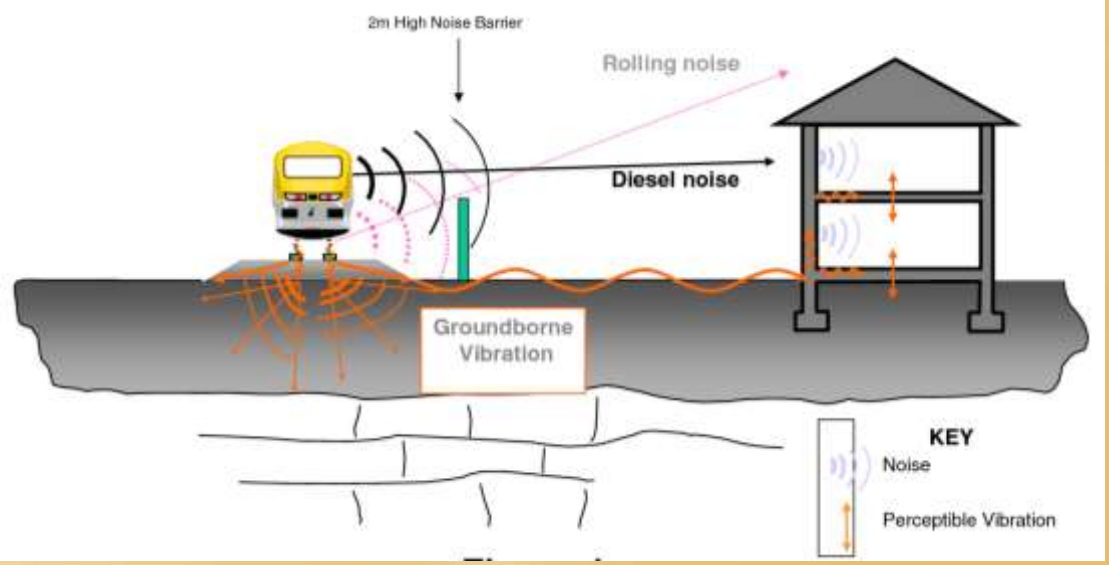
RAILWAYS

Noise & vibration

PhD CE Jarosław Zwolski



Noise and vibration sources

Noise and vibrations are caused by infrastructure problems:

- unevenness (damages) of rails,
- fisplated rail joints,
- support and fastening defects on slippers,
- threshold effects at a rapid change of subgrade stiffness (approach zones at bridges),

as well as by rolling stock problems:

- unevenness and damages of wheels,
- defects of the car body suspension,
- rolling stock hunting,
- engine vibrations, aerodynamics, breaking actions, wheels rolling on curves etc...

Noise and vibration sources



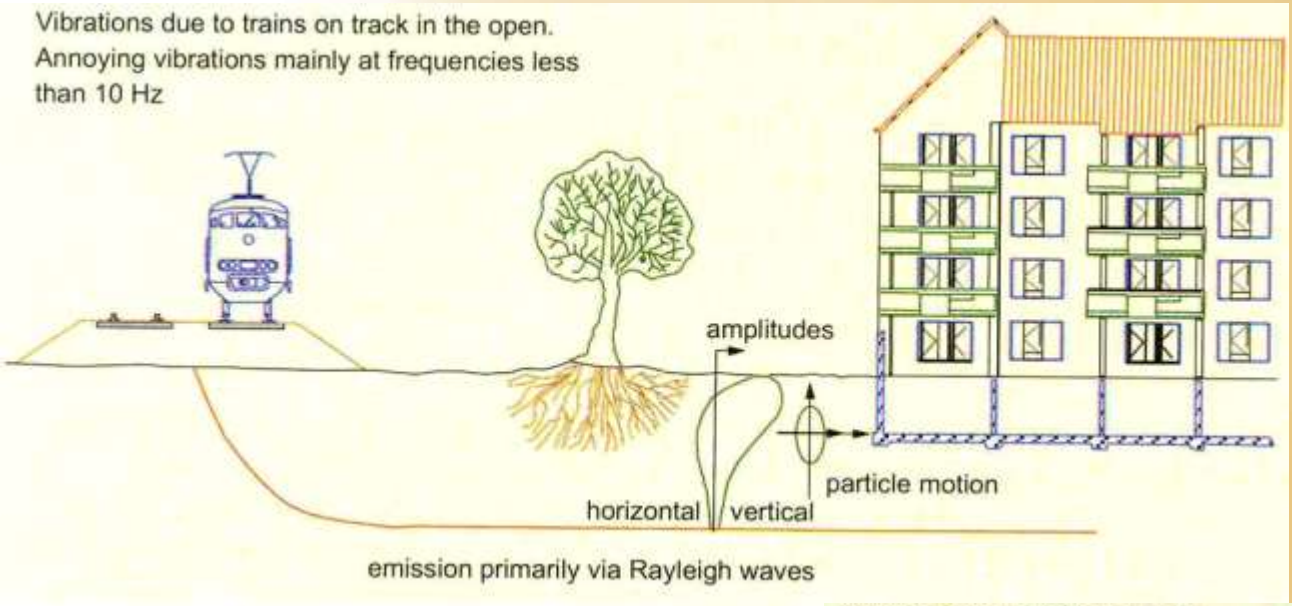






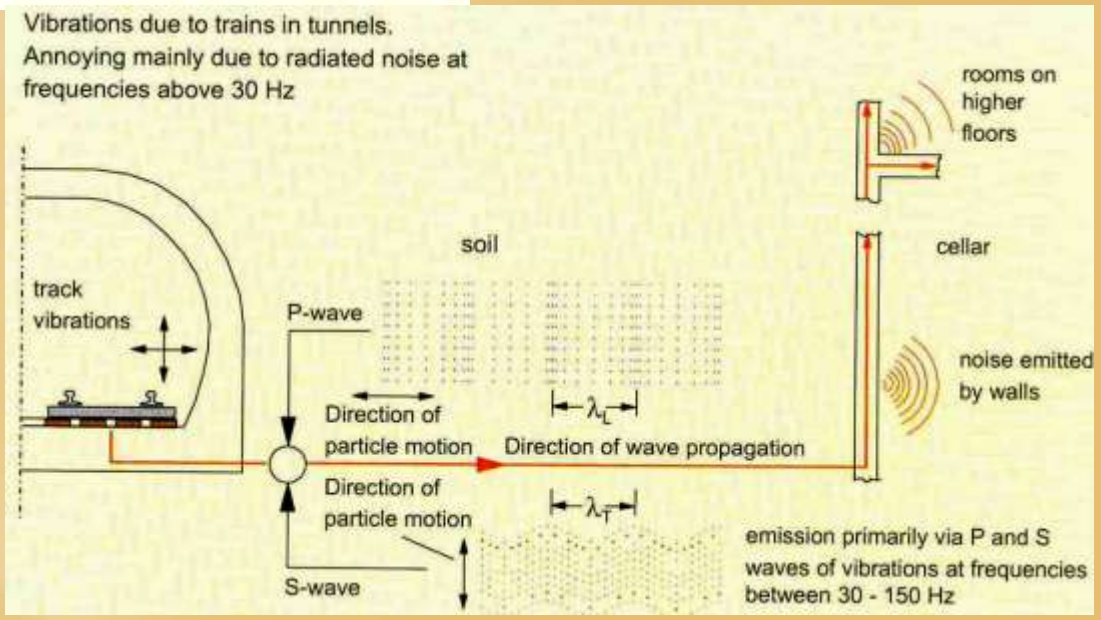


Vibrations propagation



Propagation from underground track

Propagation from surface strack

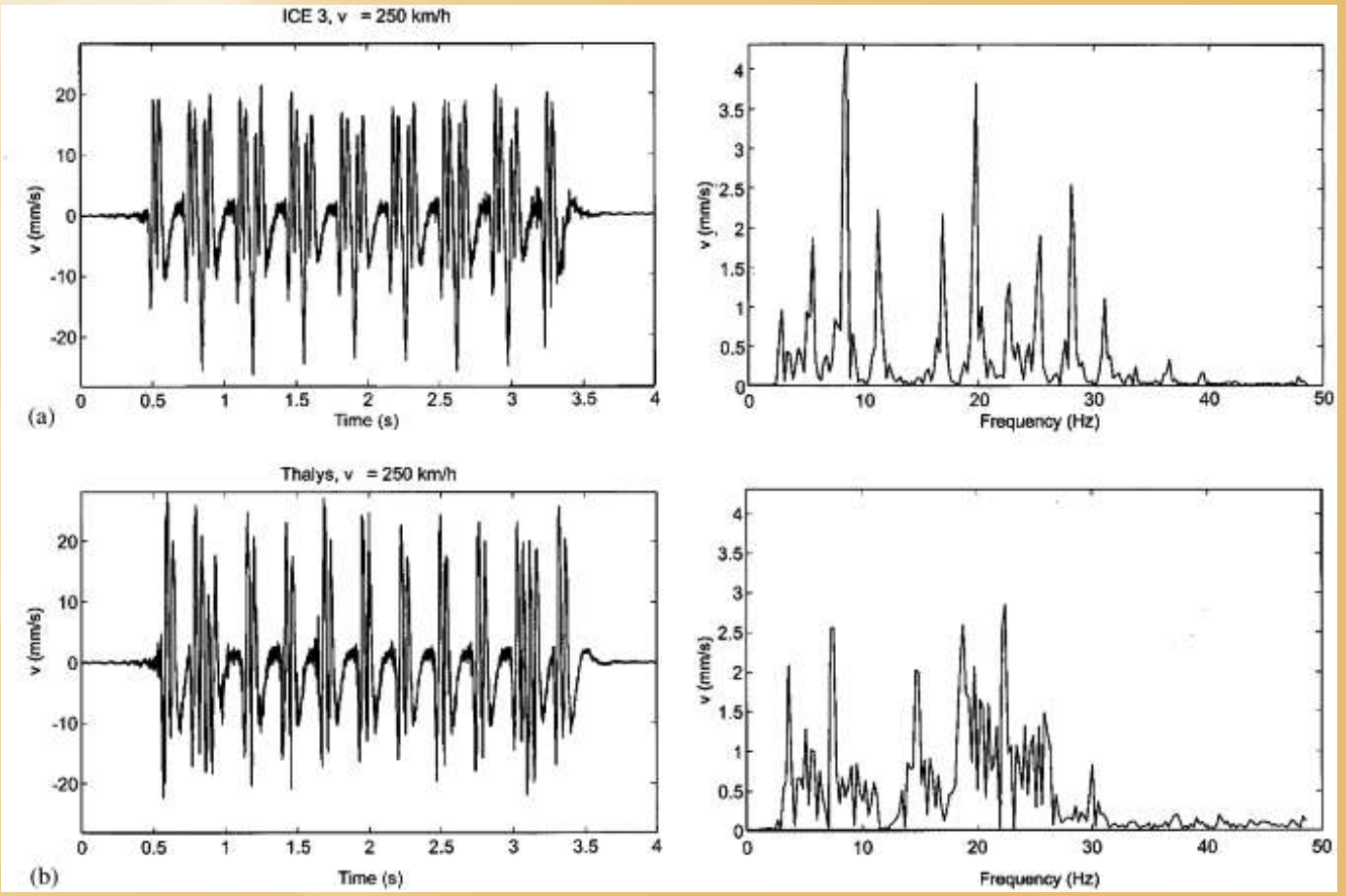


source: Modern Track, C. Esveld

Speed dependency

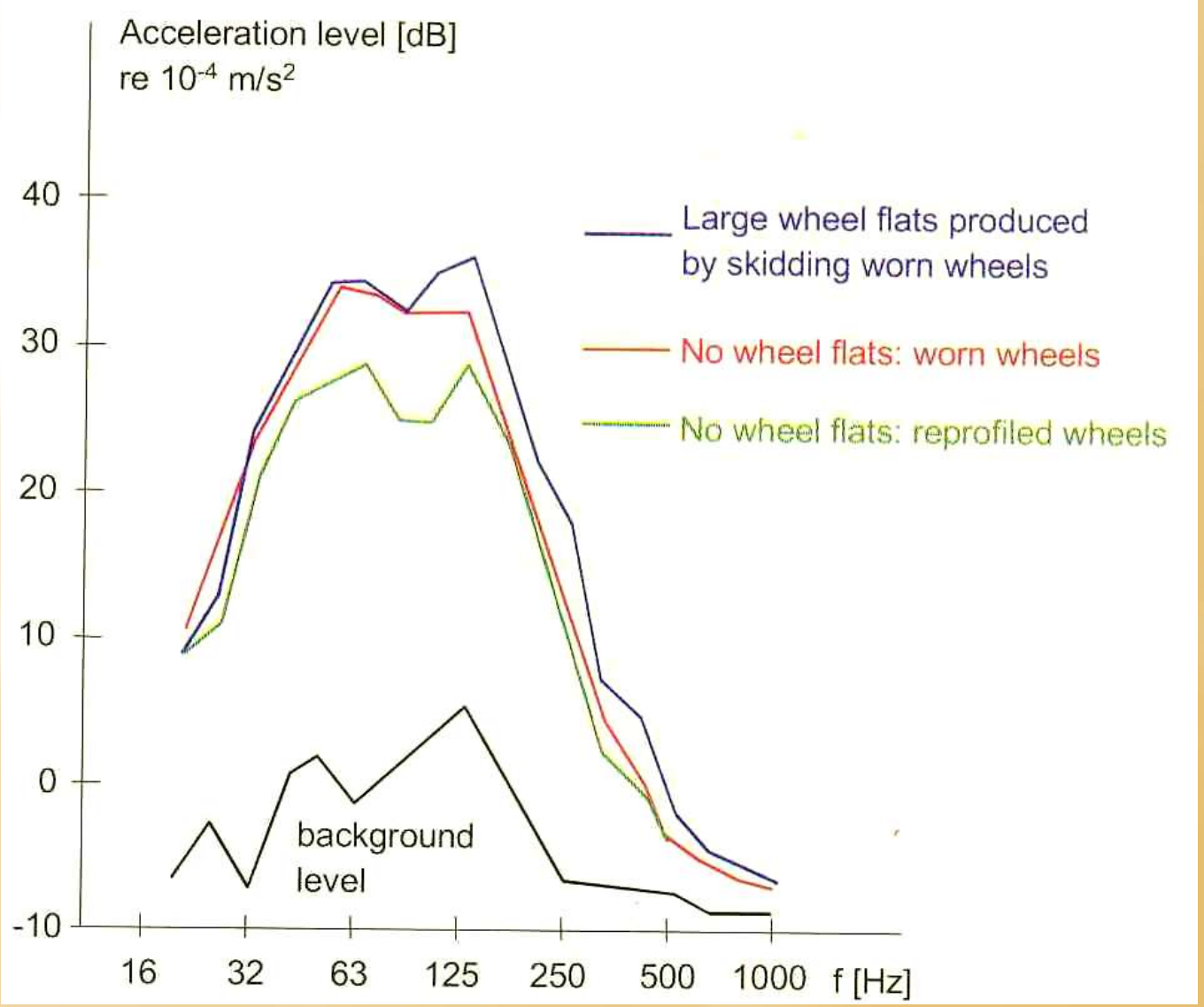
Forces exciting vibrations dependent on the train speed:

- axle load differences in cars,
- relations between modal properties of track + train system and the sleepers distance and the train speed,
- frequency of the track unevenness.



Note:
Decreasing of the speed not always leads to vibrations decrease.

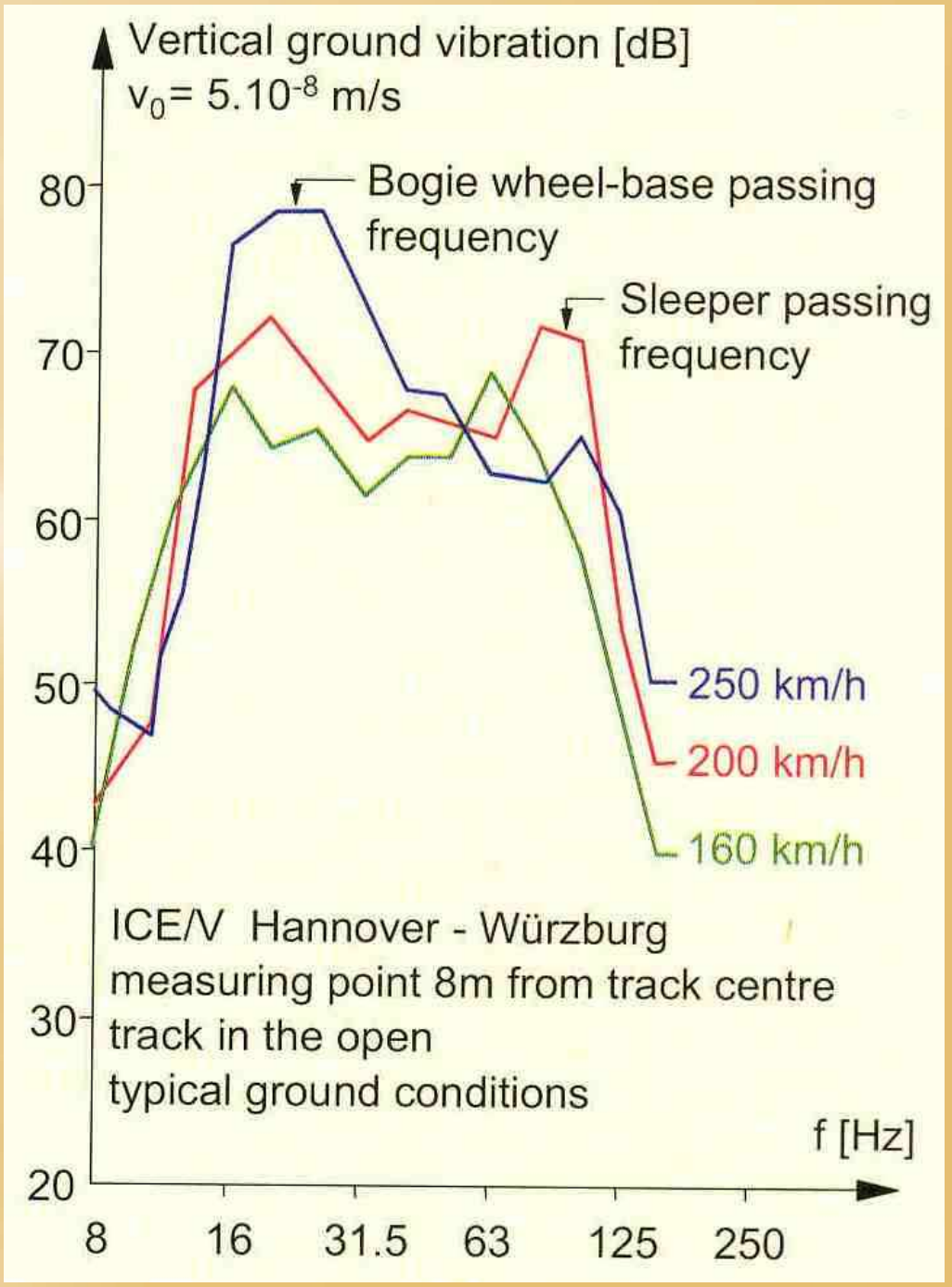
Worn wheels effect



Accelerations recorded on the first floor of a building in a underground proximity during a train passage with speed 60 km/h

source: Modern Track, C. Esveld

Speed effect



source: Modern Track, C. Esveld

Damping methods

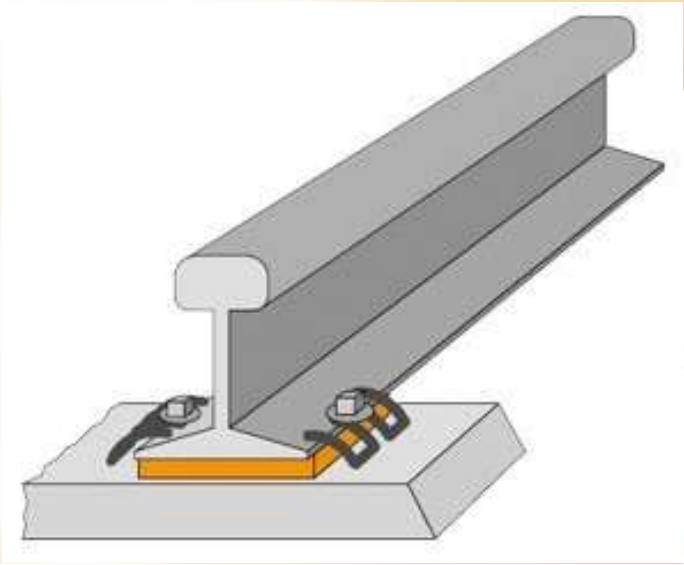
In ballasted track the reduction can be achieved by:

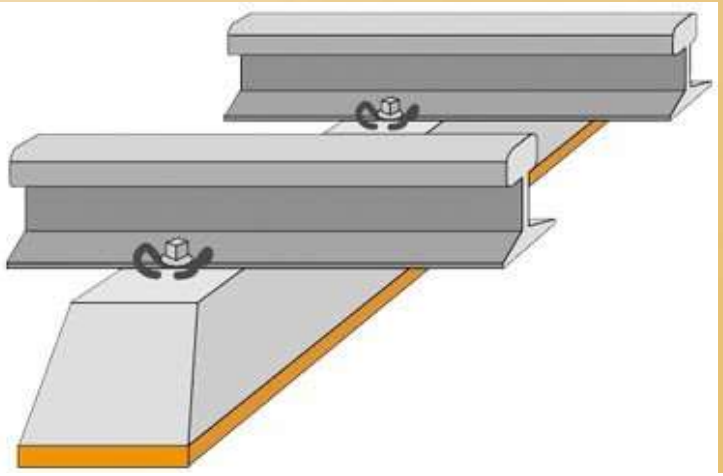
a) increasing of the ballast layer thickness;
   Increase by 30 to 75 cm can reduce vibration by 6 dB in the range below 10 Hz. The solution is not effective due to material cost, additional mass and increase of the structural thickness;
b) subballast mat installation;
c) installation of sleeper pads;
d) installation of specialised systems of nodal rail fastening and/or with aplication of special under-rail pads.

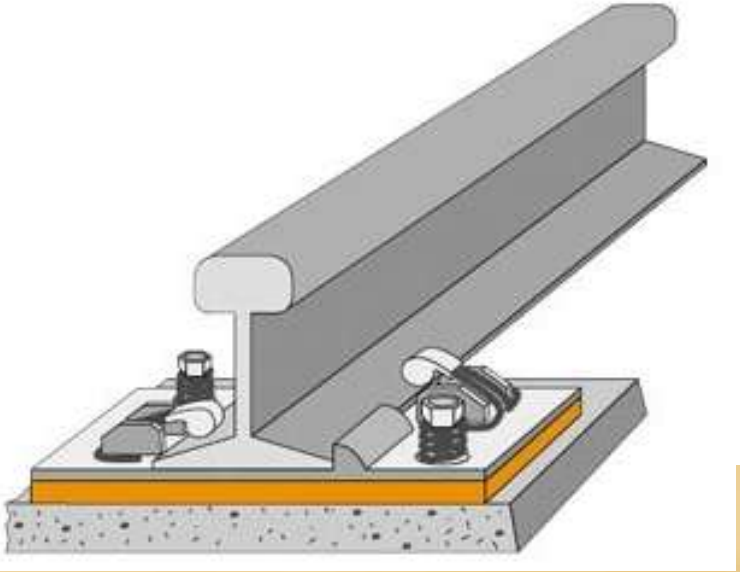
In ballastless track the reduction can be achieved by:

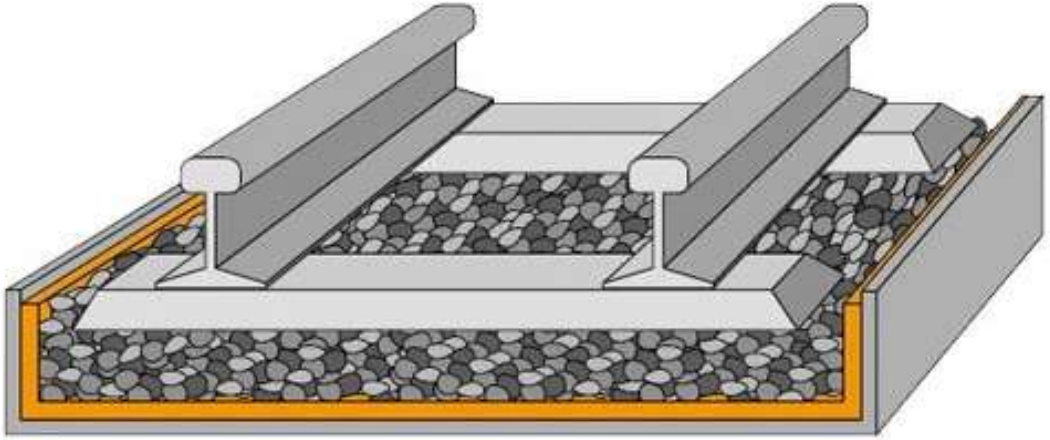
a) application of the „floating slab" solution;
b) attaching of special elements to the rail web;
c) linear fastening of the rail;
d) installation of specialised systems of nodal rail fastening and/or with aplication of special under-rail pads.

Systems for ballasted track

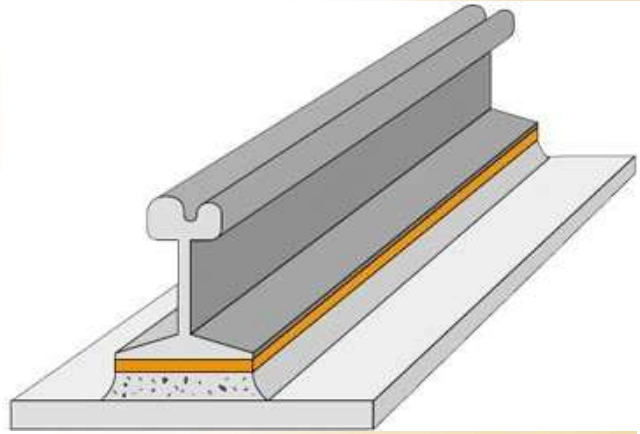


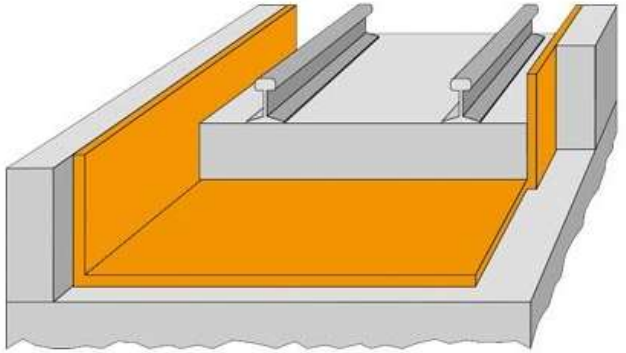


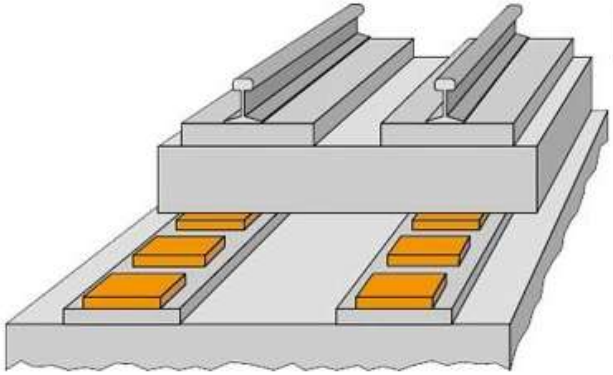


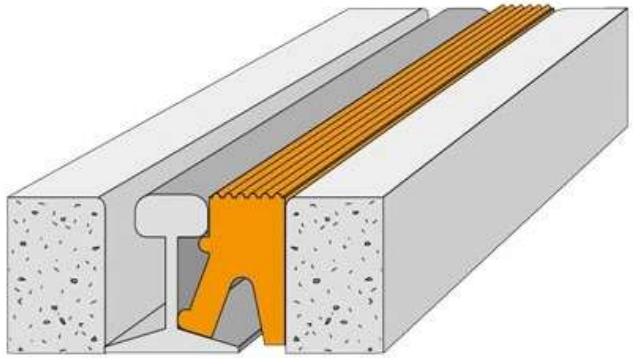


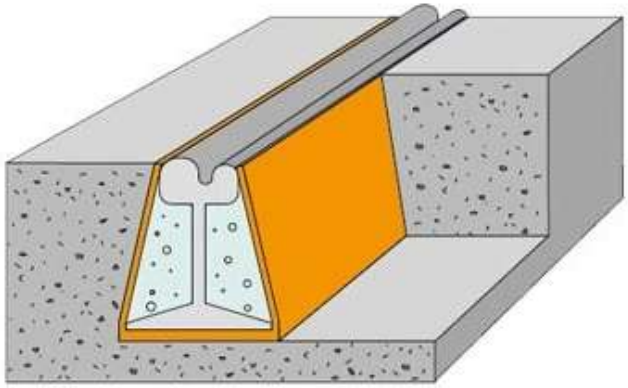
Systems for ballastless track

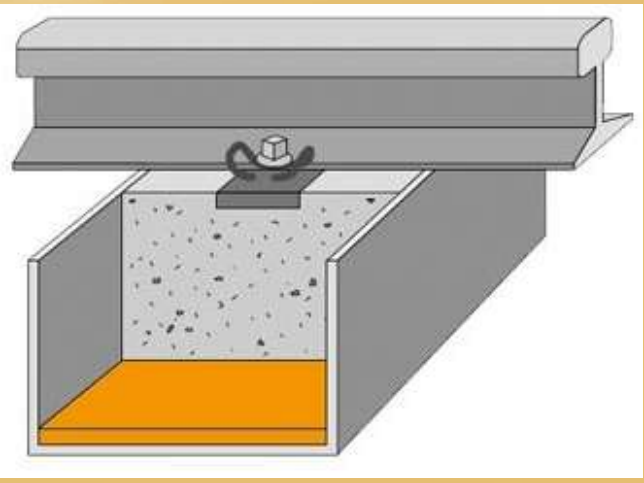




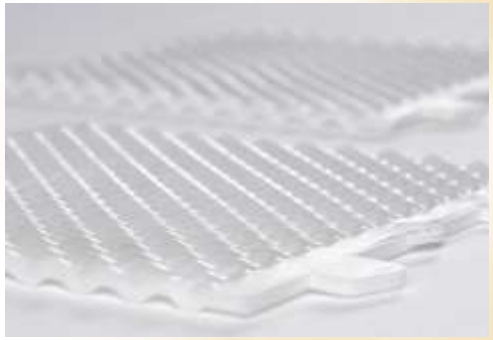






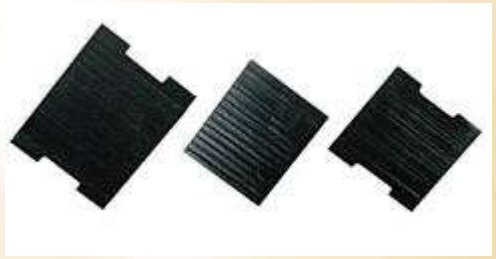


Under-rail pad









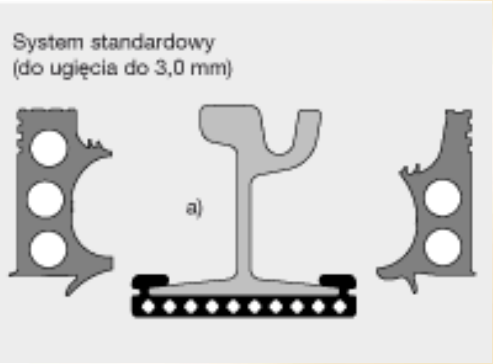


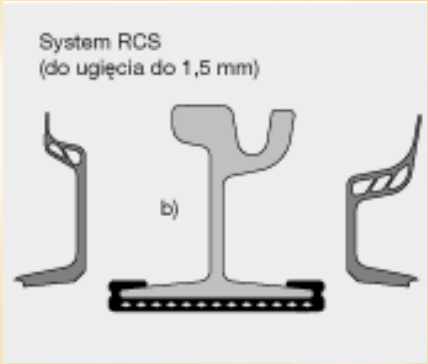
Under rail pads can be made of rubber (natural, artificial, composite), elastomer, plastic: poliethylene (HDPE), Ethylene Vinyl Acetate (EVA) or polyurethane. Before the plastic age it was a poplar wood pad.

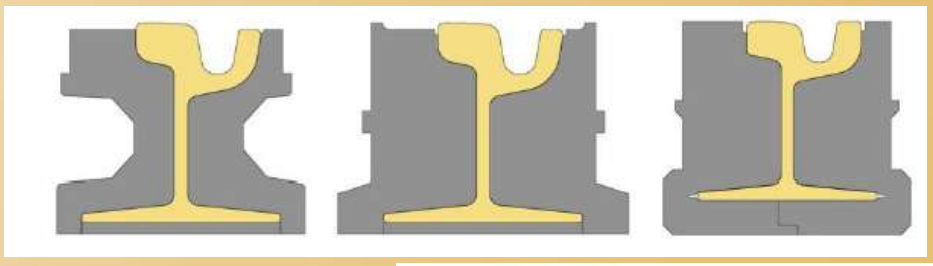




Rail web&foot coating

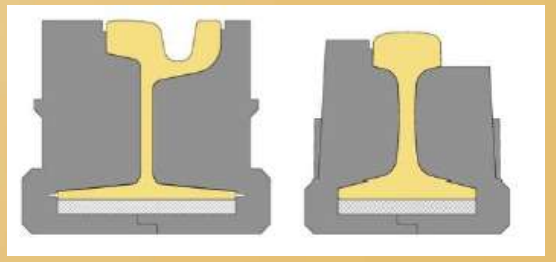


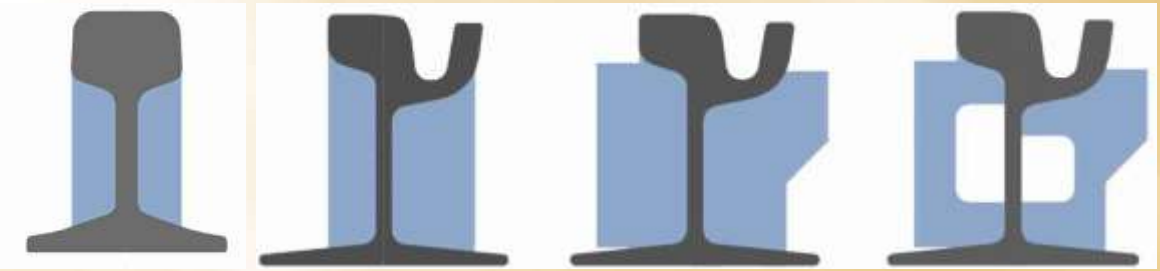




rubber

conglomerate

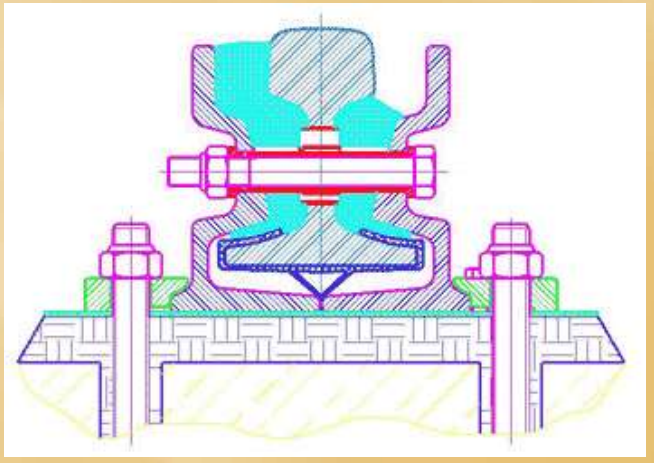


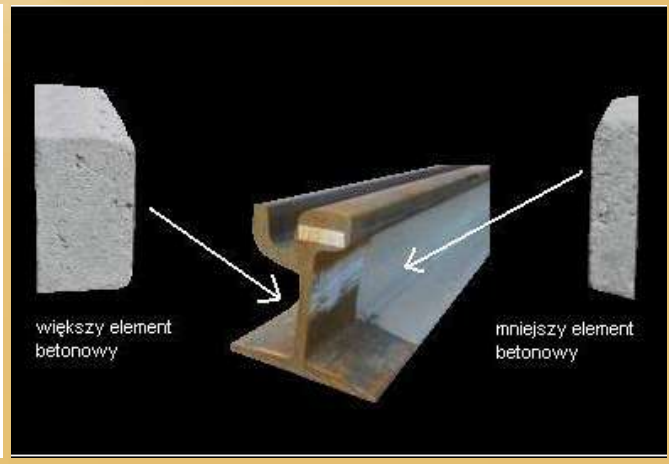


rubber

concrete

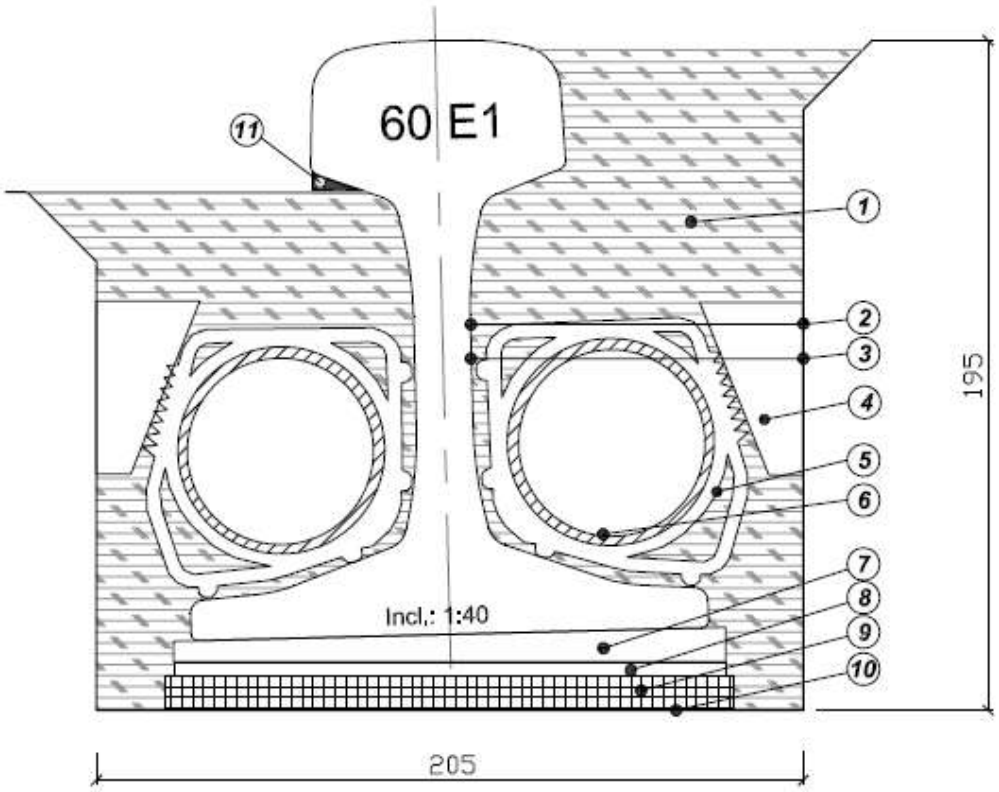






rubber + steel elements

Linear rail fastening



Precast or in-situ concrete slab or a steel structure with channels for rails. The rails fastened in the slots by a pouring mass based on polyurethane resin Edilon Corkelast®, and continuous rail support is done by Edilon Resilient Strip under the rail foot.

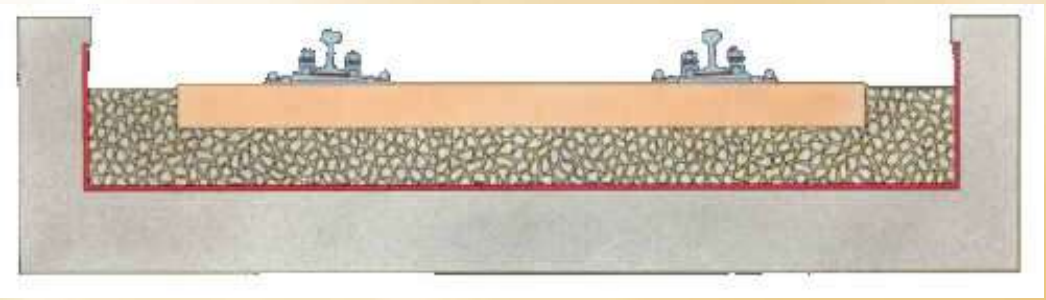
1. elastic mass coating the rail, 2, 3. the surfaces covered by primer, 4. wedge for horizontal rail rectification, 5. pipe fastening element, 6. pipe, 7. wedge pad for 1:20/1:40 rail inclination, 8. pads for vertical rail rectification, 9. antivibration pad, 10. glue, 11. rail edge sealing

Antivibration mat







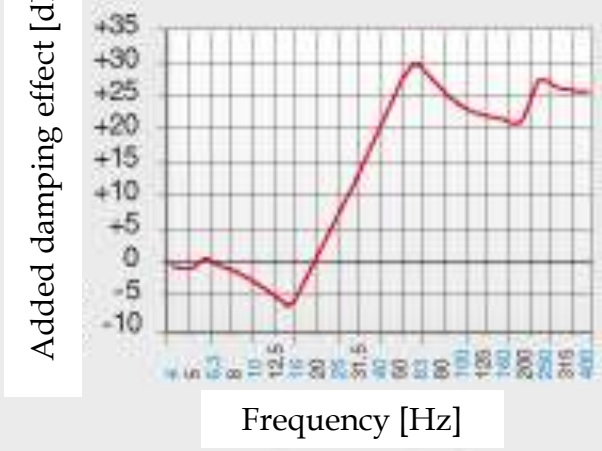




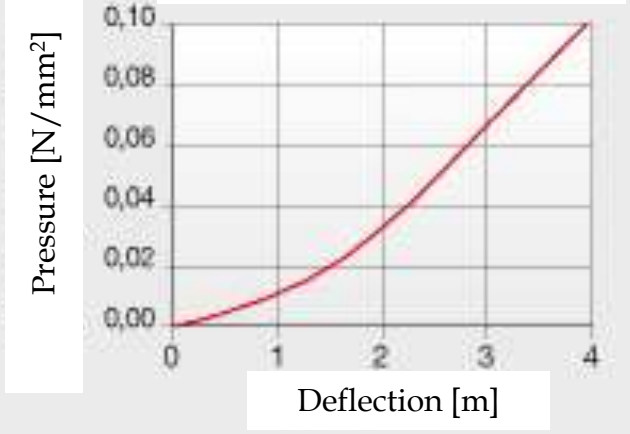
Subballast mat can be applied in ballasted track as well as in a tunnel or on a bridge. The mats can be made of rubber granulate, caoutchouc-cell structure, cork granulate, stone wool (e.g. RockDelta) and usually they are covered by polipropylene protection layer.

Antivibration mat

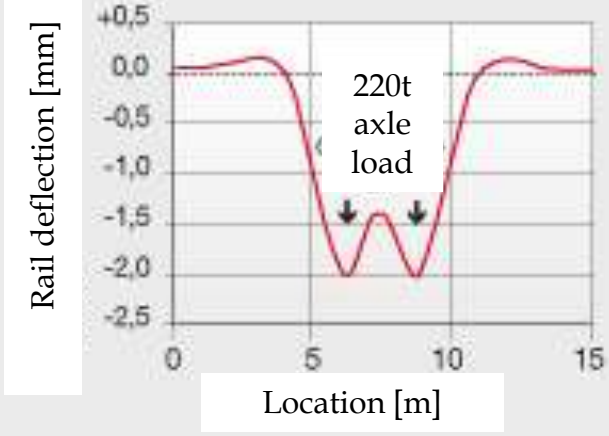
Added damping effect



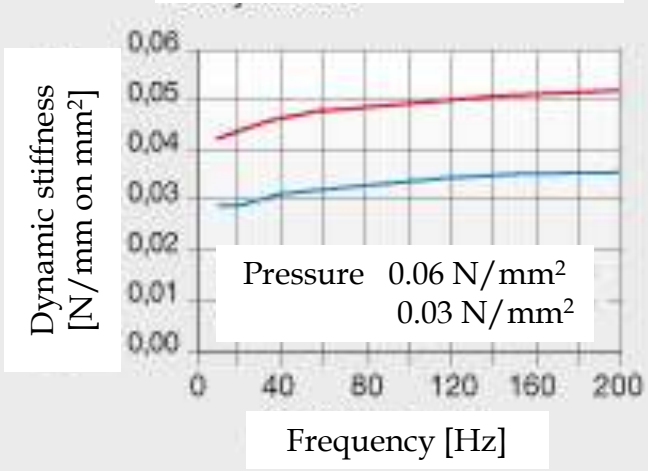
Static elasticity characteristic



Rail deflection curve



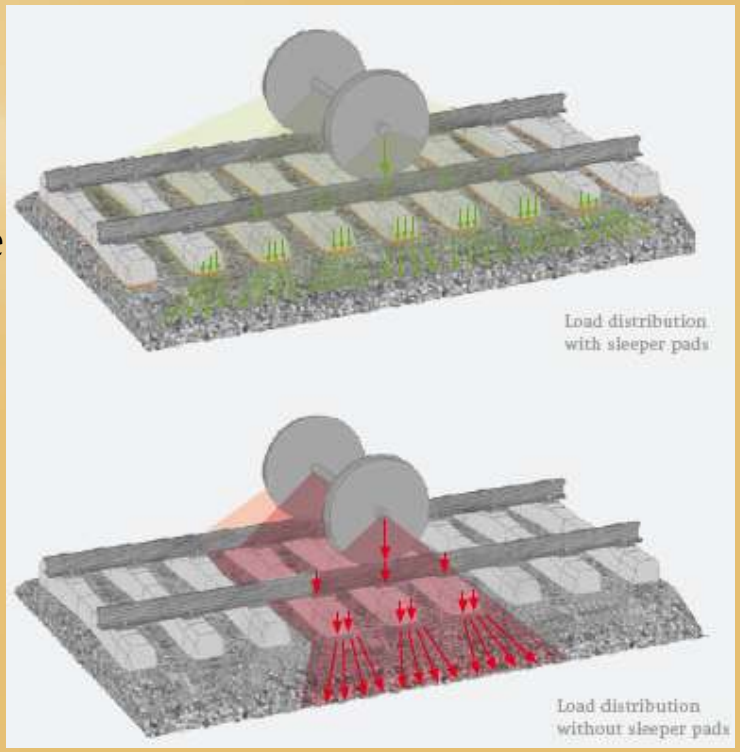
Dynamic elasticity characteristic



Under sleeper pads



Under sleeper pad: 22 mm of rubber, cork with hard surface.
Producent: Getzner Werkstoffe.
Material types (Sylomer and Sylodyn):
- elasto-plastic,
- elastic with damping characteristic,
- elastic without damping characteristic



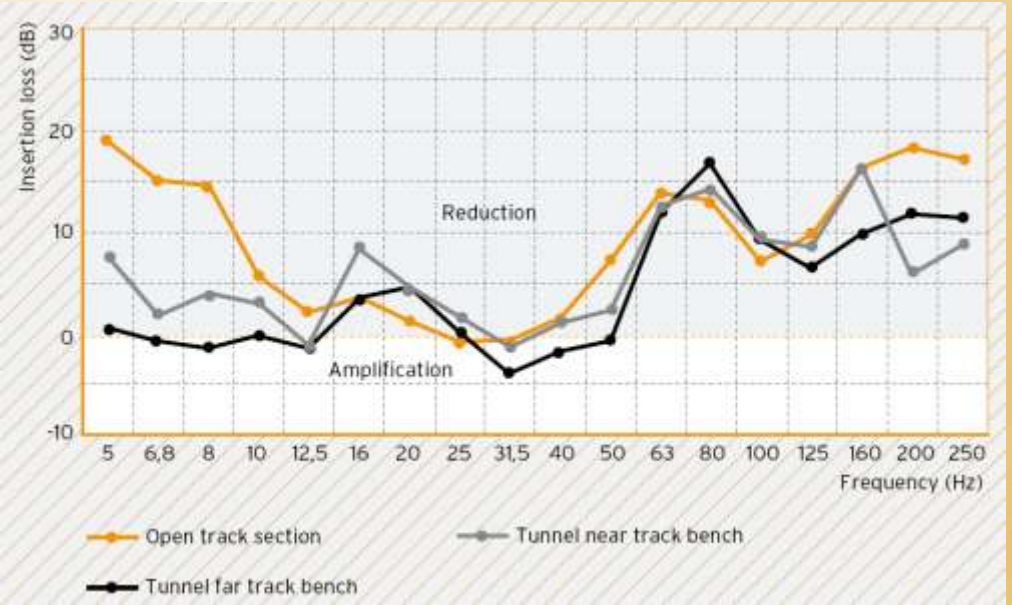
Effects:
1. Decreases rail wear.
2. Decreases the frequency of the track maintenance (tamping and rectification) 2 to 2.5 times.
3. Less material than the sub-ballas mats (more economic).

Applications:
- heavy loaded tracks,
- turnout zones,
- transition zones between various stiffness of structure or subgrade.

Under sleeper pads

Action:

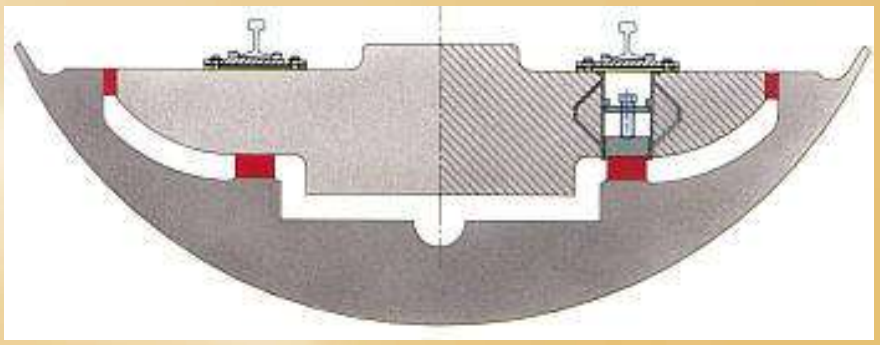
1. Increase the active contact area between the grains of ballast and sleepers (from 8% to 35% of the sleeper bottom surface) ensuring also higher resistance against horizontal movements (transverse and longitudinal).
2. Seizure of ballast grains in the sleeper bottom prevents from the ballast slipping out from below.
3. Spread out the load under the sleeper more evenly.
4. Spread out the load on more than 3 sleepers (a longer section of the rails is bent under the load).
5. Damp vibration in the range 5-8 Hz by 15 dB and in range 50-80 Hz by 10-15 dB.





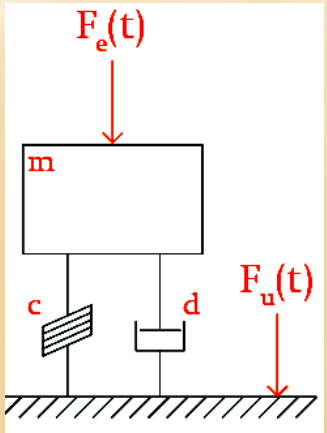
Floating slab





Principle of work:

It is to split the structure generating vibrations from the surrounding by introduction of an aditional „spring" by means of a elastic element and by the transmission path break.



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

d – damping coefficient
c – dynamic coefficient of the system elasticity
m – mass of the slab and unsprung mass of the boogie
f_0 – eigenfrequency of the structure

Floating slab



Whole surface support:
- easy attachment,
- very good support in transverse and longitudinal direction,
- enables achieving of support frequency 14-25 Hz and to damp the noise by 30 dB.

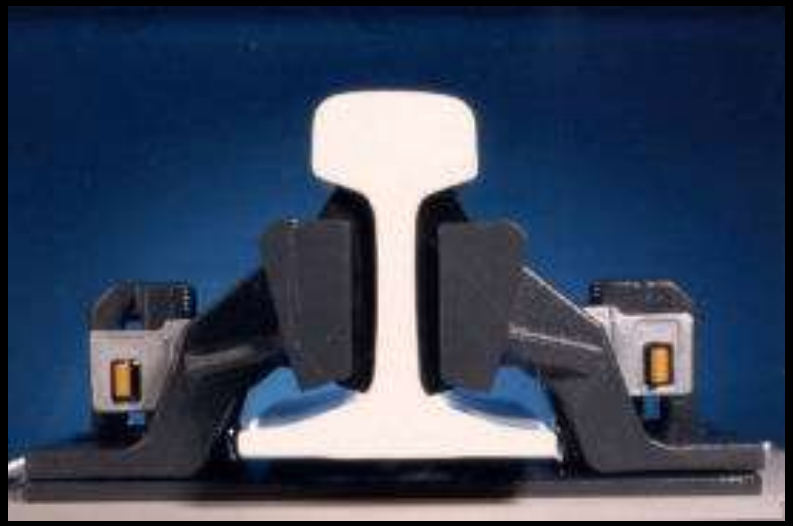


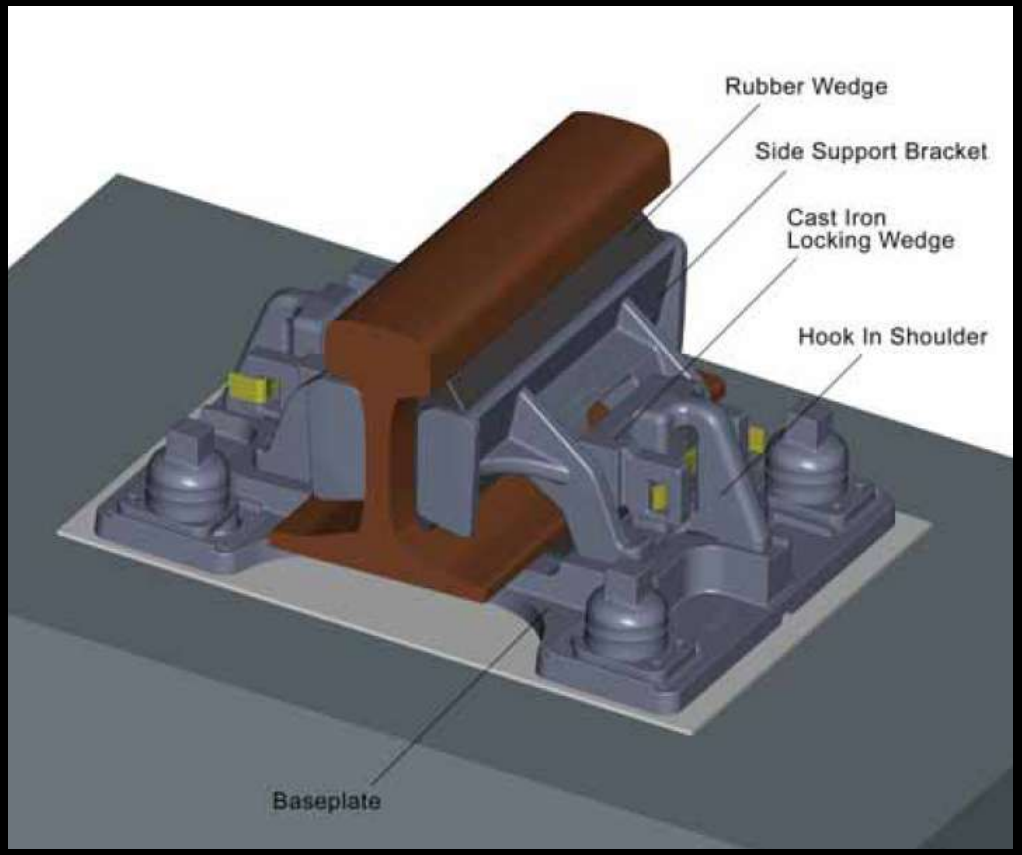
Linear support:
- the most often applied solution when precast slabs are used in the structure,
- good resistance against horizontal movements coming from breaking and accelerating, and transverse (arches curvacity and misalignments),
- cheaper solution than the surface support,
- enables achieving of support frequency 8-15 Hz.



Nodal support:
- the most often applied in case cast in situ slabs with special supports,
- the support has to be especially designed for carrying the horizoantal forces (elasticity coefficient for shear forces, area section and the thickness of the layer),
- enables achieving of support frequency 5-12 Hz and to damp the noise by over 30 dB (high performance).

Pandrol's Vanguard fastening





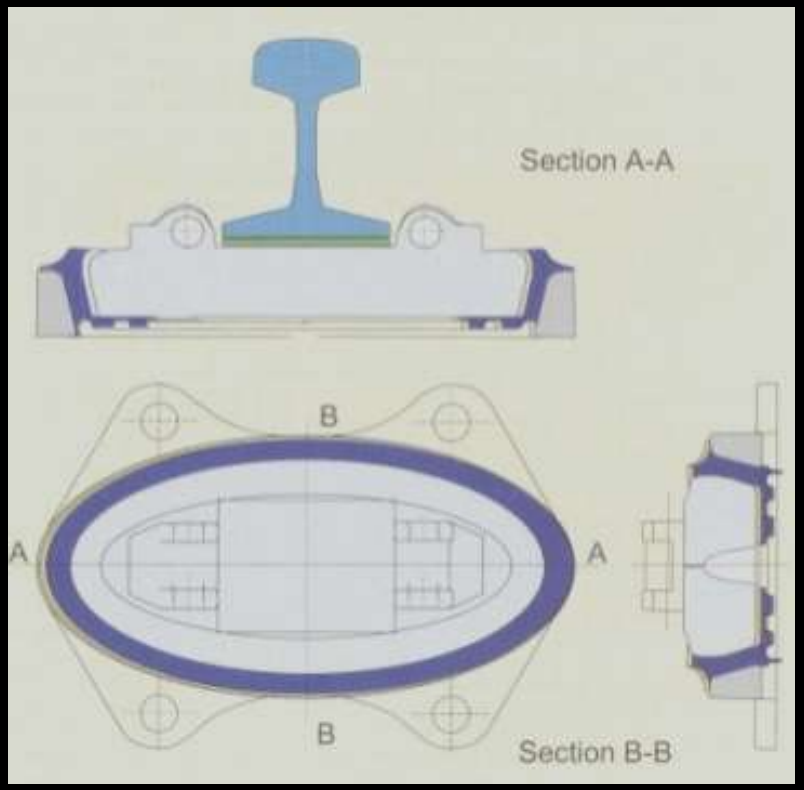
<u>The principle of work:</u>
Two side support brackets made of cast iron support the rail web from both sides. The rail web is supported indirectly, with use of rubber pads and the foot isn't supported.
Taking into account the large vertical movement of the rail (around 3 mm under 14 tonnes of load) damping of vibration starts from 20 Hz. Allowable vertical load 30 kN.

Cologne Egg fastening





ATP EGG Track Fastener



<u>The principle of work:</u>
The rail is attached to an oval plate through a spring pad inserted into the body of fastening base.

<u>Action:</u>
Vibration damping by 7 dB in the range 31.5-45 Hz and 18 dB in the range 63-80 Hz.
Low vertical load allowable – applicable in an light underground only.