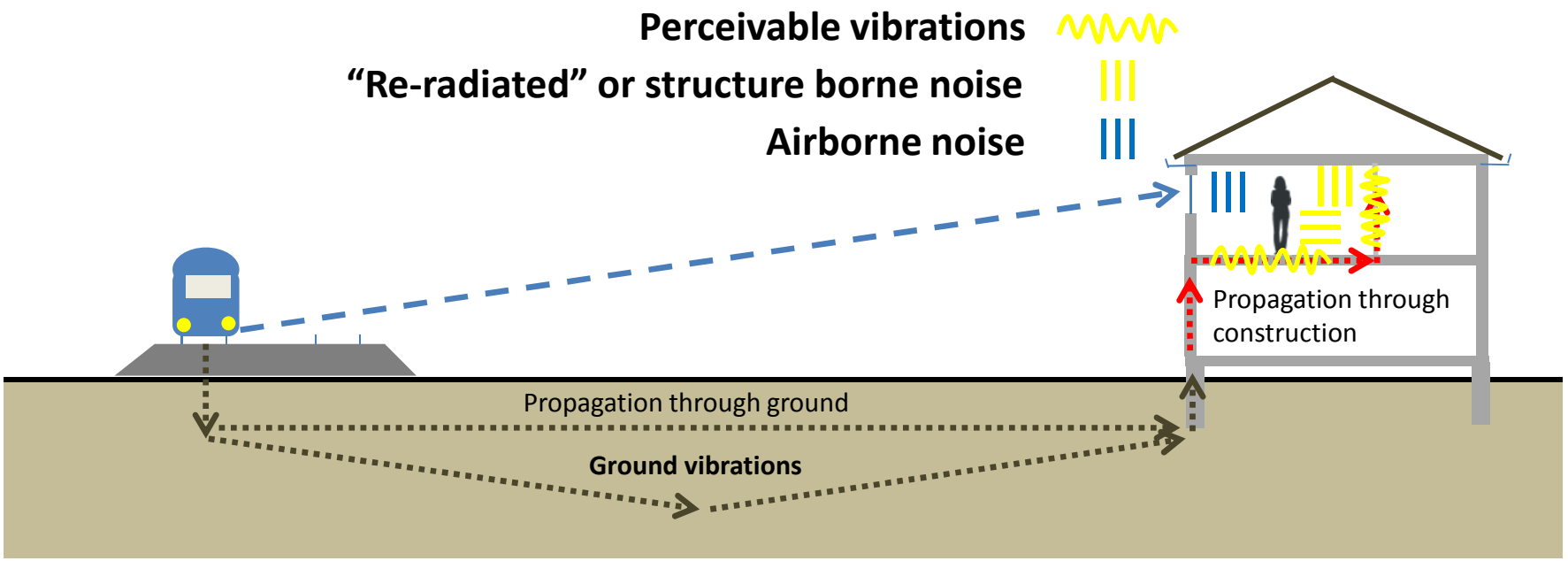
General mechanisms

14 November 2017

Baldrik Faure, SNCF

From generation to reception

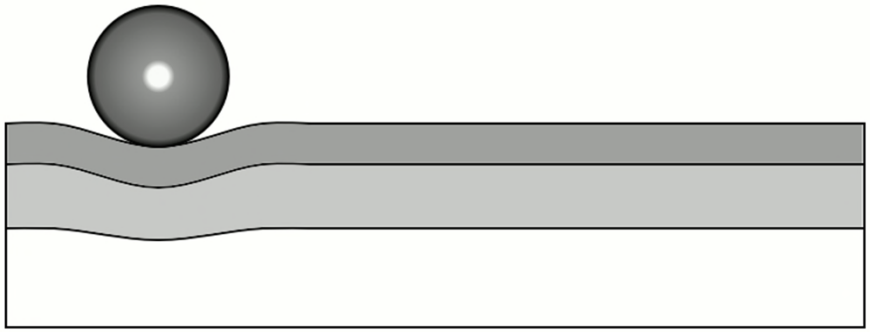
- Generation at the wheel/rail interface
- Transmission from track to ground
- Propagation through ground
- Transmission from ground to building
- Propagation through construction



Generation mechanisms

Quasi-static excitation

- Moving load on an elastic foundation
- Occurs even with perfect running surfaces
- Observed at a static position in the railway track



Characteristics

- Low frequency content, high amplitude
- Harmonic components at the passing frequencies of the axles, bogies and cars
- Influence of the whole vehicle mass
- Small influence of speeds (for low speeds)
- Do not really propagates in the ground away from the track, except for specific conditions (high speeds or soft grounds)

Generation mechanisms

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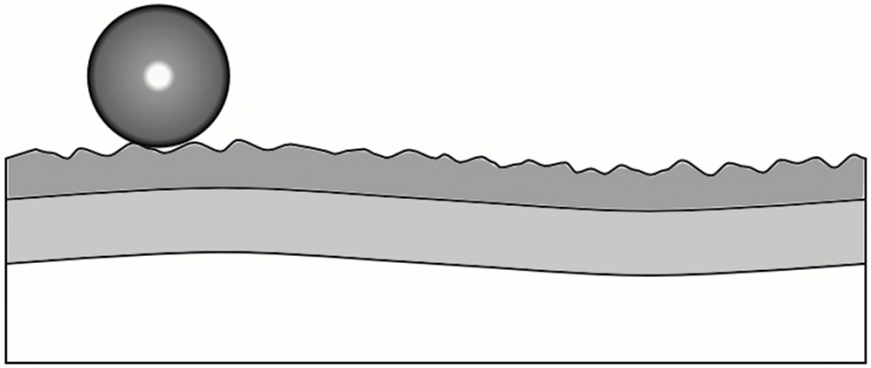
Dynamic excitation

- Vertical displacement of the wheel/rail contact imposed by the irregularities of the running surfaces
- Irregularities = roughness and defects (wheel and rail)
- Observed at the moving wheel/rail contacts



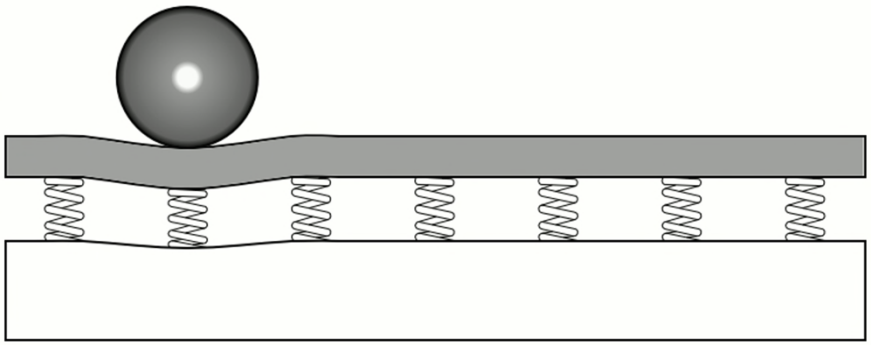
Characteristics

- Broadband content
- Influence of the unsprung masses (axles)
- Influence of speed on the frequency content
- Excitation of low amplitude
- Propagates in the ground away from the track

Generation mechanisms

Parametric excitation

- Spatial variation of the track's stiffness
- Can be periodic (rail fasteners) or local (hanging sleeper)
- Occurs even with perfect running surfaces
- Observed at a static or moving position



Characteristics

- Harmonic excitation in the case of the sleeper passing frequency, broadband excitation for local causes (hanging sleeper)
- Influence of the unsprung masses (axles)
- Influence of speed on the amplitude and the frequency content
- Excitation of low amplitude (~ same as dynamic), propagation in the ground

Generation mechanisms

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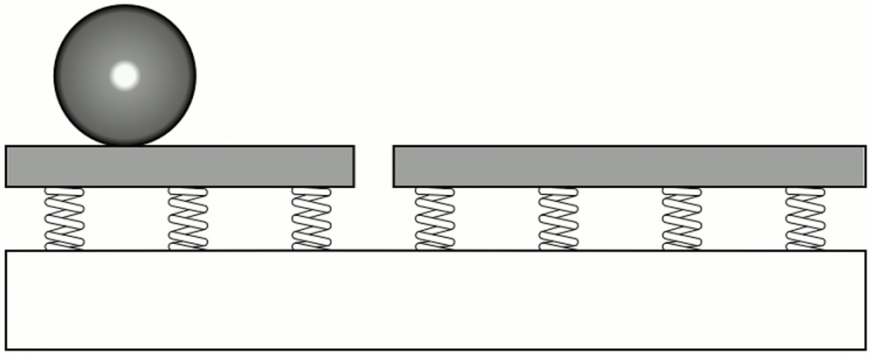
Singular excitations

- Local singularity in the track but no defect (joint, crossing)
- Vertical displacement of the whell/rail contact when crossing the gap
- Observed at a static or moving position



Characteristics

- Broadband excitation, high amplitude
- Higher influence of the unsprung masses (axles) than vehicle mass
- Influence of speed on the amplitude and the frequency content
- Influence of the geometry of the singularity
- Propagates in the ground

Propagation in the ground

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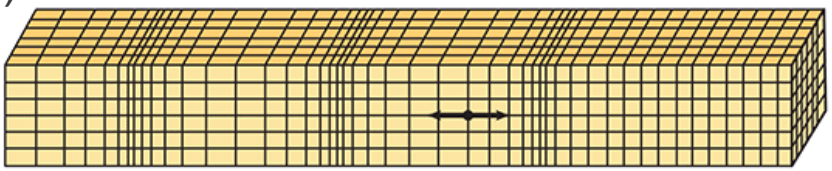
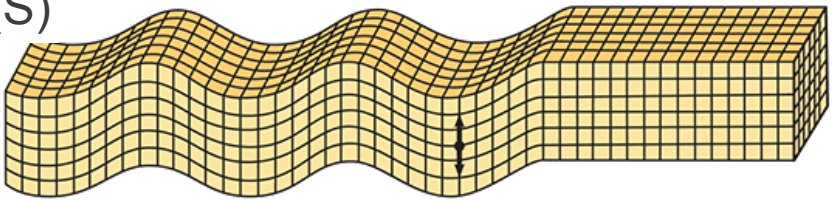
Three types of waves involved

- Compression waves (P), also called P-Waves, with the highest propagation speed, attenuation in $1/r^2$
- Shear waves (S), with lower speed, attenuation in $1/r^2$
- Surface waves (R), also called Rayleigh waves which are a combination of both S and P waves.

(P)



(S)



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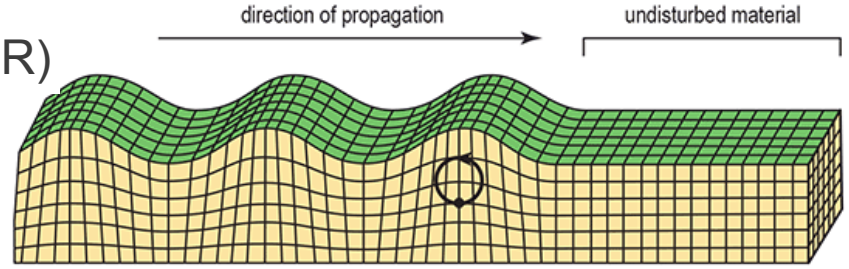

- Rayleigh waves are the slowest waves but the most energetic
- Attenuation in 1/r

Propagation in the ground

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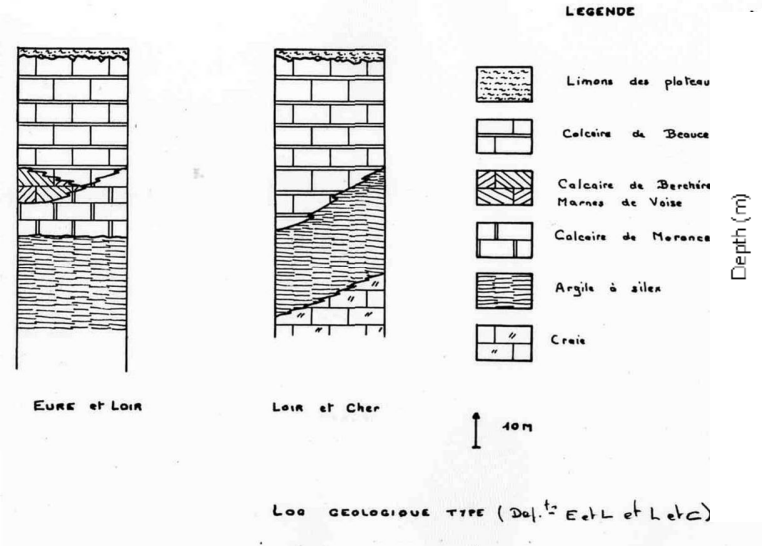
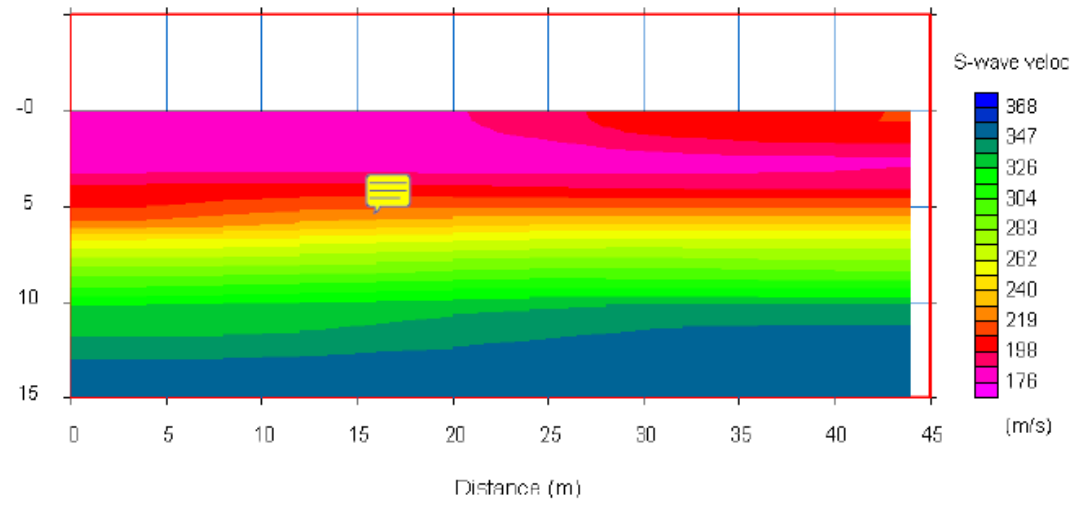
The properties of the soil determine those of the propagation

- The soil is not homogeneous but is more or less a semi-infinite layered space
- Characterization methods like SASW or MASW to measure its properties
- Understanding a GBV issue requires as much knowledge on the soil properties as on other track parameters for example (in Europe: very soft and very hard soils)



Log geologique type (Dpt. Eet L et L et C)



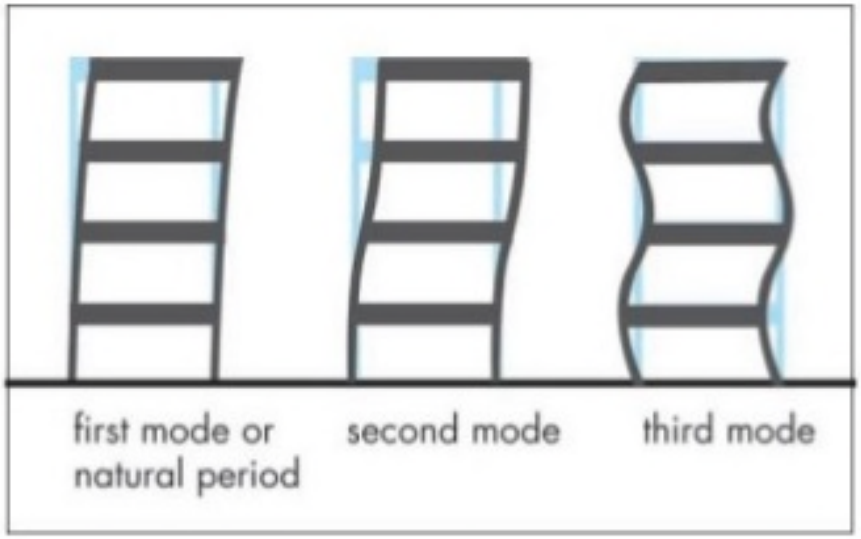
Constructions response

Coupling between the ground and the foundations

- Complicated phenomena
- Depends on the foundation geometry

Response of the construction

- Modal response of the construction
- Depends on the shape and materials
- Vibration level amplification between foundation to floors can occur up to 15x
- !! When the frequency content of the foundation excitation matches a resonance frequency of the building !!



Important characteristics

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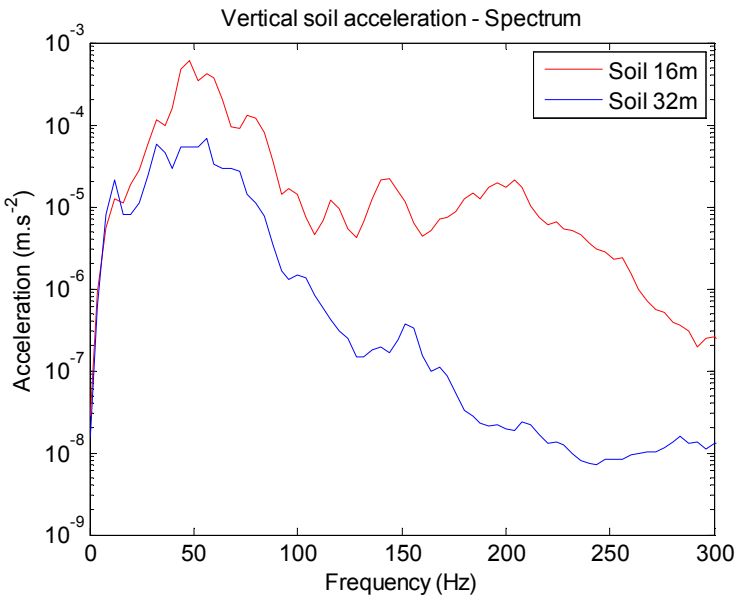
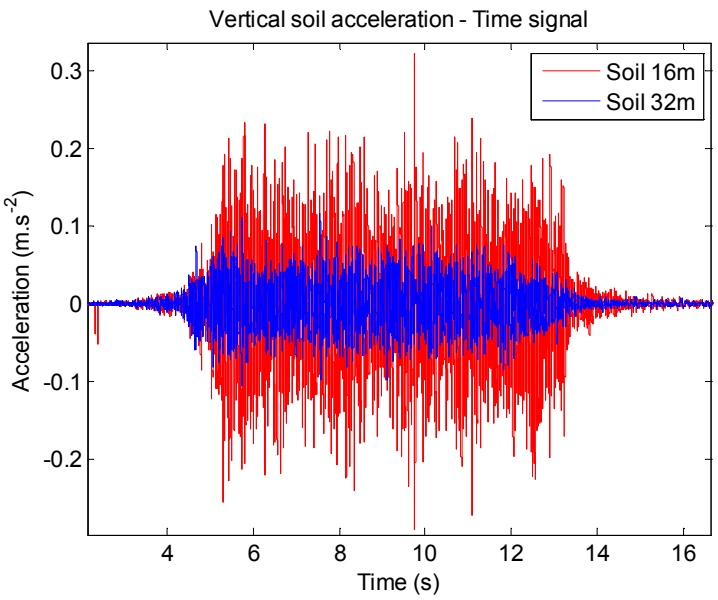
Signal approach

- Displacement, velocity or acceleration?
- Orientation in space
- Frequency content (broadband or tonal)
- Amplitude
- Duration





➔ Difficulties to build standards and indicators!

Train/Track behaviour

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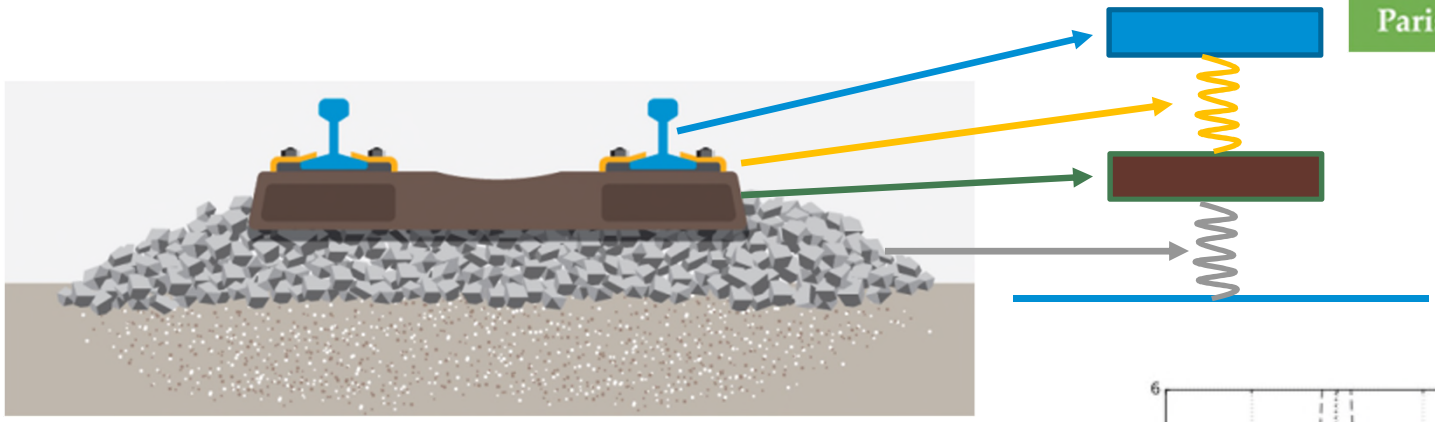
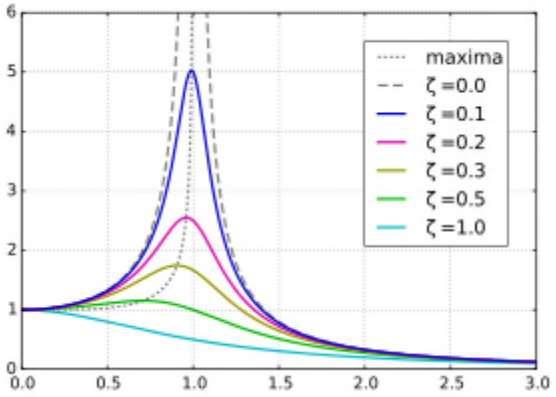
Railway track ≈ Mass / Spring system



Low-pass filter



- Low frequencies are well transmitted
- Amplification at the resonance frequency (vehicle on track)
- Higher frequencies are cut-off
- Basically no railway induced vibration in the ground above 250 Hz

Train/Track behaviour

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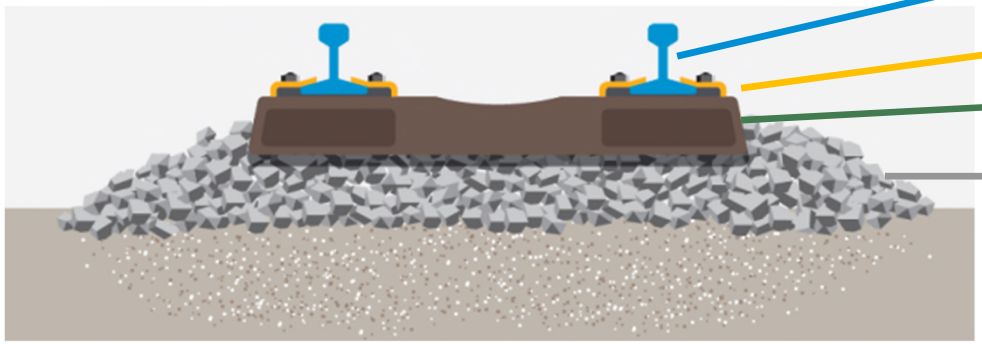
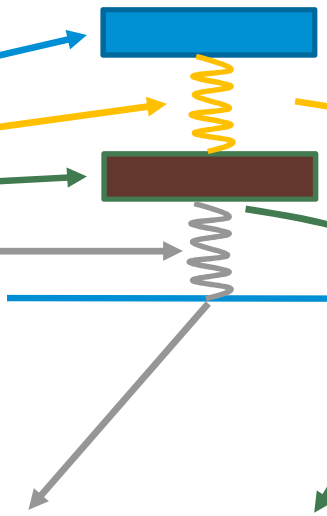
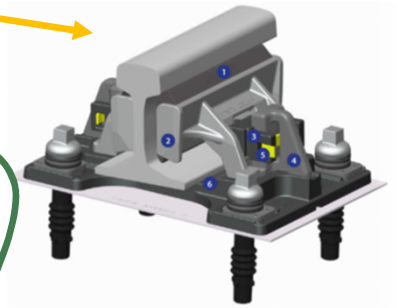
Track stiffness adjustment

➔ Modification of the low-pass filter properties







Cut-off frequency: $f_c = \sqrt{k/M}$

- Lower k for lower f_c
- Higher mass for lower f_c
- The “deeper” the softening in the track, the lower the cut-off frequency

Key points

Railway induced vibration:

Complex mechanisms from generation to reception

- The railway system is only a single part of the problem (generation)
- Equivalent importance of the vehicle/track interaction, the ground propagation and the construction's response
- The previous three may vary a lot from one case to another
- Complex phenomena involved and that concern different protagonists
- Prediction tools are not completely satisfactory
- What about measurement standards, indicators and legal framework?

Thank you for your attention! Do you have any question?