2024 European Light Rail Congress

Ernesto San Vicente

Pandrol

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Shaping sustainable rail infrastructure with innovative solutions

Pandrol Sustainable Resilient Systems

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Stakeholders expectations in Transit projects

What is expected from a Modern Track System?

- Installation and constructability
- Safety
- Track quality
- Ride comfort
- Vibration
- Stray currents
- Availability
- Reliability
- Lifetime
- Aesthetic
- Maintenance
- Sustainability

Stakeholders expectations in Transit projects

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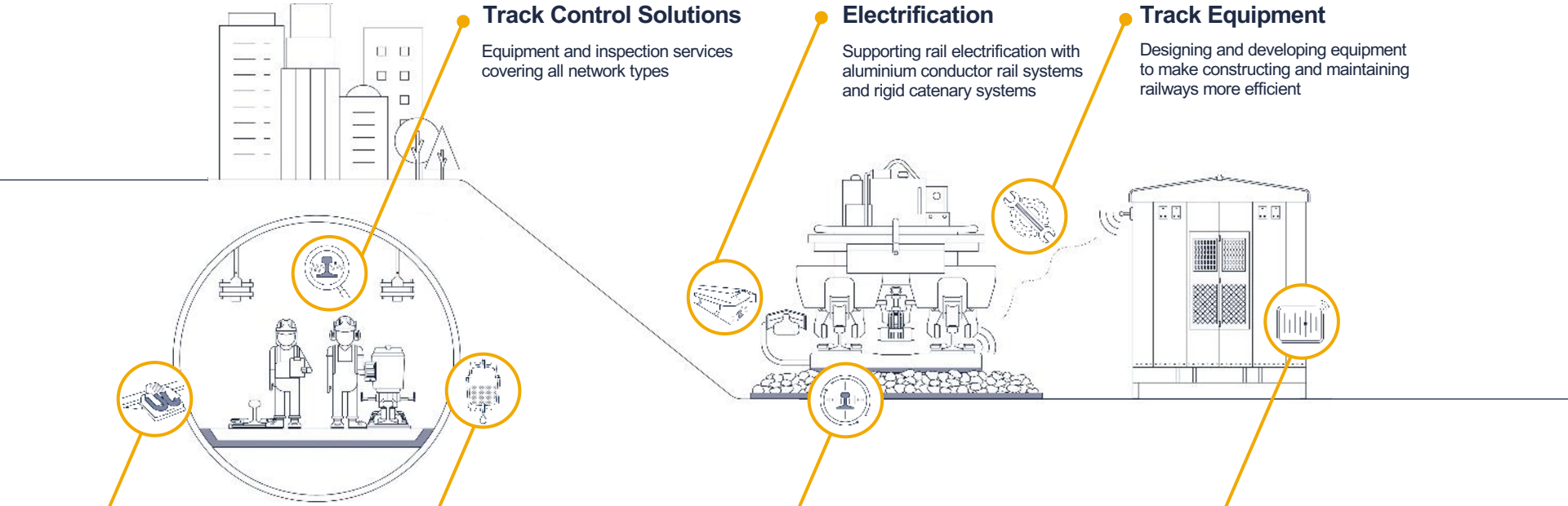
Pandrol integral track expertise



Track Control Solutions

Equipment and inspection services covering all network types

Electrification

Supporting rail electrification with aluminium conductor rail systems and rigid catenary systems

Track Equipment

Designing and developing equipment to make constructing and maintaining railways more efficient

Fastening Systems

Specialist in track engineering, track maintenance and analysis and noise and vibration attenuation

Aluminothermic Welding

Delivering technical expertise, innovative solutions and in-track services

Sustainable Resilient Systems

Environmentally sustainable systems to improve the life cycle of track components and treat structural noise and vibrations

Condition Monitoring

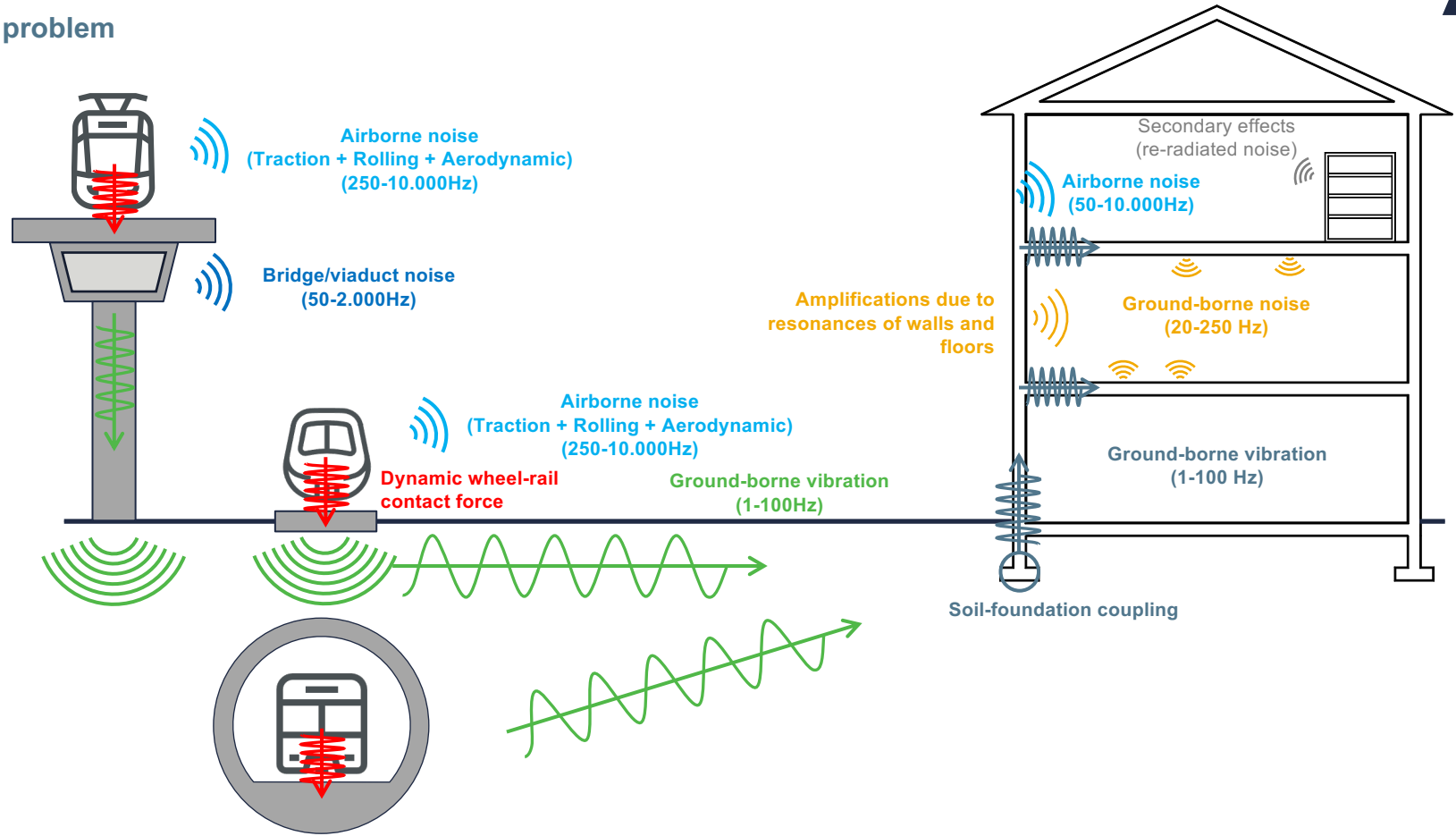
Smart control systems to increase productivity, monitor track conditions and improve life cycle

Noise and vibration

The basics

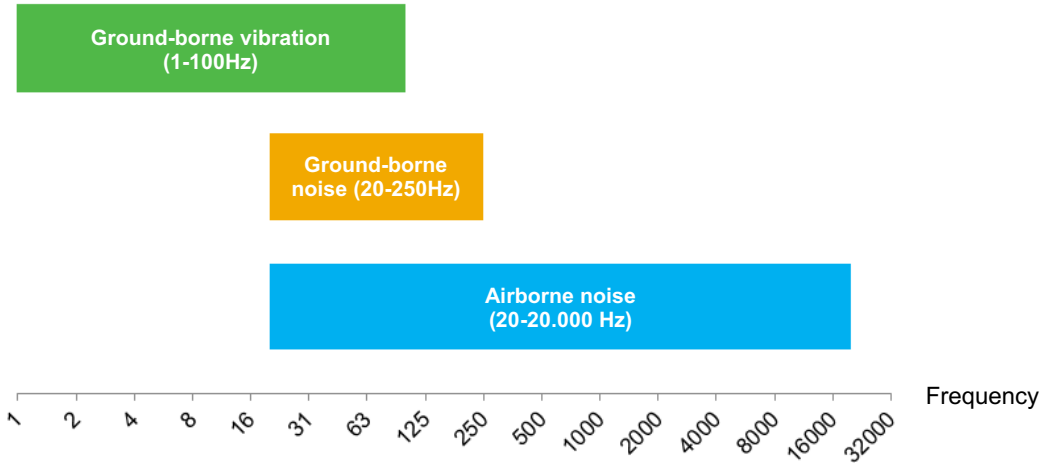
Noise and vibration

The problem



Noise and vibration

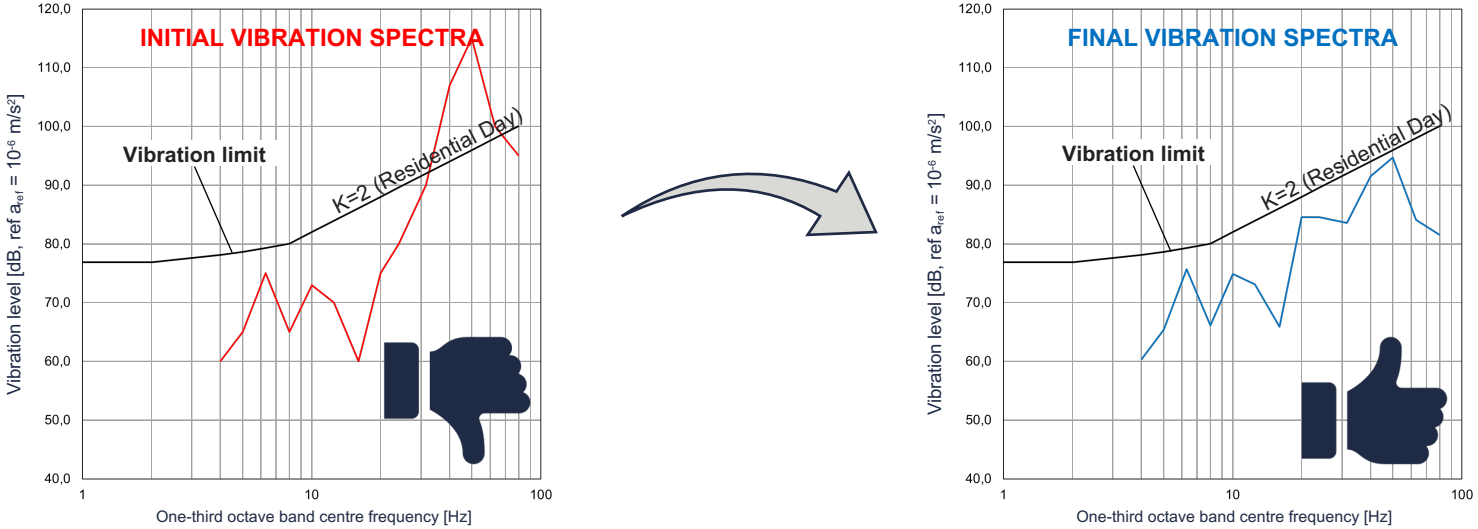
The problem



The graph shows that there is a frequency range where all the three phenomena are relevant, roughly between 20 and 100Hz.
In this range it can be difficult to distinguish one from the other

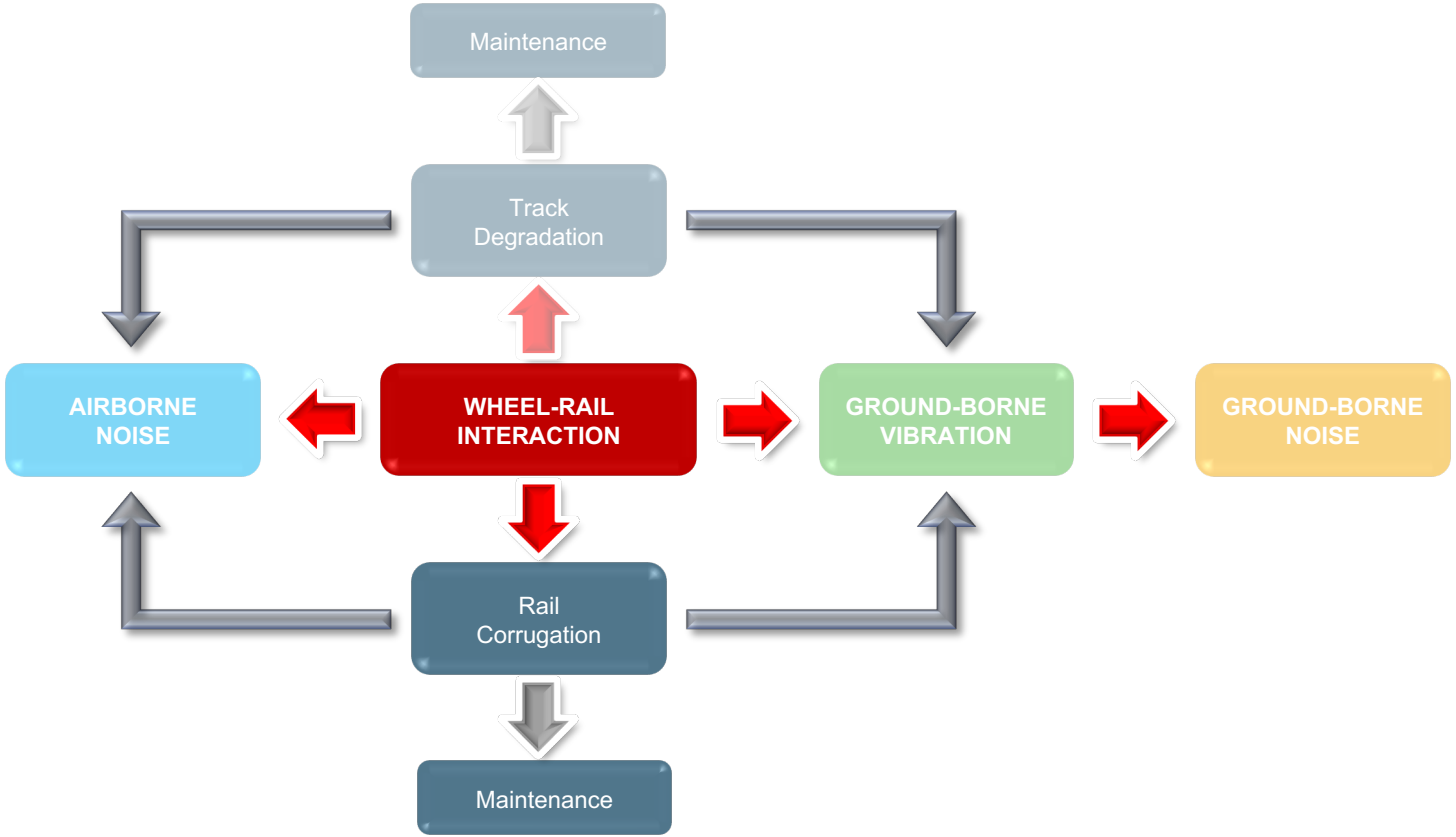
Noise and vibration

The objective



Noise and vibration

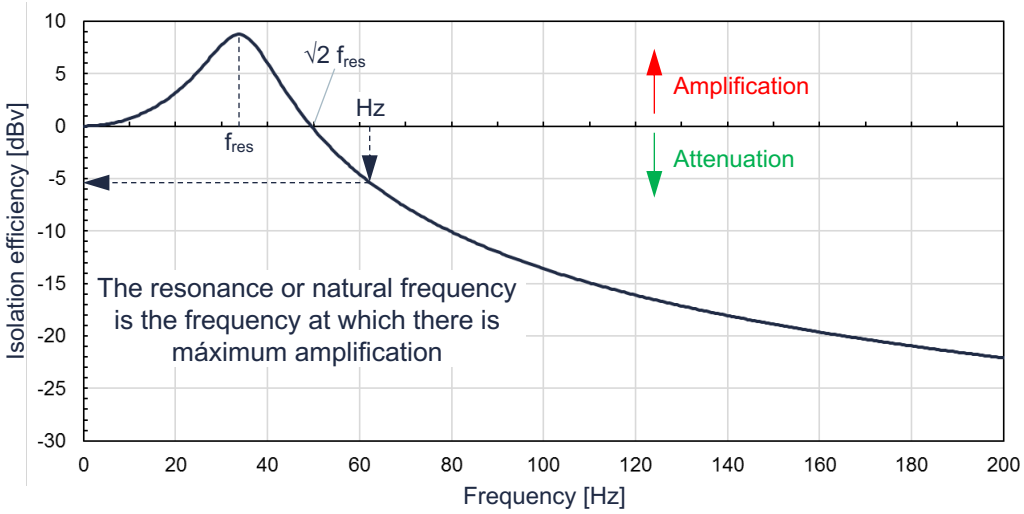
Direct effect of correct track resilience design

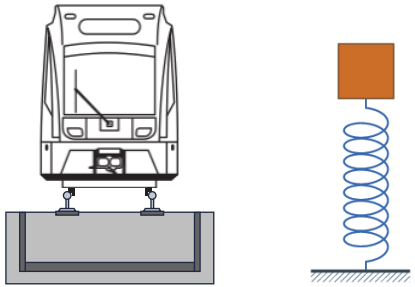


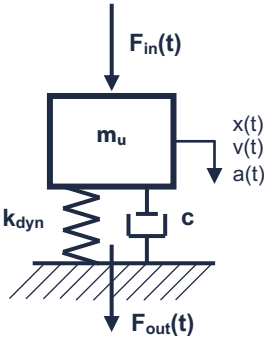
Noise and vibration

Track isolation principles

— The track can be modelized as a 1 DOF system consisting in a mass (the train) on an spring (the elastic medium) with specific stiffness and damping characteristics







$$f_{res} = \frac{1}{2\pi}\sqrt{\frac{k_{dyn}}{m_{unsprung}}}$$

Noise and vibration

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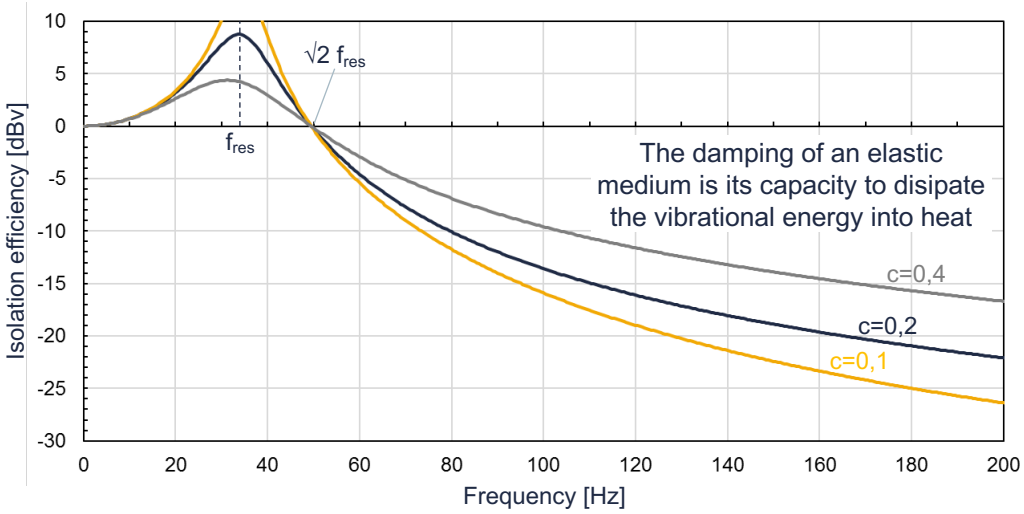

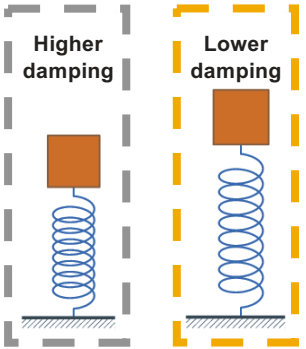

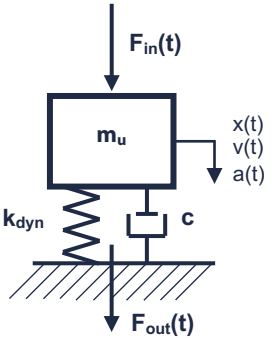

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Noise and vibration

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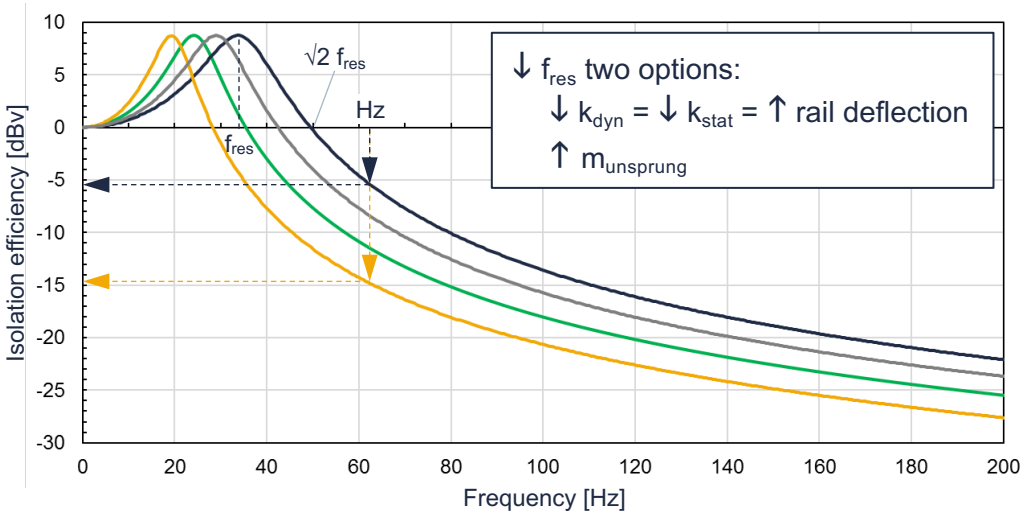
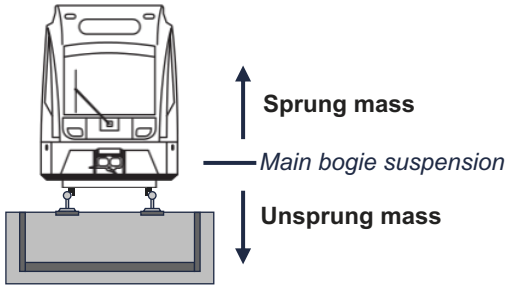
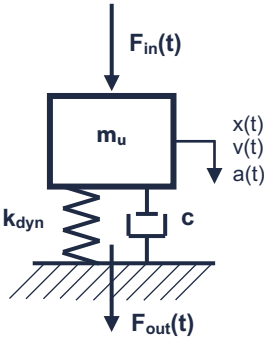




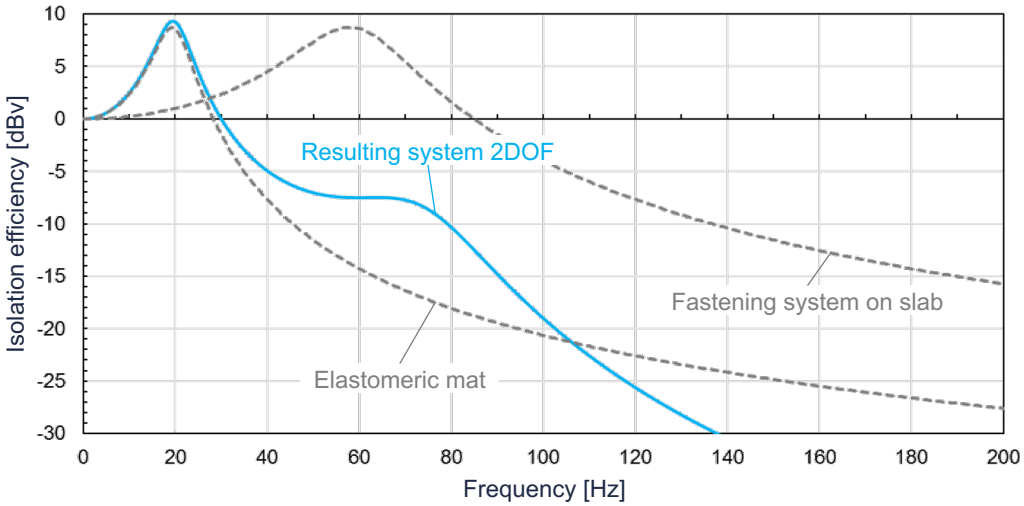


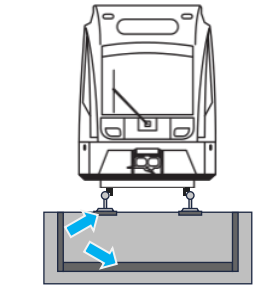
$$f_{res} = \frac{1}{2\pi}\sqrt{\frac{k_{dyn}}{m_{unsprung}}}$$

Noise and vibration

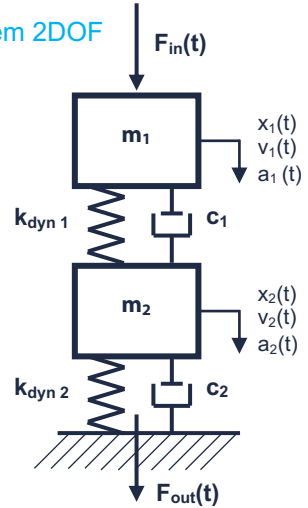
Track isolation principles

— **Multi Degree of Freedom**: supposes more than one elastic medium within the same system
— Represents better the reality





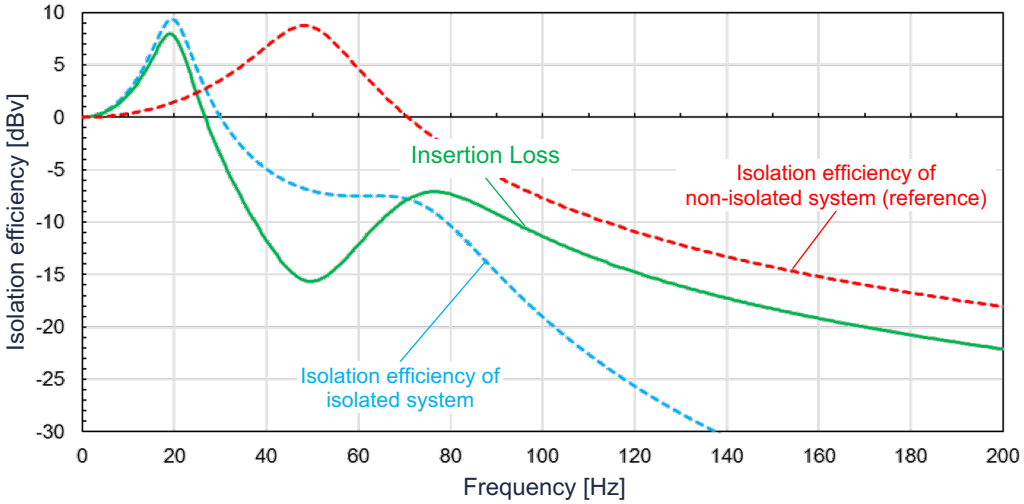
Isolated system 2DOF

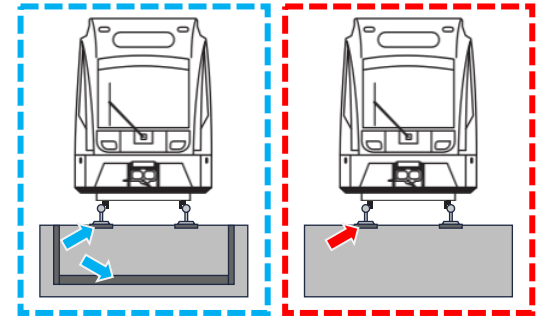


Noise and vibration

Track isolation principles

— **Insertion loss (IL)** determines the performance of a mitigation measure
— It is a comparison between 2 systems, not a “property” of a system:





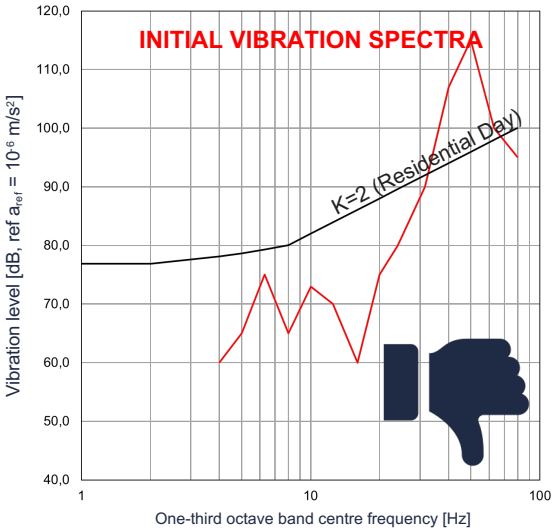
$IL = dBv_2 - dBv_1$

Noise and vibration

Track isolation principles

— **Insertion loss (IL)**. Practical application

$IL = dBv_2 - dBv_1$ → re-writing: $dBv_1 + IL = dBv_2$



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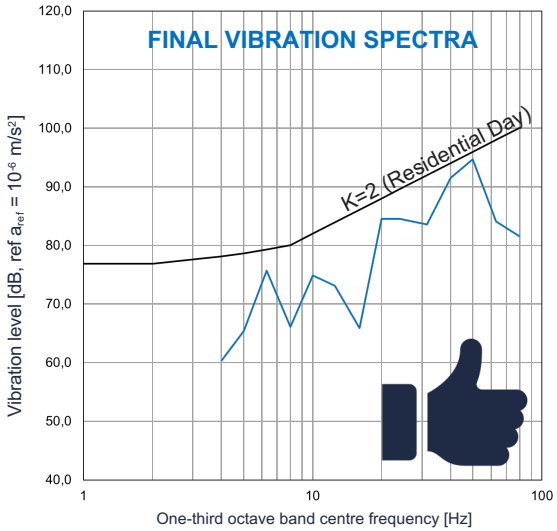
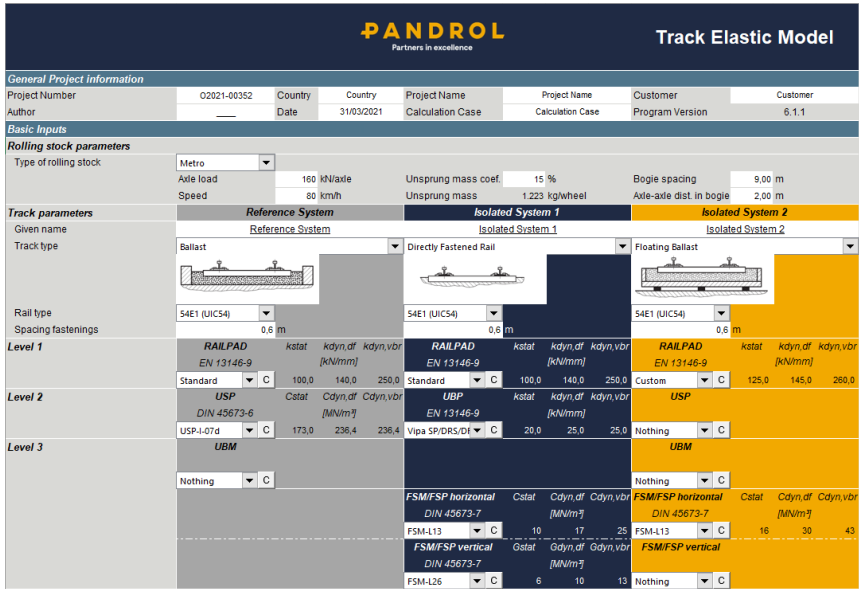


Noise and vibration

Track Elastic Model (TEM) simulating software



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Track Elastic Model

General Project information							
Project Number	02021-00352	Country	Country	Project Name	Project Name	Customer	Customer
Author	___	Date	31/03/2021	Calculation Case	Calculation Case	Program Version	6.1.1

Basic Inputs								
Rolling stock parameters								
Type of rolling stock	Metro							
	Axle load	160	kN/axle	Unsprung mass coef.	15	%	Bogie spacing	9,00 m
	Speed	80	km/h	Unsprung mass	1.223	kg/wheel	Axle-axle dist. in bogie	2,00 m

Track parameters	Reference System	Isolated System 1	Isolated System 2
Given name	Reference System	Isolated System 1	Isolated System 2
Track type	Ballast	Directly Fastened Rail	Floating Ballast
Rail type	54E1 (UIC54)	54E1 (UIC54)	54E1 (UIC54)
Spacing fastenings	0,6 m	0,6 m	0,6 m
Level 1	RAILPAD EN 13146-9	RAILPAD EN 13146-9	RAILPAD EN 13146-9
	kstat / kdyn,df / kdyn,vbr [kN/mm]	kstat / kdyn,df / kdyn,vbr [kN/mm]	kstat / kdyn,df / kdyn,vbr [kN/mm]
	Standard C 100,0 140,0 250,0	Standard C 100,0 140,0 250,0	Custom C 125,0 145,0 260,0
Level 2	USP DIN 45673-6	UBP EN 13146-9	USP
	Cstat / Cdyn,df / Cdyn,vbr [MN/m²]	kstat / kdyn,df / kdyn,vbr [kN/mm]	
	USP-I-07d C 173,0 236,4 236,4	Vipa SP/DRS/Df C 20,0 25,0 25,0	Nothing C
Level 3	UBM		UBM
	Nothing C		Nothing C
		FSM/FSP horizontal DIN 45673-7	FSM/FSP horizontal DIN 45673-7
		Cstat / Cdyn,df / Cdyn,vbr [MN/m²]	Cstat / Cdyn,df / Cdyn,vbr [MN/m²]
		FSM-L13 C 10 17 25	FSM-L13 C 16 30 43
		FSM/FSP vertical DIN 45673-7	FSM/FSP vertical
		Gstat / Gdyn,df / Gdyn,vbr [MN/m²]	
		FSM-L26 C 6 10 13	Nothing C

- The TEM is a **track performance simulation software**
- It is a **Multi Degree of Freedom model: up to 6 DOF**
- All detailed track parameters are considered (masses, stiffnesses, geometries) together with rolling stock characteristics

Advanced Inputs			
Sleeper / Base plate / Booted block parameters			
Type	Sleeper	Base plate	Sleeper
Length (per rail seat)	1,35 m	0,20 m	1,35 m
Width	0,25 m	0,30 m	0,25 m
Height	0,25 m	0,05 m	0,25 m
Material	Concrete	Concrete	Concrete
Density	2.500 kg/m³	2.500 kg/m³	2.500 kg/m³
Mass (per rail seat)	210,94 kg	7,50 kg	210,94 kg
Contact area (per rail seat)	0,3375 m²	0,0600 m²	0,3375 m²
Ballast parameters			
Thickness under sleeper	0,30 m		0,30 m
Height of ballast shoulder	0,15 m		0,15 m
Width of ballast shoulder	0,25 m		0,25 m
Angle of friction	48 °		48 °
Density	2.000 kg/m³		2.000 kg/m³
E module	100 MN/m²		100 MN/m²
Static stiffness (per rail seat)	233 MN/m		233 MN/m
Static bedding modulus	333 MN/m³		333 MN/m³
Dynamic ratio	2,00		2,00
Loss factor	50 %		50 %
Slab and/or auxiliary prefab element (in case of floating ballast) parameters			
Layout		Single track	Single track
Width		3,00 m	3,00 m
Thickness		Single track m	Single track m
Density		2.500 kg/m³	2.500 kg/m³
Inertia		0,0080 m⁴	0,0080 m⁴
Cross section area		1,20 m²	1,20 m²
Foundation plate (under slab) parameters			
Width		3,00 m	3,00 m
Thickness		0,20 m	0,20 m
Soil parameters			
Soil type	Hard Soil	Hard Soil	Hard Soil
Modulus Type	EV2	EV2	EV2
Modulus value	80 MN/m²	80 MN/m²	80 MN/m²
Density	1.900 kg/m³	1.900 kg/m³	1.900 kg/m³
Poisson ratio	0,35	0,35	0,35
Extra notes (if any)			

Noise and vibration

Track Elastic Model (TEM) simulating software

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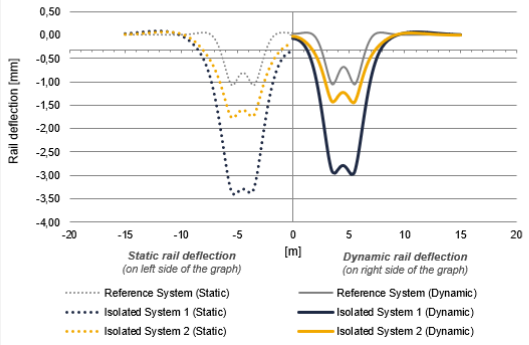
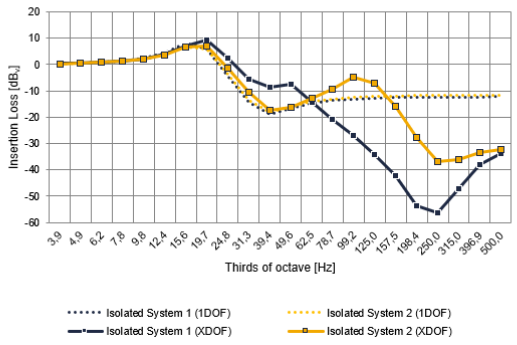
Track Elastic Model

Outputs

Rail deflection



Insertion Loss



Eisenmann parameters for dynamic deflection calculations			
Standard deviation, t	2,5	2,0	2,0
Track condition, φ	10 %	10 %	10 %
Dynamic Amplication Factor	1,29	1,23	1,23
Equivalent track stiffness *(track deflection by one single axle)*			
Static	149,13 kN/mm	47,02 kN/mm	91,00 kN/mm
Total deflection at rail head			
Static	1,07 mm	3,40 mm	1,76 mm
Dynamic	1,05 mm	2,98 mm	1,44 mm

Results vibration		1DOF	XDOF	1DOF	XDOF
First resonance frequency		17,7 Hz	19,6 Hz	18,2 Hz	18,8 Hz
Insertion loss at	80 Hz	-13,6 dB,	-21,2 dB,	-13,0 dB,	-9,2 dB,
Insertion loss between	30 and 150 Hz	-14,2 dB,	-23,2 dB,	-13,5 dB,	-10,0 dB,

— Obtained results:
- **Track deflection**
- **Insertion Loss**
- Others…

— At **Pandrol**, as **full integrated track systems** supplier, we have the expertise and understand the complexity of all the track elements, **from the fasteners to the floating systems** through all the intermediate components

— We can find and **optimize the solution** from different approaches

Case studies

Case studies

Florence Lines 2 and 3

Challenges

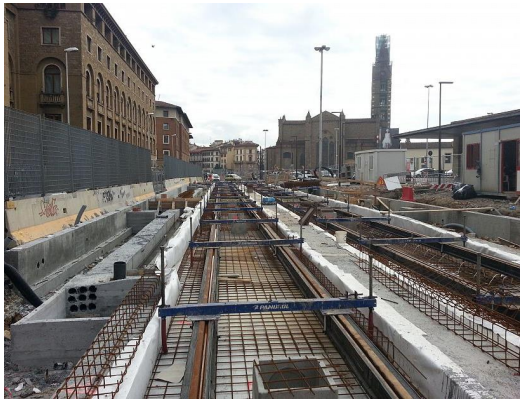
- Downtown Historic city
- Limited depth (slab thickness 250mm in some areas)
- Achieve 20dBv
- Constructability for a minor disturbance
- Stray currents protection

Requirements

- Level L0: embedded rail solution (~18 klmst)
- Level L2 (along 10.900 lmst): > 17 dBv @ 63-125 Hz
- Level L3 (along 6.680 lmst) : > 20 dBv @ 63-125 Hz

Solution

- All challenges and requirements fixed by Pandrol QTrack® system:
  - Level L0: Pandrol QTrack® SP
  - Level L2: Pandrol QTrack® SP + Pandrol FSM-L13
  - Level L3: Pandrol QTrack® SP + Pandrol FSM-L06
  - Stray currents protection via QT ELEC film type ELEC-L



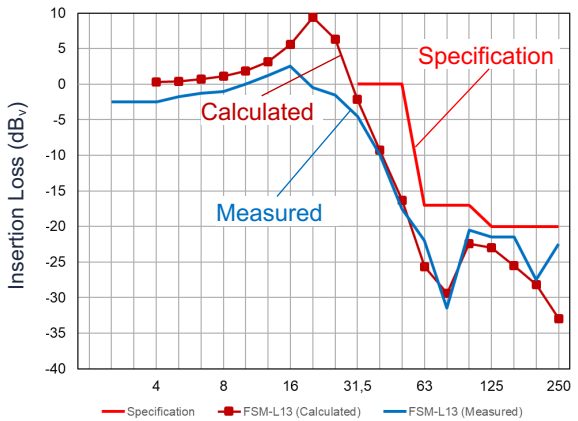
Case studies

Florence Lines 2 and 3

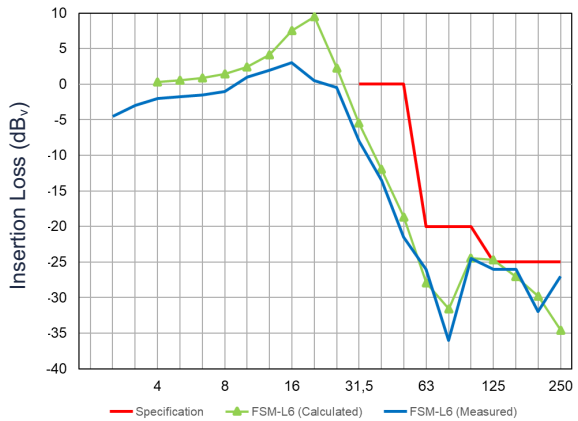
Results

— N&V measurements by third party

Insertion Loss Level L2 solution
Pandrol QT-60R-SP-R-59 + Pandrol FSM-L13
(ref: Pandrol QT-60R-SP-R-59)



Insertion Loss Level L3 solution
Pandrol QT-60R-SP-R-59 + Pandrol FSM-L06
(ref: Pandrol QT-60R-SP-R-59)



— On site stray currents measurements

— **Total satisfaction of the operator and the contractor → Prolong the solution to additional extensions in Florence**
→ Replicate experience to Bologna tramway

Case studies

Tramway Zaragoza Line 1

Challenges and requirements

- Line North-South across downtown
- Urban integration
- Grass Track
- Quick installation 26 track kilometers

Solution

- Pandrol QTrack® HP
- Pandrol QTrack® HP + Pandrol FSM-L13

Case studies

Tramway Zaragoza Line 1

Results

- Project completed in <3 years
- Successful re-urbanisation of the city → UITP Light Rail Award
- Total embracement of the population
- Good installation experience from contractor(s) → Export QTrack system to Sydney LRT
- Very positive feedback from maintenance team

Case studies

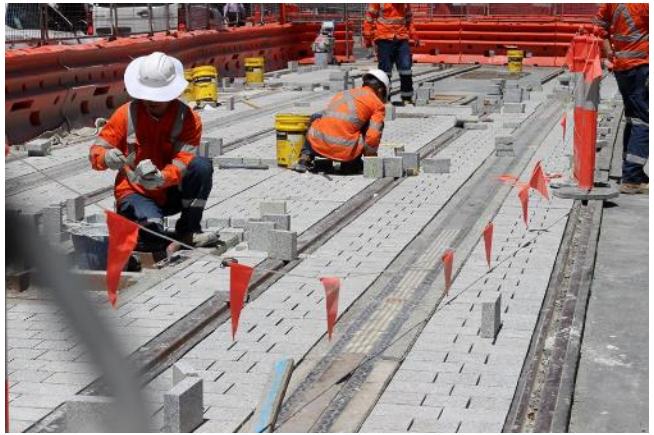
Sydney CBD & South East Light Rail

Challenges

- Central Business District → Minor disruption during works
- High labour cost → Constructability
- Highly occupied level crossings

Requirements

- Catenary-free by third rail technology
- High stray currents insulation 10 Ohm·km
- Track finishing in granite stones with no concrete shoulder



Case studies

Sydney CBD & South East Light Rail

Solution

- Pandrol QTrack® XP
- Pandrol QTrack® HP + Pandrol FSM-L13
- Pandrol QTrack® HP + Pandrol FSM-L4,5
- QT ELEC type ELEC-M

Results

- QT JIGs with added features:
  - Lowering tubes for single concrete shot without metal plate imprint
  - Auxiliary holding plate to enhance third rail installation
- Level crossings with high traffic demand fulfilled using QT JIGs and within super reduced installation window time
- Verified stray currents performance

Case studies

Edinburgh Trams to Newhaven

Challenges and requirements

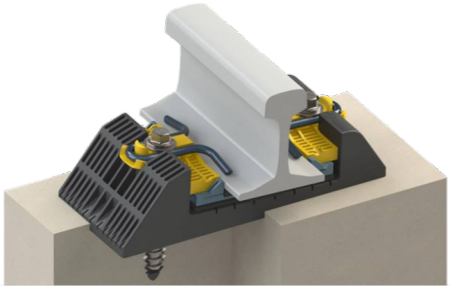
- Stray currents protection combined with sharp curves 25m
- Top of concrete level to be absolutely ToR level

Solution

- The Pandrol QTrack® meets at the same time
  - **Required stray current protection level thank to the QT ELEC level**
  - **Suitable for sharp curves with no need of additional clips nor tiebars**
- QT ENCAPSULATION modified for Top of rubber level = ToR level

Case studies

Santiago de Chile Metro: Integrated SD fastening and FSM system for vibration attenuation



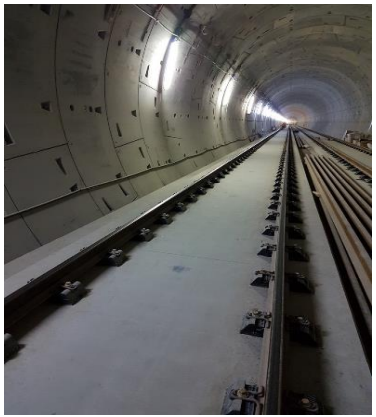
Pandrol has developed the SD (**S**afe **D**riven) family, with an **innovative design** that makes the product more **environmentally sustainable**, more **robust** and cost **competitive** and an **optimized geometry** that allows **automatic installation** giving higher rates of construction and savings during track construction and maintenance.

Challenges and requirements

- Vibration mitigation
- Earthquake prone-area that required a fastening solution with potential +30 mm vertical adjustment

Solution

- **Pandrol Floating Slab mat for vibration attenuation and correct track resilience integrated with Pandrol fastenings stiffness: Integral track design**
- SEE-SD rail fastening system with a new plastic baseplate to facilitate installation in concrete



Sustainability

Sustainability

Growth of rail transport and pathway to net zero emissions

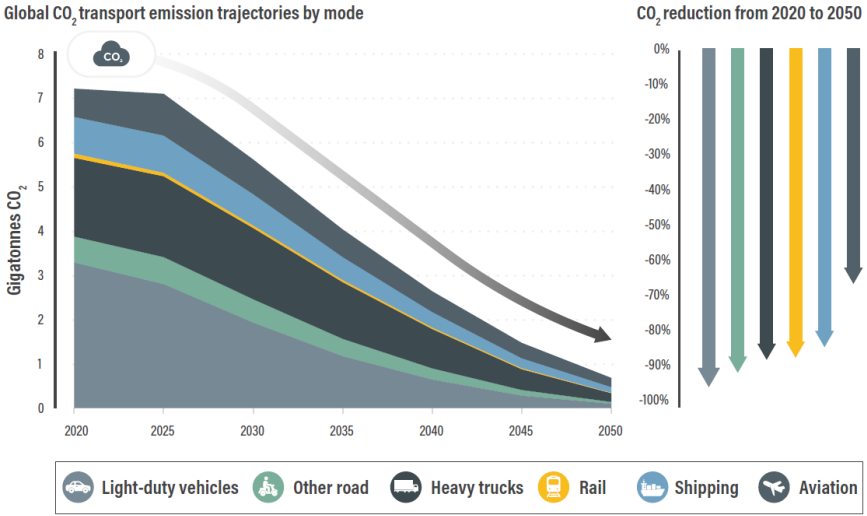
The big challenges

— With **urban-dwellers predicted to account for 75% of the global population by 2050**, urban rail transport is critical to help cities grow successfully.

— At the same time, even rail being today one the most sustainable modes of transport, it must still **decrease its CO_2 emissions by 85%** in order **to reach IEA net zero emissions scenario by 2050.**

FIGURE 9. Global CO_2 transport emission trajectories by mode required to achieve IEA net zero emissions scenario

Source: See endnote 87 for this section.

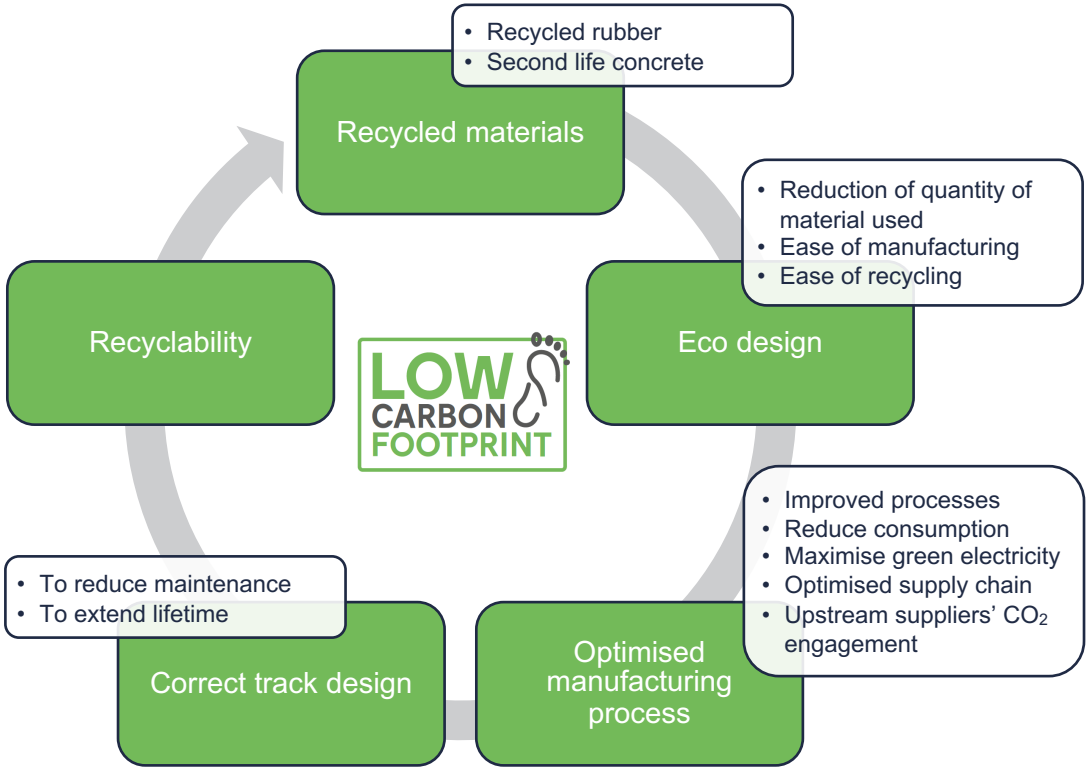


SLOCAT Transport, Climate and Sustainability Global Status Report – 3rd Edition
Accessible at https://tcc-gsr.com/

Sustainability

Growth of rail transport and pathway to net zero emissions

Pandrol response through integral development approach



Sustainability

Growth of rail transport and pathway to net zero emissions

Pandrol response through integral development approach

Pandrol Recycled Rubber

— **Core material**
- Tyres = made of an engineered and **reliable material** used worldwide on a daily basis for any road traffic
- End-of-Life tyres = because of wear (friction vs ground), not because of properties change

— **Resilient properties are defined by fine-tuning and research of the following aspects**
- Origin/type of the granules
- Granule dimensions
- Binder type and content
- Density of the final product
- Thickness of the final product

— **Fully compliant systems**
- **Continuous QC monitoring**
- **EN fully tested**
- Experienced in major rail networks
- For all Track Loads & Applications
- References for > **25 years** of service life across the globe
- Dedicated engineering teams supporting

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Environmental Product Declarations

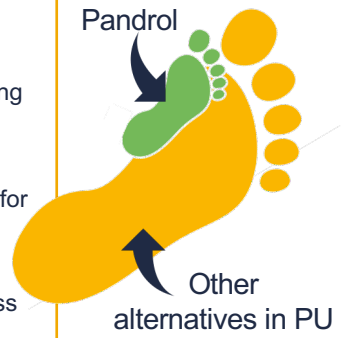
EPD®
THE INTERNATIONAL EPD® SYSTEM

— **What are EPD reports?**

- **Standardized**, **verified** documents that transparently present **credible information** about a product's **environmental performance** or impact over its lifetime
- All elements are considered for a detailed lifecycle analysis, from the collection of **raw materials**, through **production process** to **transport to the customer**
- **Internationally accepted**. **Third-party audited**. **Public** report available
- EPDs are useful for **communication**, **comparison** and **decision-making**

— **Pandrol proposition and strategy**

- Pandrol is proud to be the **first supplier in the field** to be assessed and certified to EPD criteria confirming the company commitment to reducing the environmental impact of railway infrastructure
- Today many of the products count with an EPD assessment and keep working to have it in all the range
- Pandrol Recycled Rubber solutions **2-4 times lower CO_2 values** than alternative materials based on PU for similar railway applications
- The Pandrol aspiration is to provide up front specific footprint score **for each product and project** needs
- **Continuous improvement** by the implementation of the EPD analysis in the circular development process



Conclusions

Conclusions

An adequate track design needs to face many complex challenges: constructability, N&V performance, stray currents control, track quality, maintenance and sustainability

Pandrol as full integrated track systems supplier has the capability to offer comprehensive solutions to help the right track design:

- Correct track resilience for vibration mitigation, reduced maintenance and extended lifetime
- Climate Change challenge demands CO_2 neutrality

The Environmental Product Declaration (EPD) gives railway networks an objective and 3rd party audited evaluation for assessing their track components from a Green Procurement approach

Pandrol Recycled Rubber solutions combine technical performance and sustainability, with lower CO_2 values than alternative materials for similar railway applications

Thank you

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PANDROL

Partners in excellence