Schweizerische Eidgenossenschaft
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Bundesamt für Umwelt BAFU

Bundesamt für Verkehr BAV

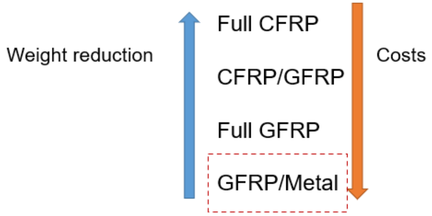
Hybrides Drehgestell aus GFRP (GFK)

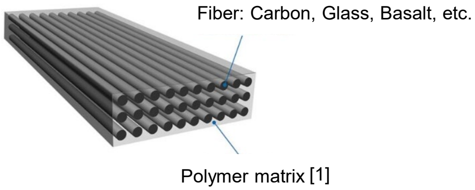
Prof. Dr. Moslem Shahverdi & Dr. Ali Saeedi, Empa

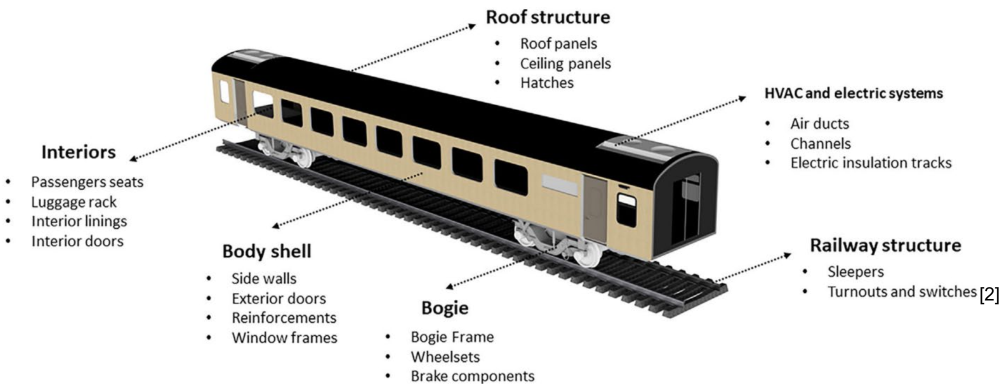
LÄRM FORSCHUNG EISENBAHN FORUM '25

ALLIANZ FAHRWEG

Introduction: FRPs in railway transport







Benefits of employing FRPs in railway industry

- ✓ Significant weight reduction
- ✓ Flexibility control of the structure
- ✓ Tailorable mechanical properties
- ✓ High corrosion resistance
- ✓ Intrinsic damping behavior
- ✓ High damage tolerant

Barriers of replacing metals with FRPs

- Lack of standard specifications and performance history
- High cost of raw material and fabrication
- Complexity in design and analysis of FRP structures
- Fire resistance and high temperature behavior
- Transverse impact resistance

[1] Adapted from [What is CFRT? - Thermoplastic Composite Manufacturer (Link)

[2] Saeedi, A., Motavalli, M., & Shahverdi, M. (2024). Recent advancements in the applications of fiber-reinforced polymer structures in railway industry—a review. *Polymer Composites*, *45*(1), 77-97

Project Goals

To develop an FRP based bogie concept for freight wagons, with:

- ❑ Improved running behavior
- ❑ Noise benefits
- ❑ Weight reduction
- ❑ Market acceptance potential

Could a hybrid FRP-steel design accelerate adoption of noise-reduced bogies?

Standard Y25 bogie, with block brake (Y25Lsd1-k)

[https://www.railteco.com/cpinfo.aspx?id=68]

Project partners

Phase 1
01.2022, 12 months

Phase 2
09.2023, 24 months

Phase 3
36 months (planned)

BAFU/BAV
Financing, Supervision

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Empa 303
Project leader and contractor

Empa
Materials Science and Technology

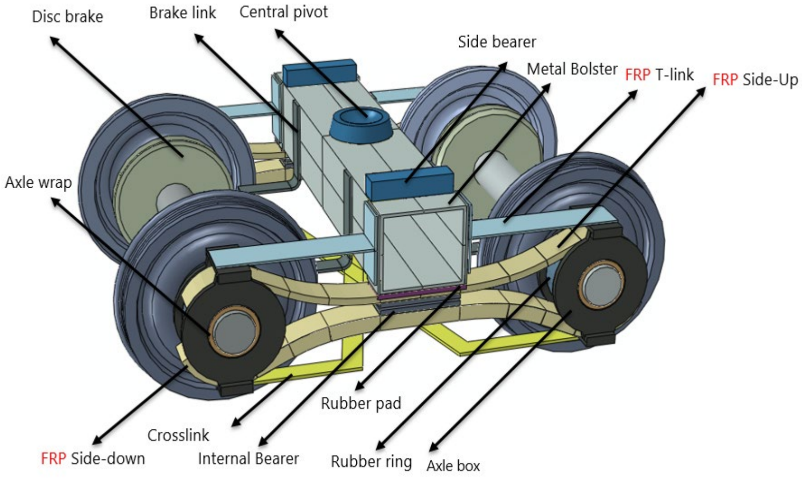
- **Empa Structural 303** – Structural design and analysis (Empa, Materials Science and Technology)
- **Empa Noise 509** – Noise experts, noise control
- **PROSE** – Railway and certification knowledge (PROSE)
- **Ensinger** – manufacturer, FRP knowledge (Ensinger)
- **WASCOSA** – Consulting end user (wascosa)
- **SBB Cargo** – Consulting end user (SBB CFF FFS Cargo)
- **OST- IWK** – manufacturer, FRP knowledge (OST Ostschweizer Fachhochschule; iwk Institut für Werkstofftechnik und Kunststoffverarbeitung)

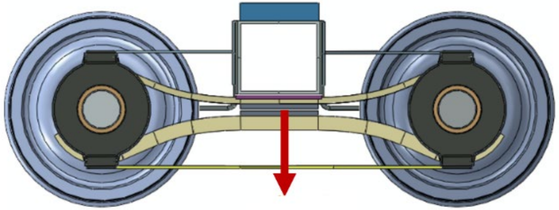
intended additional partners

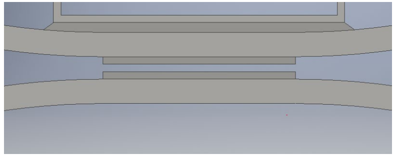
- ELH – production partner
- TÜV SÜD / VUZ Výzkumný Ústav Železniční, a. s. – testing partner
- PROSE – homologation consulting

Design Concept (v1)

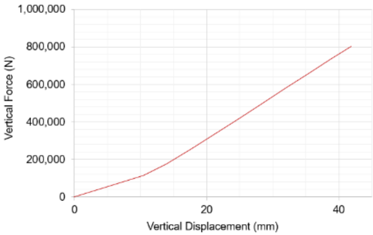
Flexible FRP beams + Solid metal component







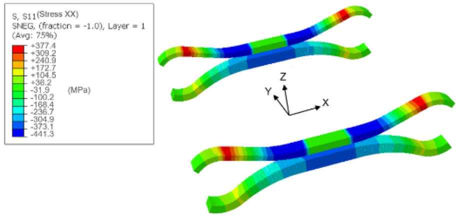
Initial gap between FRPs



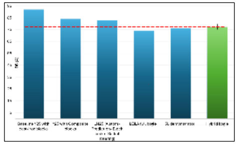
Variable vertical stiffness

Newer versions: after loops of modifications based on FE, running dynamics simulations, experiments

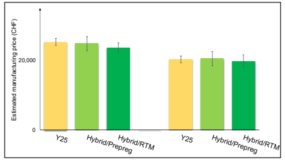
Project tasks



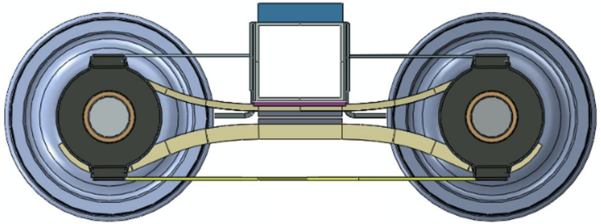
FE mechanical analyses

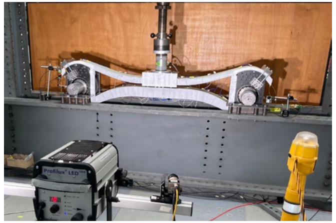


Total noise estimation

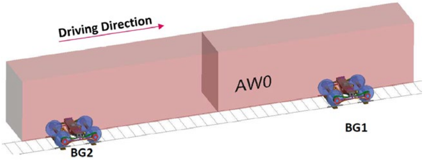


Cost analysis

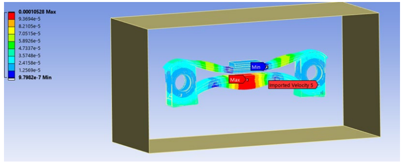




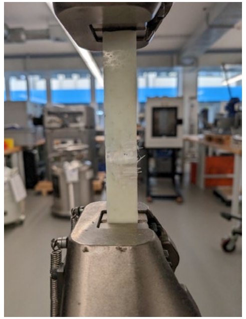
Experiments on bogie side assembly



Running dynamic analyses



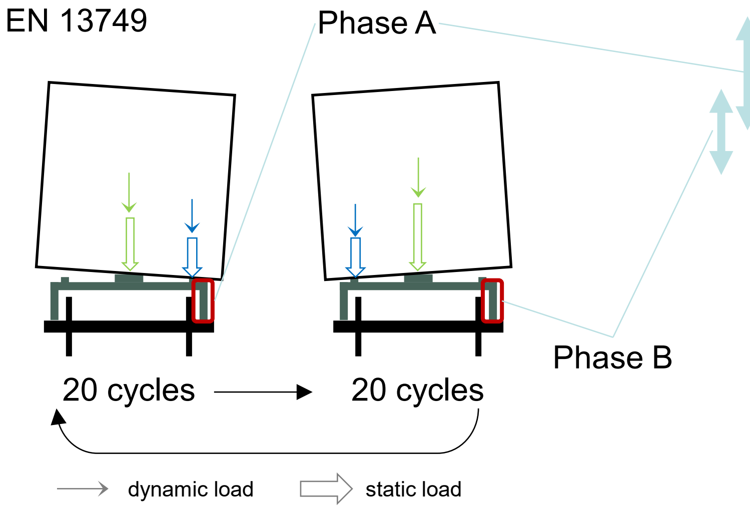
Frame noise simulation

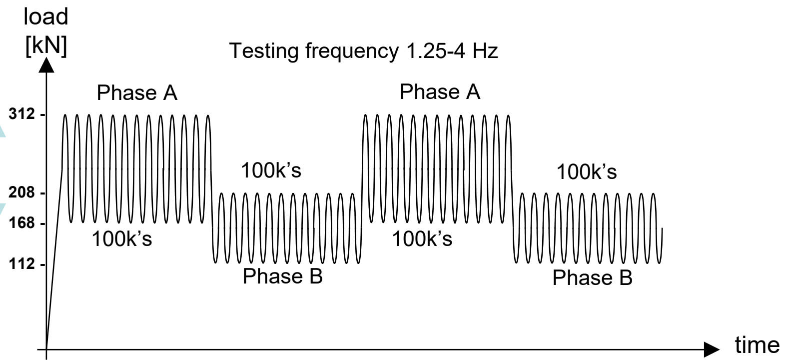


Material Characterization

Manufacturing of full-scale FRP beams

Fatigue tests





Experiment-caused temperature increase due to friction and self heating → cooling system around bolster

Noise reduction potential

Noise sources:
Rolling noise
Structure-born noise (bogie frame)
Aero-dynamic noise (negligible for freight)
Traction noise

Expected improvements in:
- Noise on straight track
- Curve squeal noise

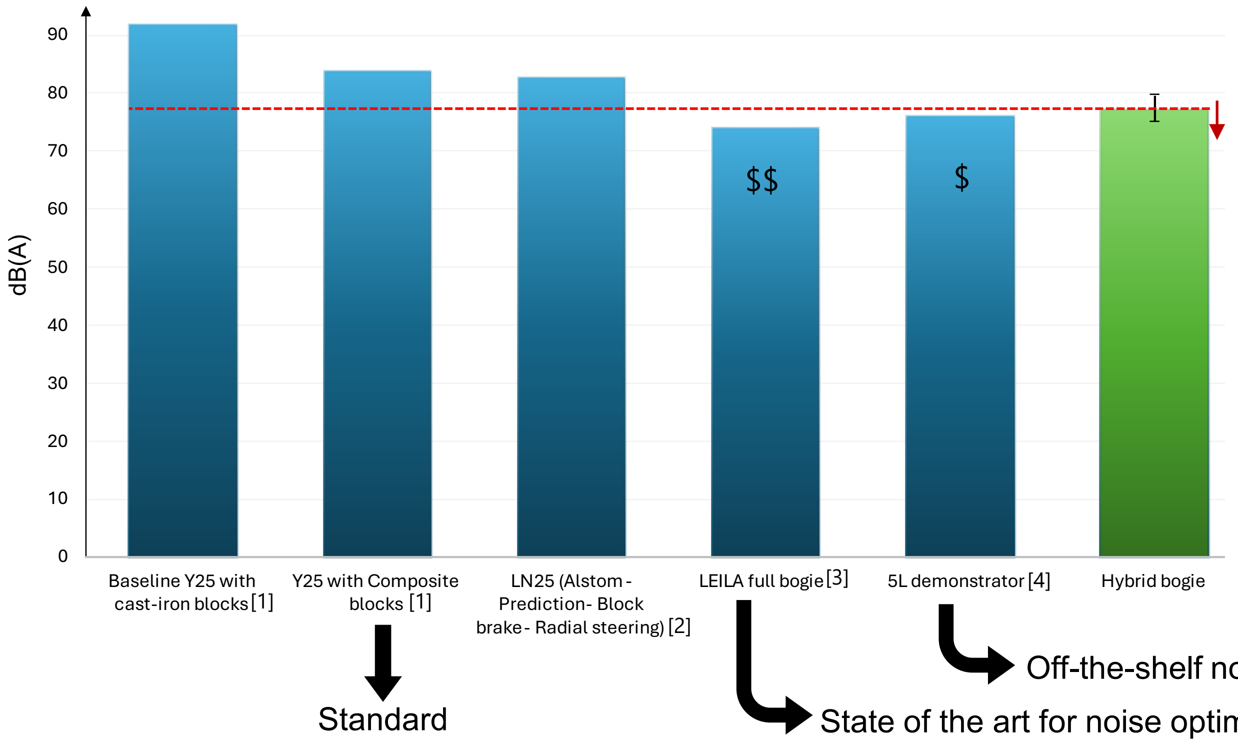
Noise reduction potential for Hybrid bogie due to:

- Disc brakes (3-5 dB) based on [1]
- Primary suspension: FRP beams+ rubber elements (2.5-3 dB) based on [2]
- Improved steering (axel box design + steering links) (3-7 dB) based on [3]
- Potential contribution of lower mass, and higher damping of FRP elements (? dB)

- Add-ons (optional) (up to 8 dB)

[1] Massnahmen zur Verminderung von Flachstellen und Ausbröckelungen (=Rollkontaktermüdung) bei scheibengebremsten Güterwagen, HUPAC, 2024
[2[Gigabox, Extensive noise reduction by interaction of various technologies ContiTech technology makes freight trains quieter
[3]Hur, H., Moon, K., Seo, J., Choi, J., & Lee, J. (2024). Wheel noise reduction performance of active steering bogie in curved section. Journal of Mechanical Science and Technology, 38(9), 4733-4741.

Noise level estimation



Wheel absorber
Bogie skirt
Optimizing the wheel

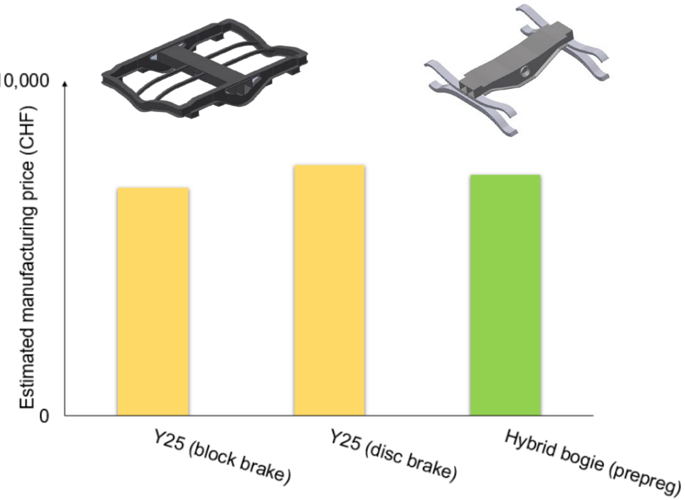
[1] UIC / ERRI Noise and Vibration Unit. (1998). Railway Noise Research: Summary of Activities since 1990

[2]University of Southampton, Reducing freight wagon noise at the source, March Southampton N+V:Layout 1.qxd

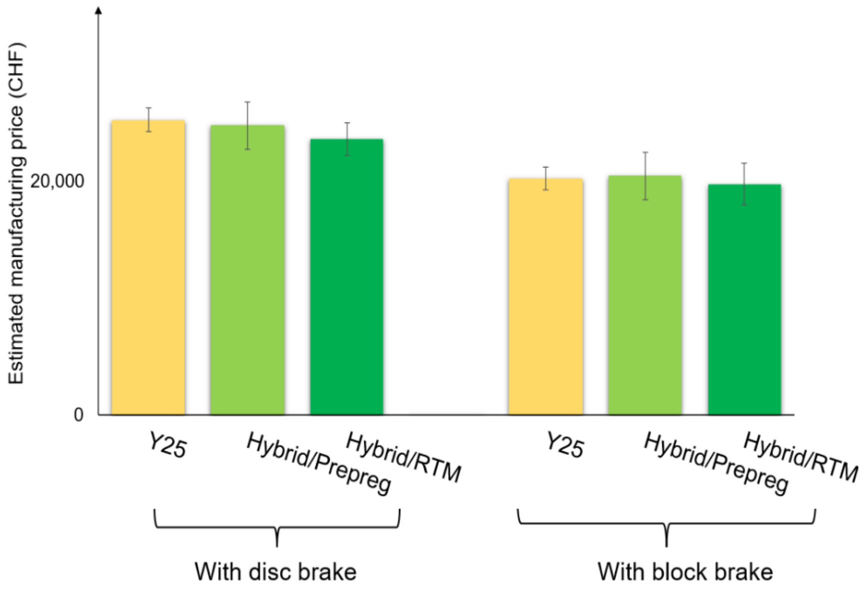
[3] Leila bogie report, https://laermforschung-eisenbahn.ch/site/wp-content/uploads/2022/03/2009_Publikation-ZEVRail_LEILA_Josef-Mayer.pdf

[4] Federal Office of Transport (BAV, Switzerland). (2018). 5L-Demonstratorzug: Ergebnisse zur Lärm- und Verschleißminderung. Bern, Switzerland.

Cost estimation



Comparable price range for frame manufacturing



Estimation on the manufacturing cost of the full bogie, for different variants

Cost estimation

Cost saving factors

- Light weight
- Improved steering
- Simplified design

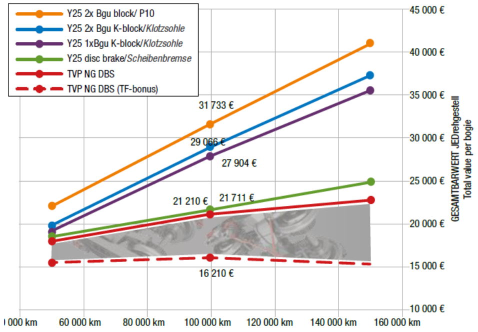
- Weight Savings
- Noise Bonus
- Wear-Related Track Cost
- Maintenance Costs
  - Reduced workshop runs
  - Reduced workshop stays
  - Reduced reprofiling costs

Cost increasing factors

- New bogie
- FRP elements

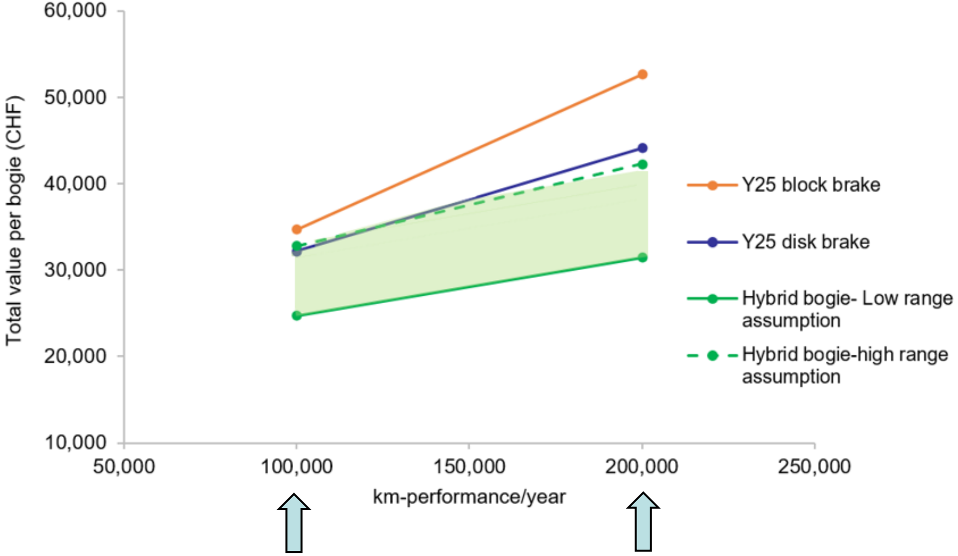
- Trainings for assembly/repair/maintenance
- More expensive health monitoring method
- Part replacements/repairs

Cost estimation



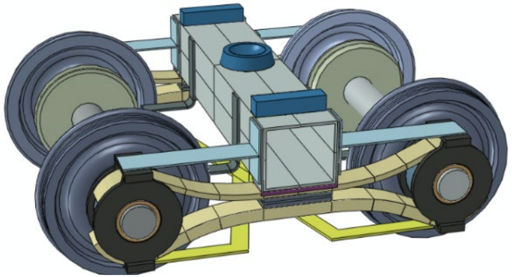
[TVP NG-DBS, Tatrawagonka, 2017]

Expected benefits in total ownership costs for Hybrid bogie



Design highlights

FRP/Metal Hybrid bogie



Simple design integration of springs and longitudinal beam → fewer parts to maintain / replace

Less noise due to disk brakes, FRP leaf springs, rubber elements → acoustic benefit for people, incentive for operator

Lightweight because of integral design and FRP leaf springs → more payload / lower transport cost per km

Radial steering with longitudinally elastic axle mounts → less wear on wheels and track

Health monitoring methods specific for FRP parts → benefit for fleet operator

Low-cost maintenance removal of wheelset similar to Y25 → increased acceptance from operator

Comparable manufacturing costs for optimized production at scale → increased acceptance from owner

Thank you!