RAILWAYS

Track elements

Jarosław Zwolski, PhD CE

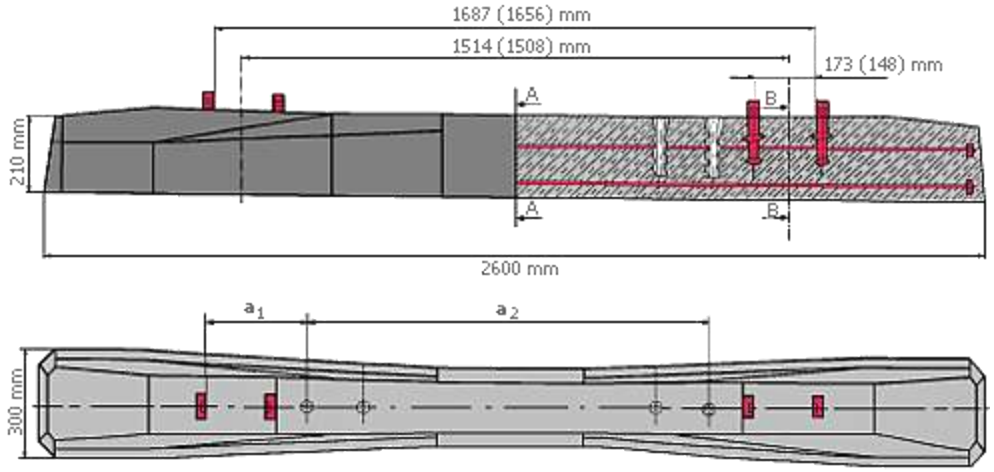
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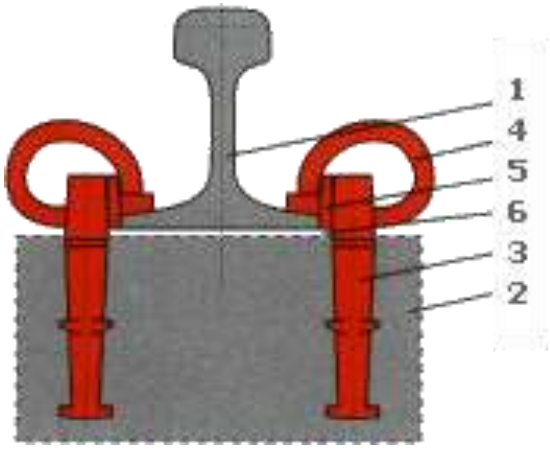
Elements of pavement

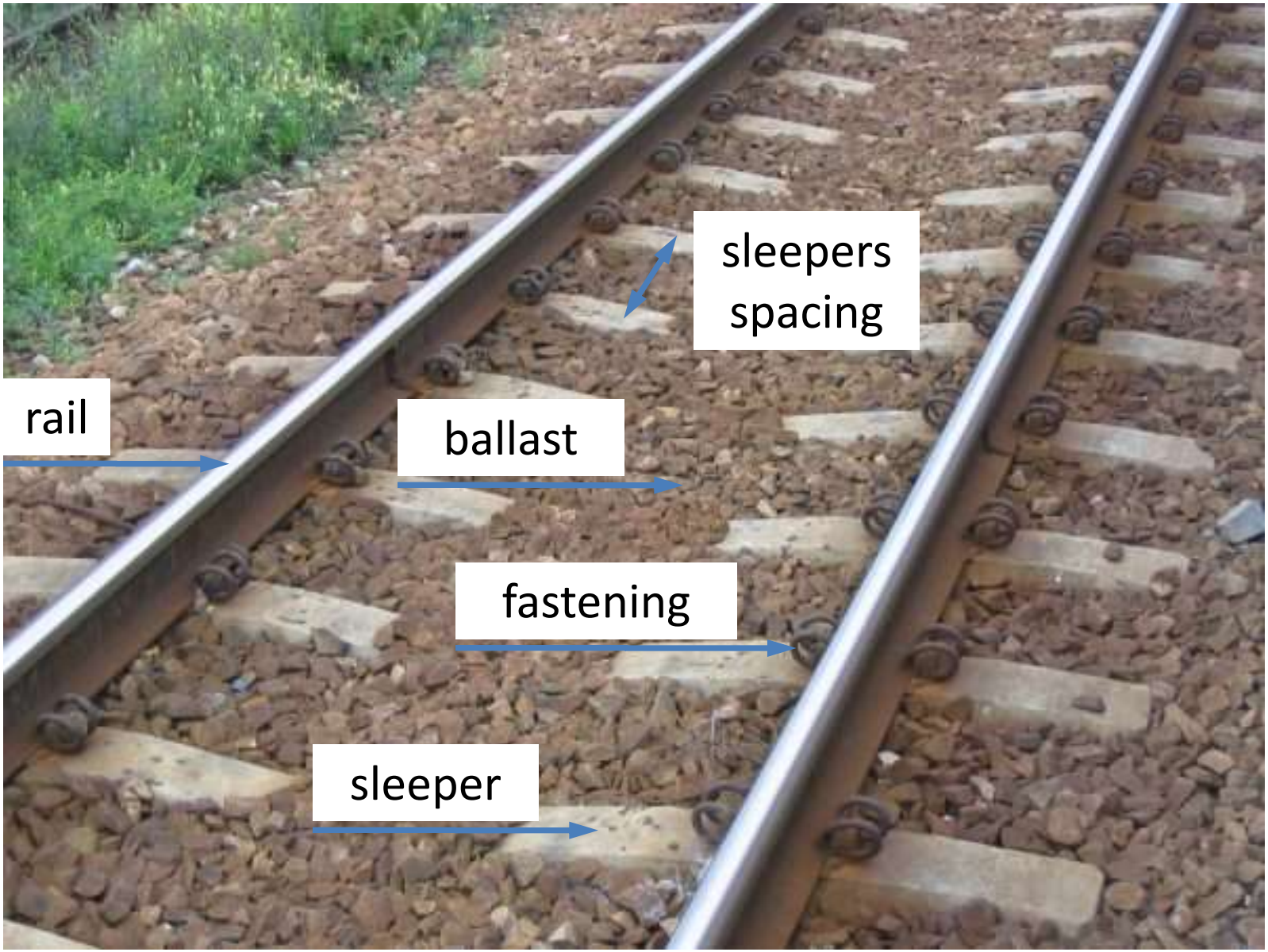
- rails
- fastening
- sleepers
- ballast



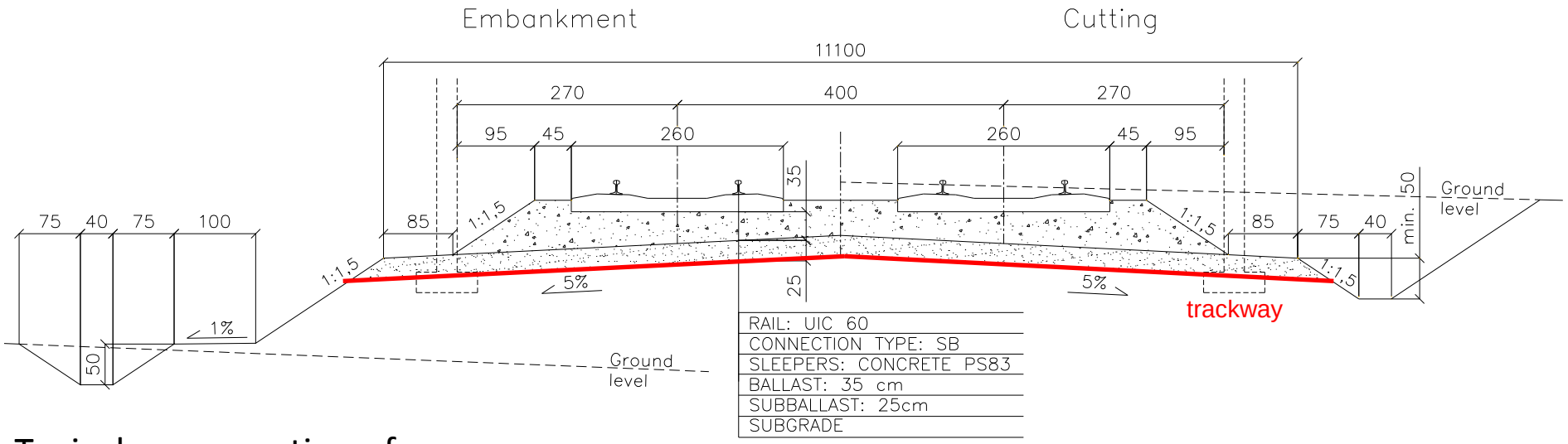




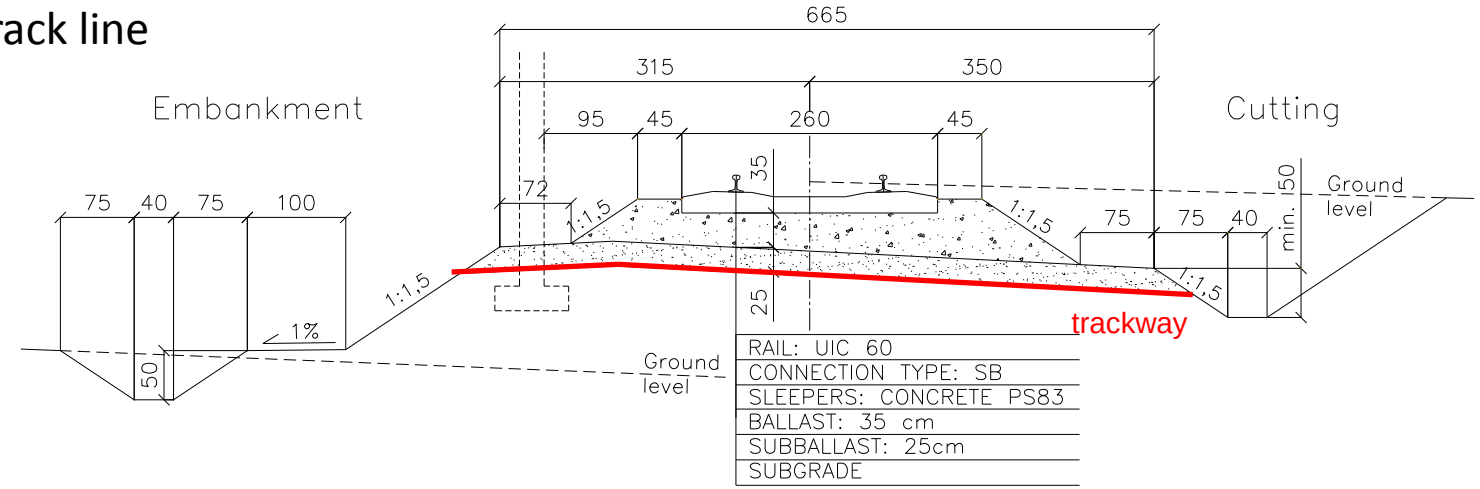



sleepers
spacing
rail
ballast
fastening
sleeper

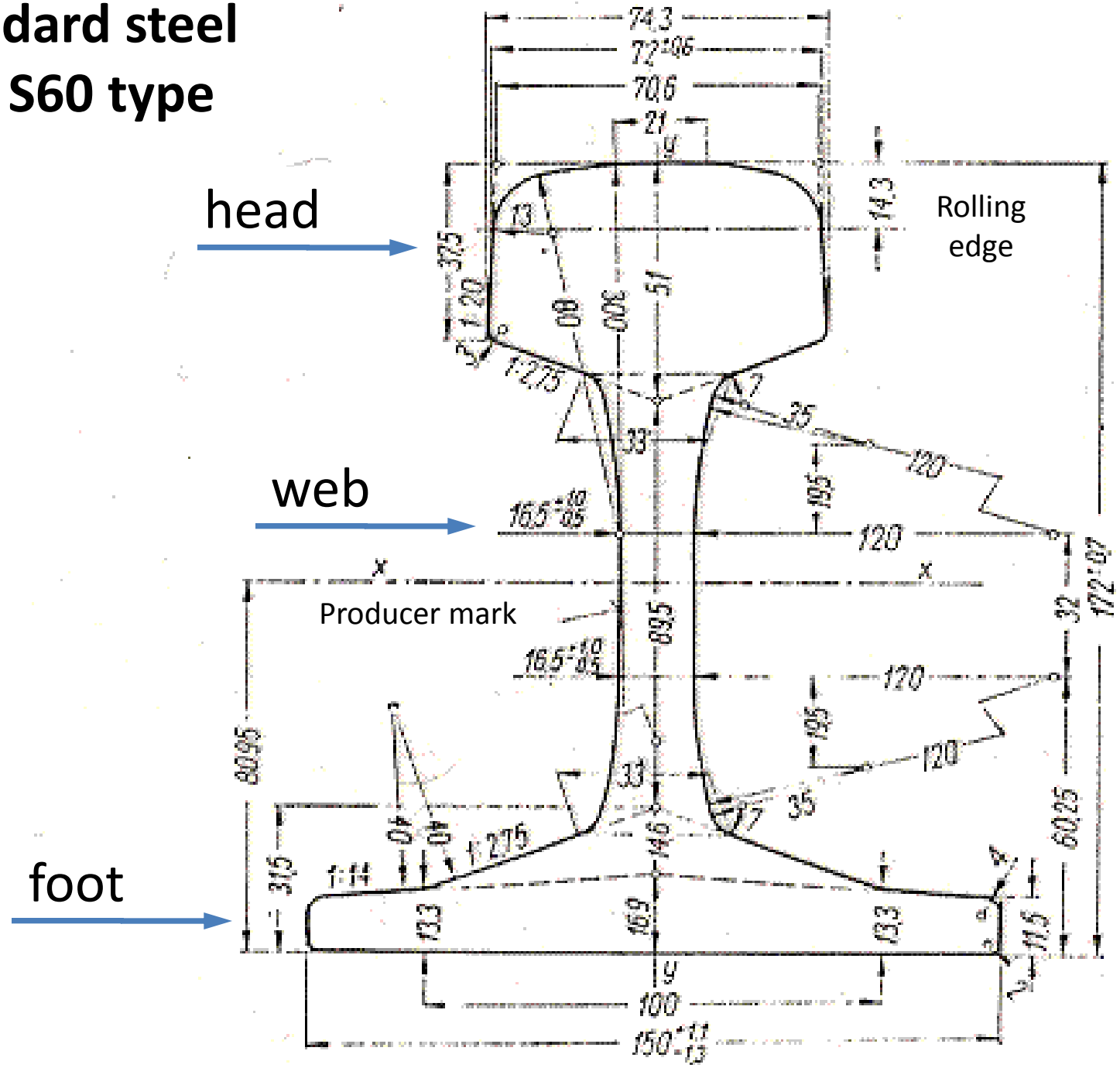
Typical cross-section of a double track line



Typical cross-section of a single track line



Standard steel rail S60 type



Technical data of European rails

Type	Mass kg/m	Bending characteristic W_x [mm^3]	Moment of inertia I_x [mm^4]	Height H [mm]	Foot width S [mm]	Head width G [mm]
S49	49,43	240×10^3	1819×10^4	149	125	65,4
S54	54,54	262×10^3	2073×10^4	154	125	65,8
UIC50	50,18	$253,6 \times 10^3$	1940×10^4	152	125	68,6
UIC54	54,43	$279,19 \times 10^3$	2127×10^4	159	140	68,6
UIC60	60,34	$335,5 \times 10^3$	3055×10^4	172	150	70,6

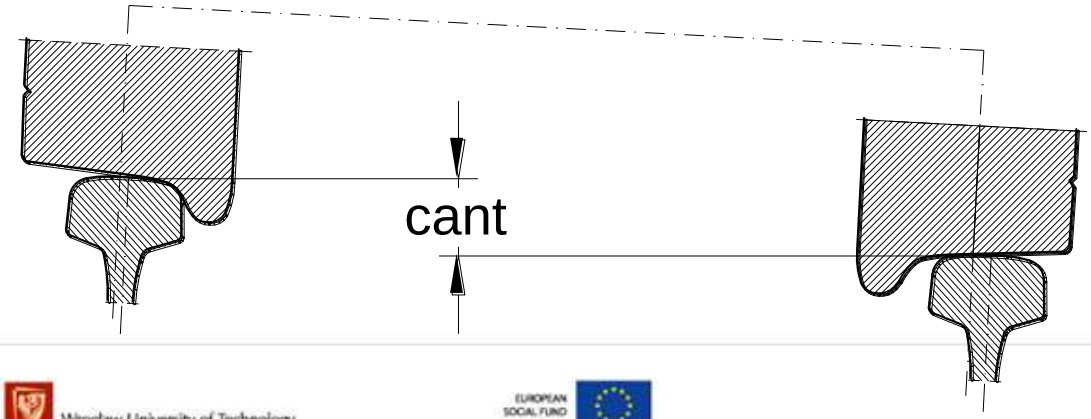
Role of rails

- Transfer of load from vehicles to lower elements of the track.
- Provide a smooth and hard running surface.
- Damping of vibrations excited by vehicles.
- Guide wheel flanges in 3D (on straight and curved sections).

ON STRAIGHT SECTION



ON CURVED SECTION



Common joints of rails

Supported joint
a – wooden sleepers,
b – double steel pad,
c – 4-hole fishplate,
d – a gap between adjacent rails





Unsupported joint
1 – 4-hole fishplate,
2 – bolts and nuts,
3 – a gap between adjacent rails,
4 – single steel pad.

source: www.transportszynowy.pl

Continouos welded track

A modern trackwork uses long welded rail lengths to provide a better ride, reduce wear, reduce damage to trains and eliminate the noise associated with rail joints. The most often used method for welding rails is Thermite welding.

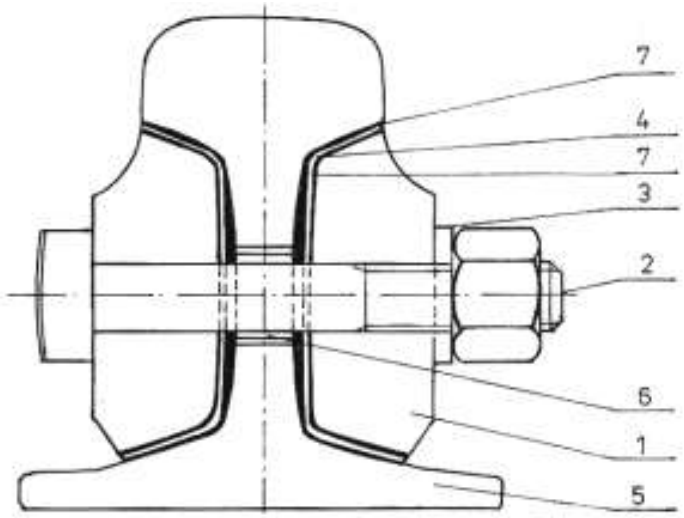


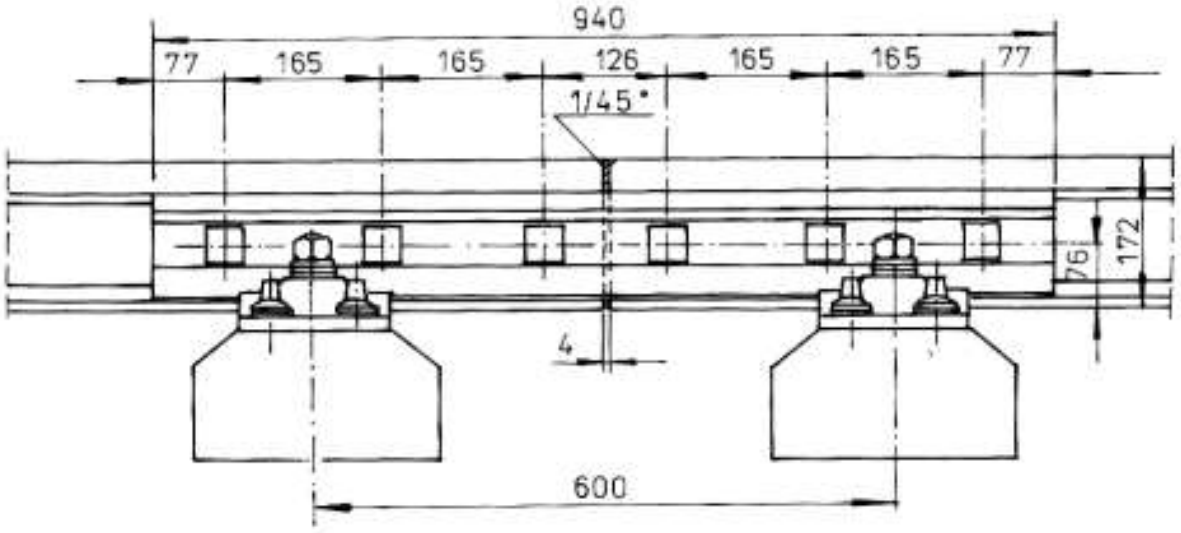




Glued-prestressed joint

Legend:
1 - 6-hole fishplate,
2 - friction grip bolt (prestressing the joint),
3 - washer,
4 - longitudinal insulation spacer,
5 - transversal insulation spacer (shape of the rail profile),
6 - insulation bush on the bolt.
7 - epoxy raisin glue.





Types of fastening

- Direct,
- Classic (K-type),
- Elastic (SB-3, Skl, Nabla, Pandroll-Fastclip, etc.)





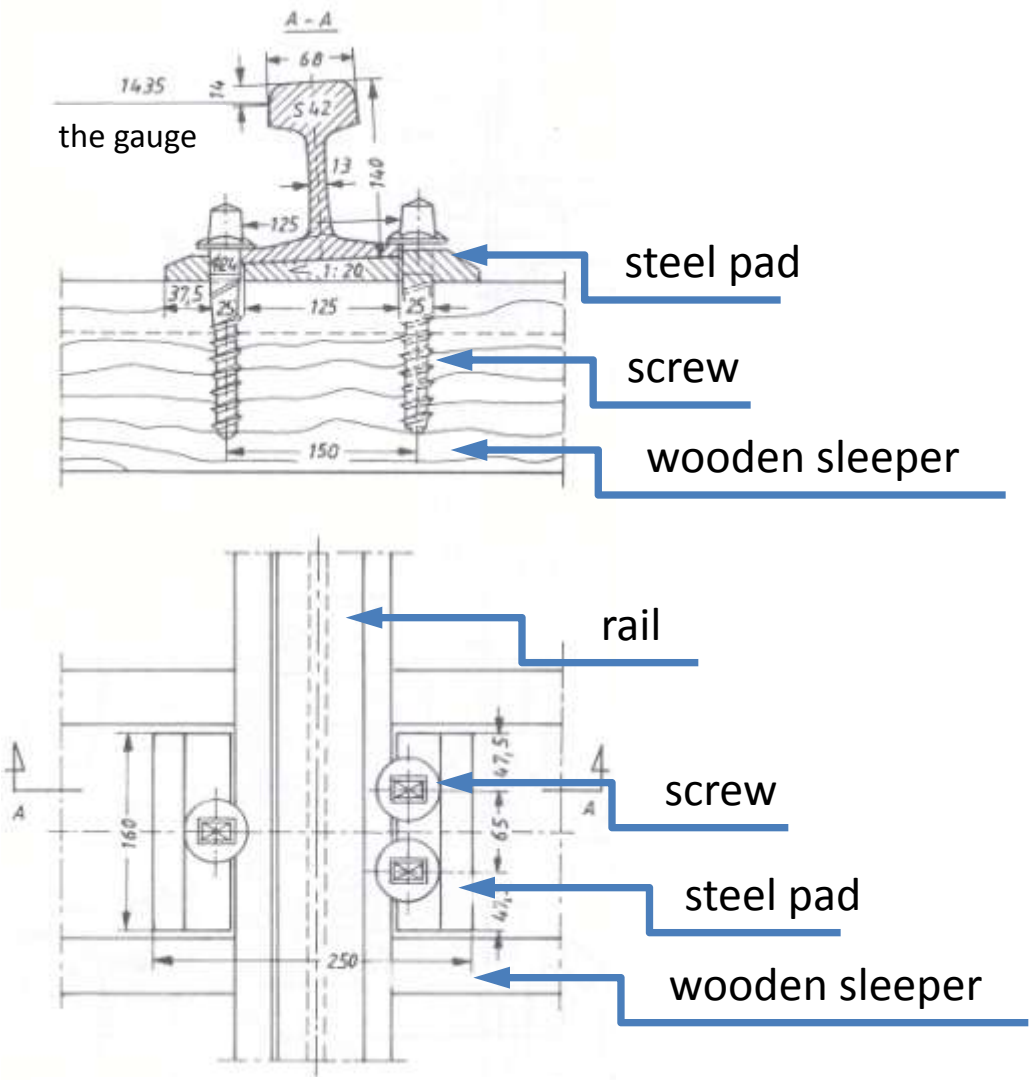




Role of fastening

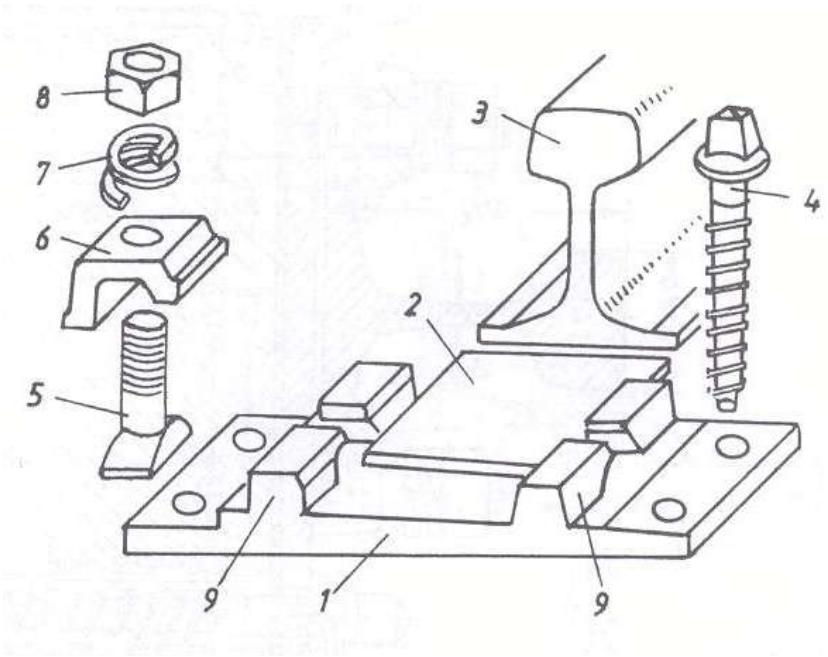
- Keeps rails fastened to sleepers (transfer of forces).
- Provides a proper slope of rail foot (1:20, 1:40) in the transverse plane.
- Prevents the rail from longitudinal movement.
- Damps noise and vibration coming from rails.

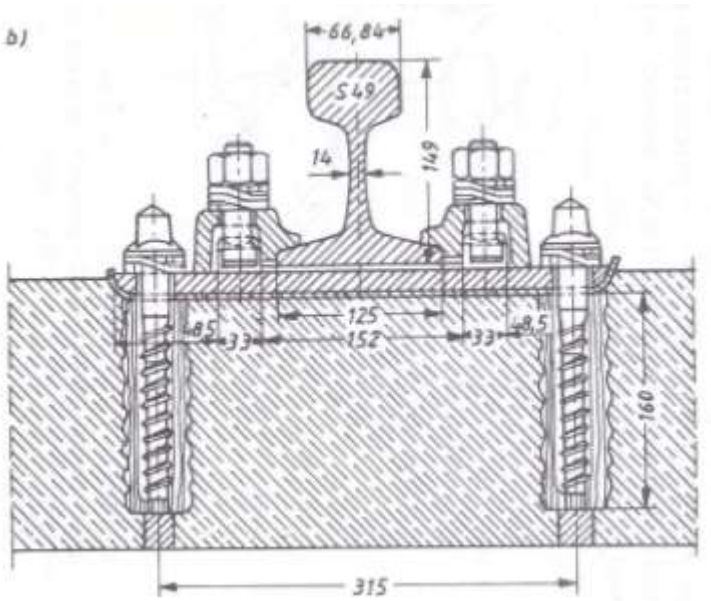
Direct fastening

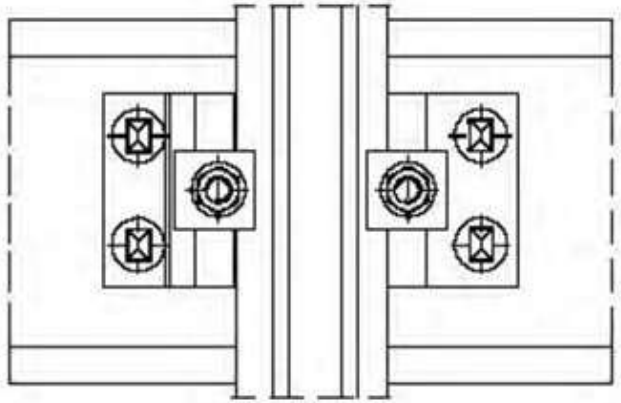


- old, obsolete fastening type
- screws loosening causes improper fastening of the rail

Classic fastening (K-type)



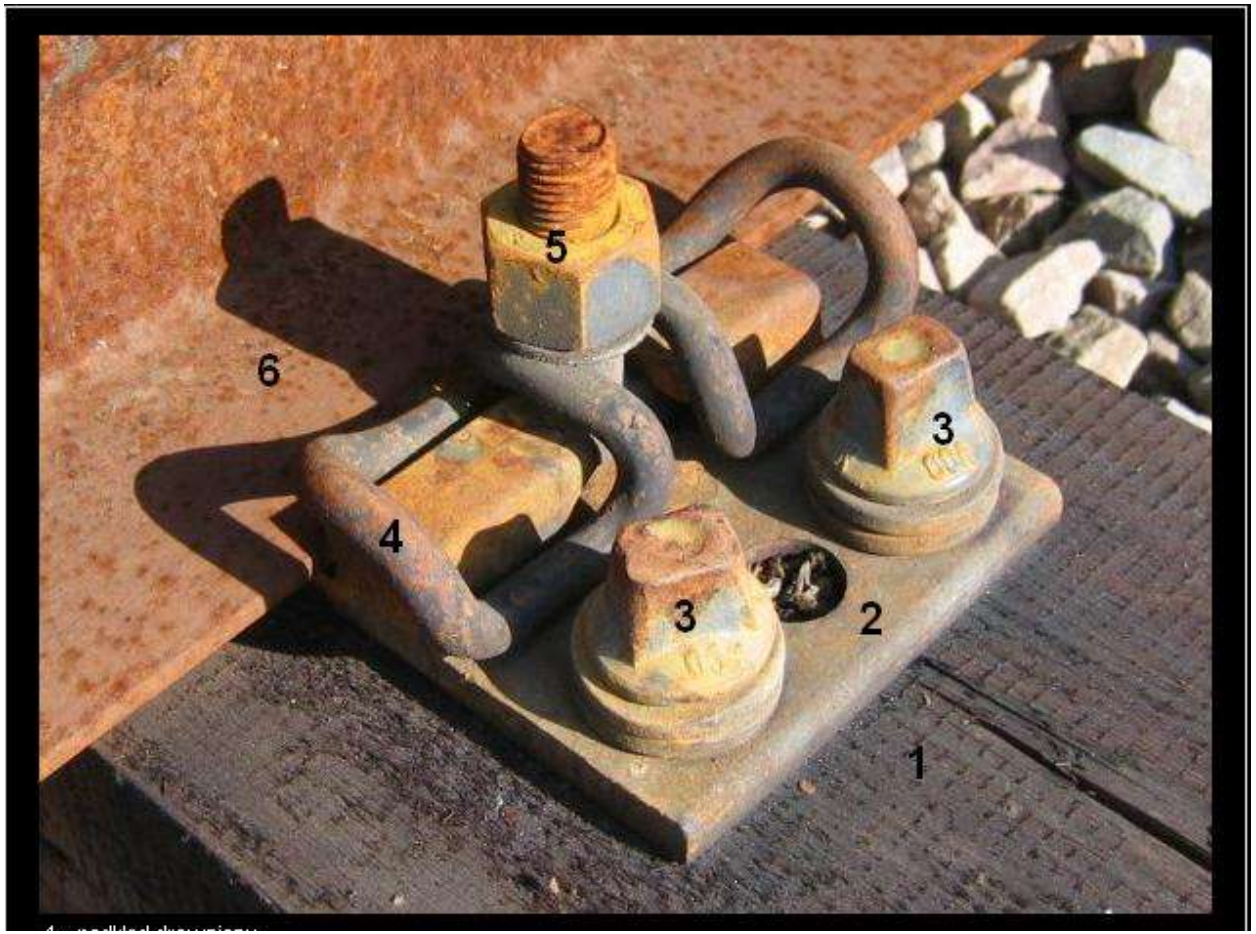




Disassembled K-type fastening:
1 – steel pad, 2 – poplar or rubber pad,
3 – rail, 4 – screw, 5 – bolt, 6 – frog,
7 – spring washer, 8 – nut, 9 – rib

- old, gradually withdrawn fastening type
- rails are rigidly bonded what causes transfer of vibrations,
- difficult method of assembly, impossible to automate

Semi-elastic fastening (Skl-12 type)



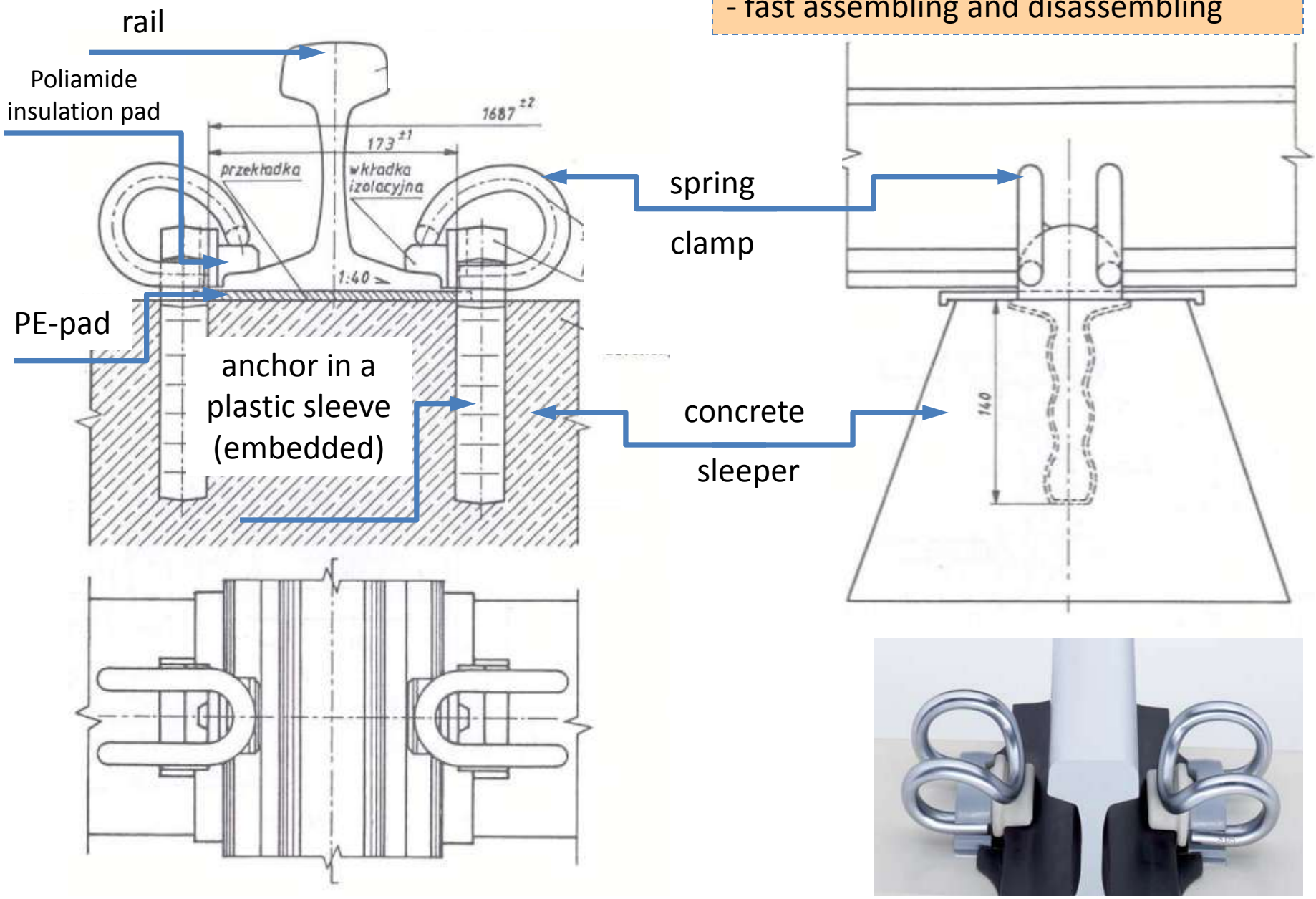
1 – wooden sleeper, 2 – steel pad, 3 – screw,
4 – spring clamp, 5 – bolt, 6 – rail foot

- transition type between K-type and elastic type,
- enables use of some elements of K-type fastening,
- the spring clamp enables semi-elastic rail fastening and damping vibrations,

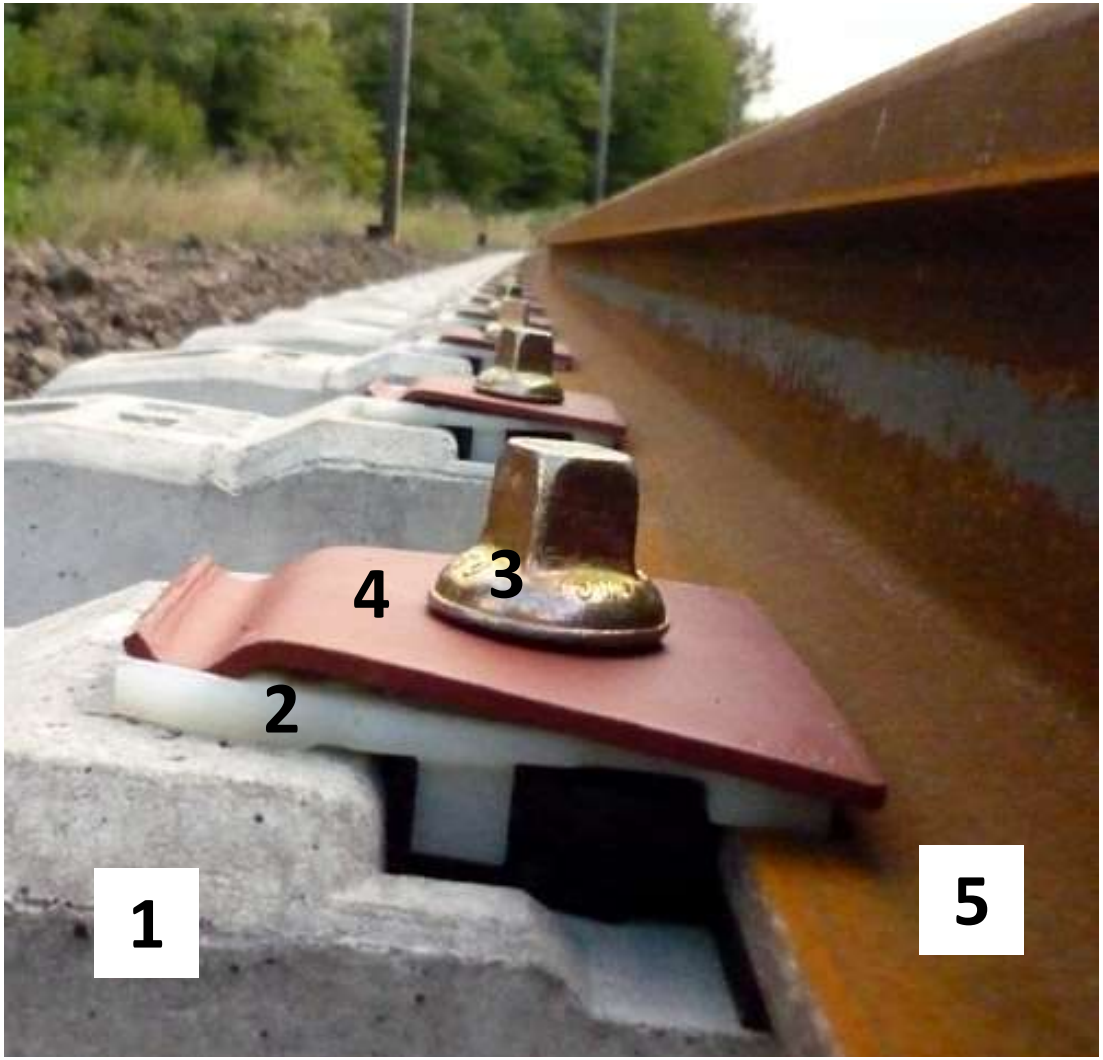
source: www.transportszynowy.pl

Elastic fastening (SB-3 type)

- ensures proper electric insulation and damping of noise and vibration,
- fast assembling and disassembling

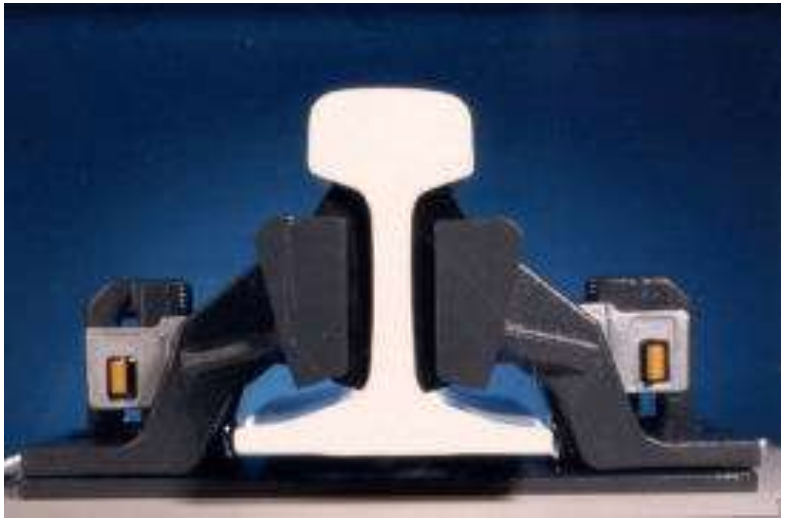


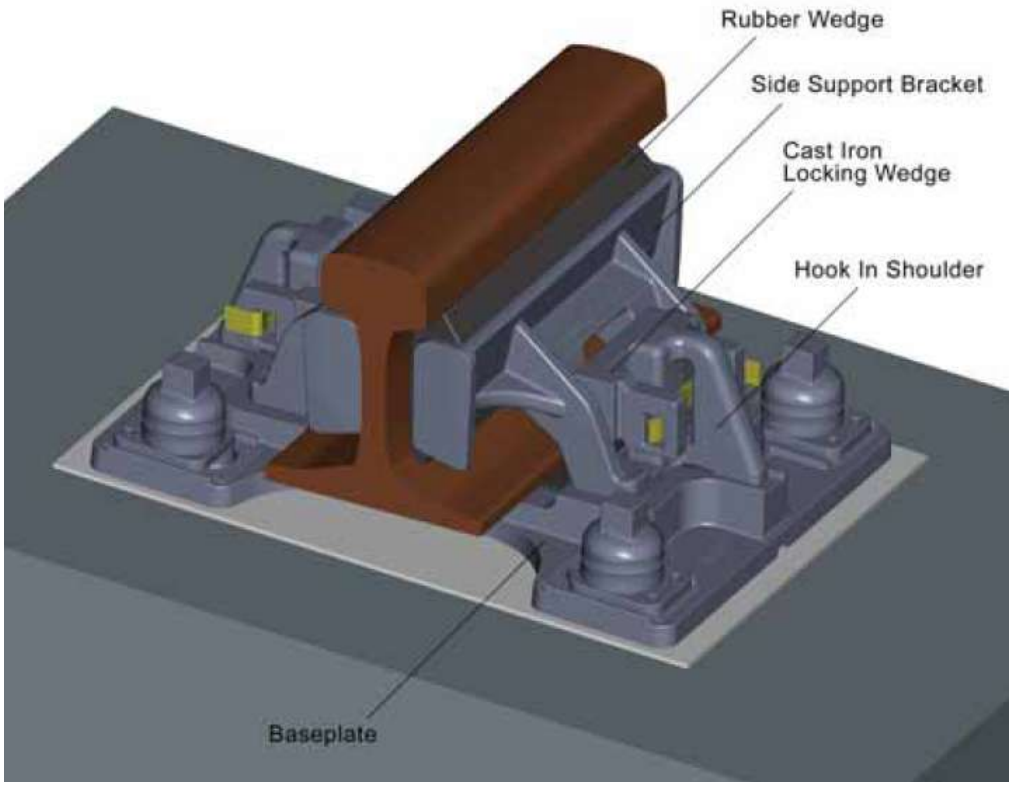
Elastic fastening (Nabla)



1 – concrete sleeper, 2 – PE-pad, 3 – screw,
4 – clamp, 5 – rail

Pandrol's Vanguard fastening



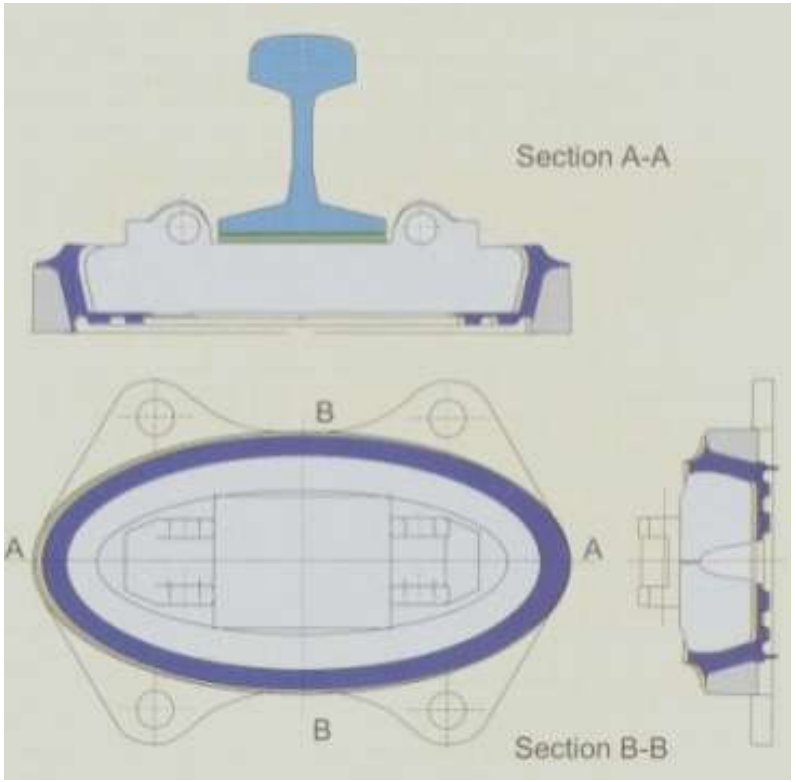


<u>The principle of work:</u>

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.

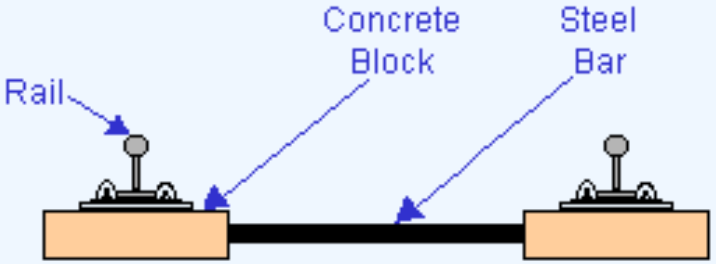
Cologne Egg fastening





<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.
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.

Types of sleepers



Depending on material:

- wooden,
- concrete,
- concrete-steel,
- steel
- plastic/rubber.





Role of sleepers

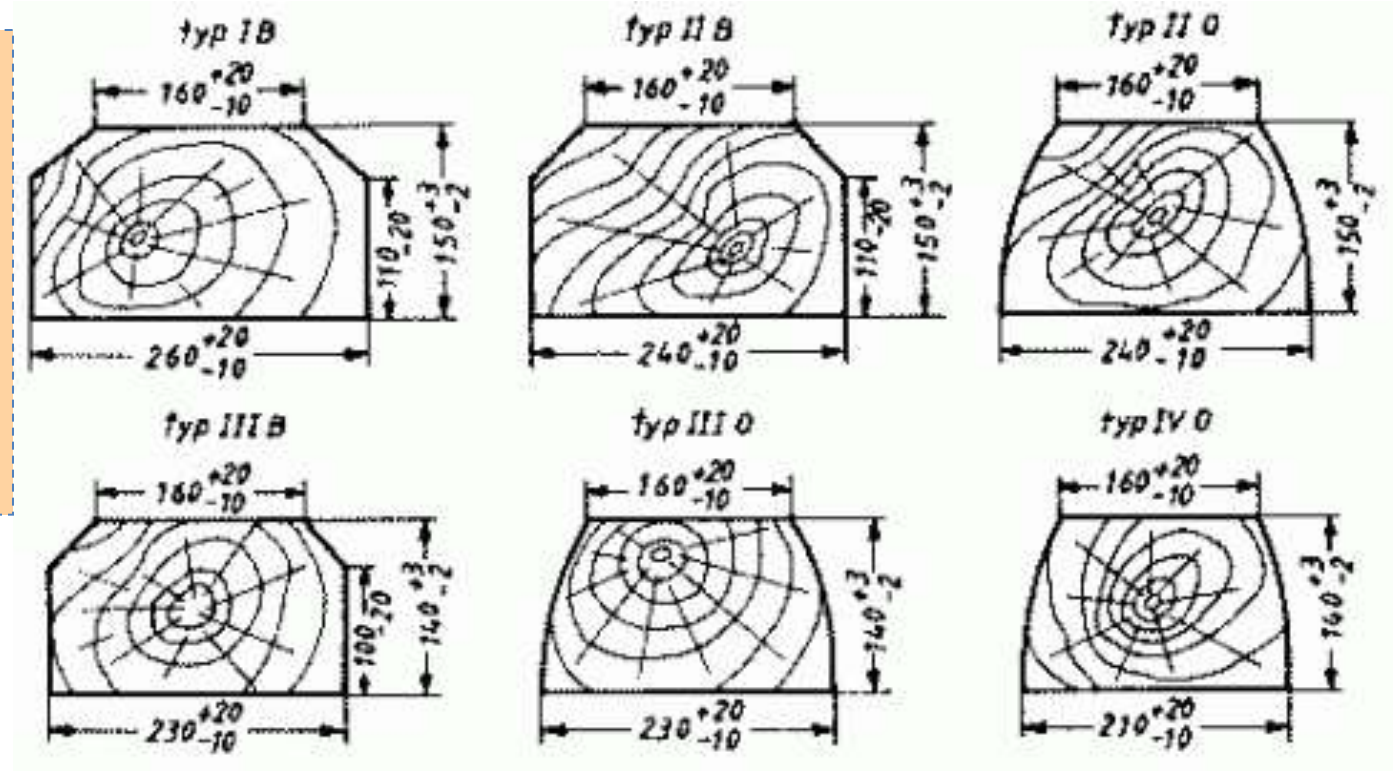
- Transfer of load from rails to the ballast.
- Support of rails in horizontal direction (especially on curved sections of track).
- Provide a constant gauge between rails.
- Maintain proper cant on curved sections.
- Damp vibration coming from the rails.

Standard wooden sleepers

oak, azobe: 35-40 years,
beech: 22-25 years,
pine: 18 years.

Type	Length [m]	Volume [m^3]	Cross section area [mm^2]	Moment of inertia [mm^4]	Bending modulus [mm^3]
IB	2600	0,0962	37000	6493×10^4	829×10^3
IIB	2600	0,0894	34400	6099×10^4	783×10^3
IIO	2600	0,0923	35500	6210×10^4	788×10^3
IIIB	2500	0,0770	30800	4711×10^4	647×10^3
IIIO	2500	0,0755	30200	4741×10^4	644×10^3
IVO	2500	0,0730	29200	4526×10^4	621×10^3

- easy to cut to the required length,
- ensures proper electric insulation and damping of noise and vibration
- require fungicide chemicals (non-eco)



Types of concrete sleepers

Depending on type of reinforcement:

- reinforced concrete,
- prestressed concrete.

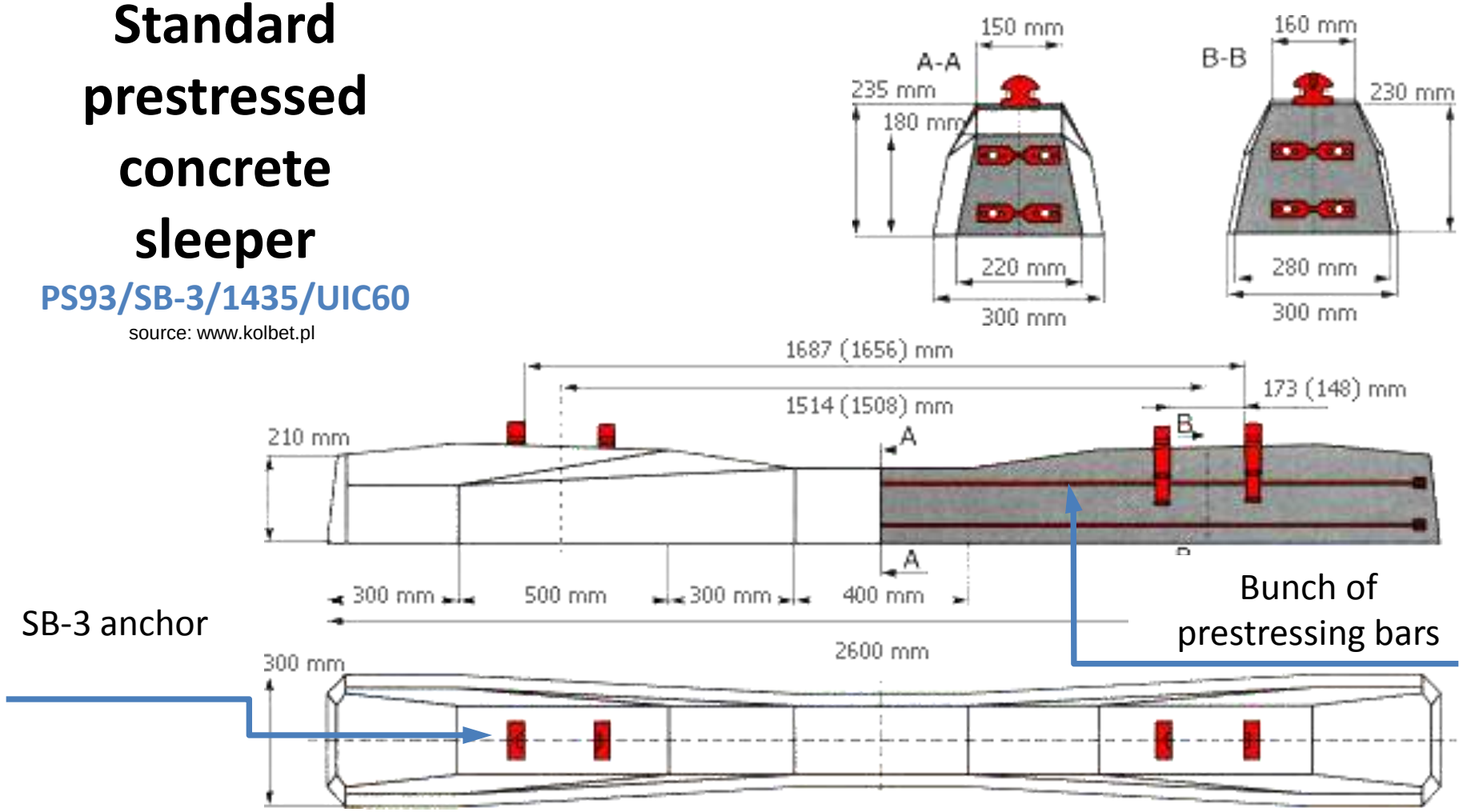
Depending on shape:

- beam,
- block,
- slab.

Standard prestressed concrete sleeper

PS93/SB-3/1435/UIC60

source: www.kolbet.pl

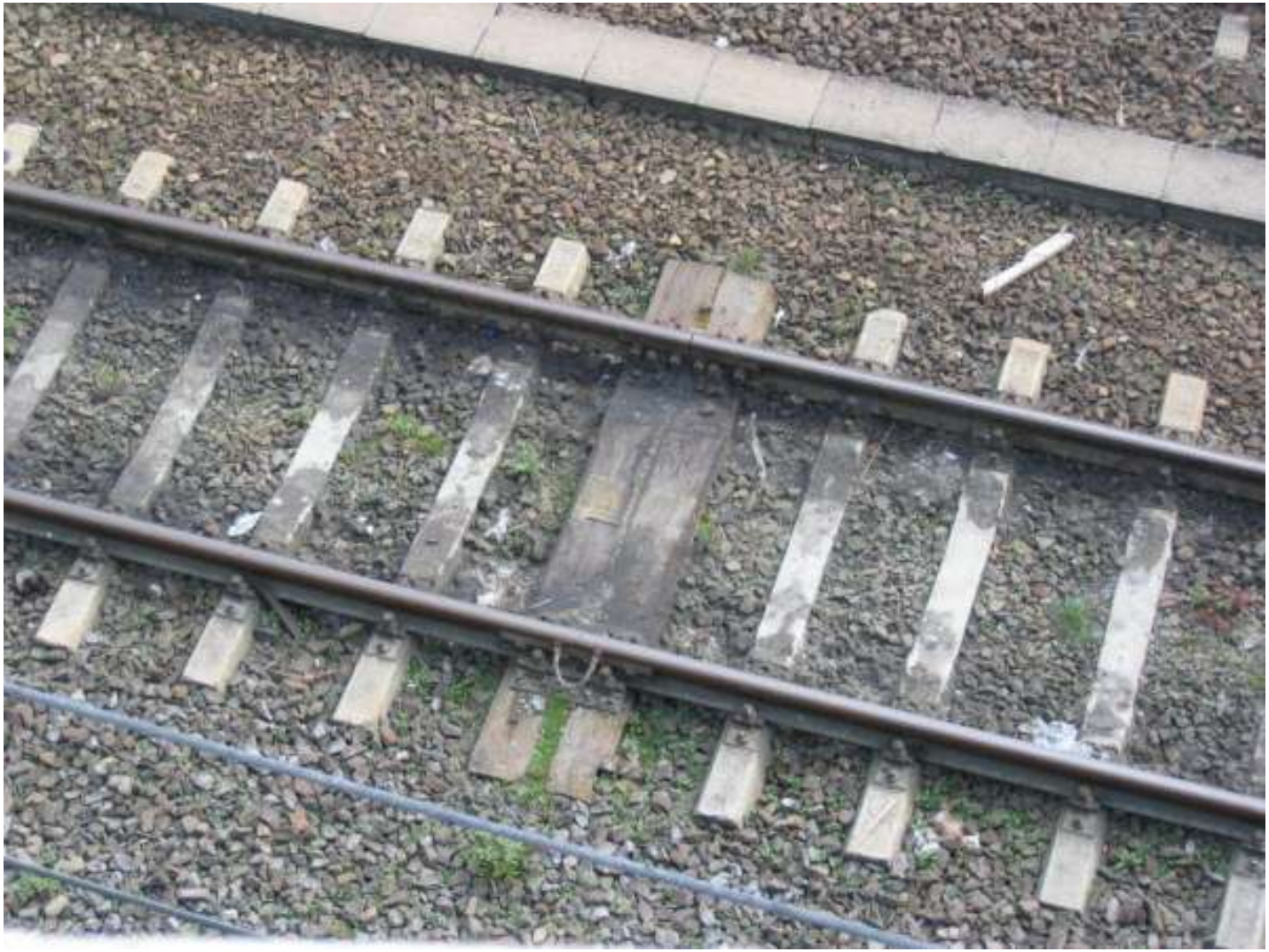


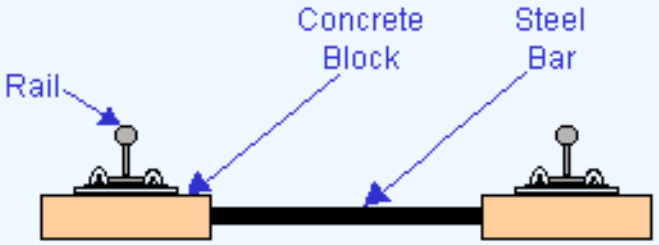
Technical data

Concrete:	**B60**
Prestressing steel:	**8 bars ϕ7 mm**
Consumption of ϕ7steel:	**6.10 kg**
Mass:	**320 kg**
Volume:	**0.1224 m^3**
Area of ballast support:	**0.6805 m^2**

- much better durability than wood,
- worse parameters of noise and vibration damping (cracking),
- reduces the cutting down of trees

The most damaging vibrations occur in the classic joints and are caused by wheels crossing the gap between adjacent rails. In this spot wooden sleepers perform better than concrete ones due to a better damping coefficient and better vibration resistance.





Twin block track form using a sleeper with two cast concrete blocks held to gauge by a steel bar. The system is favoured by the French and is also known by the names Sonneville block or Stedef track. It has the advantage of being lighter than standard concrete sleepers and the four faces of the two blocks resist movement better.

Concrete-steel block sleepers

Mixed concrete and wooden sleepers used on the Sheffield Supertram LRT system. The concrete sleepers are of the twin block type. Note that the steel bar connecting the two blocks is normally covered by the ballast. Wooden sleepers are used for the crossover because the timber is easy to cut to the required size.

source:
http://www.railway-technical.com

Concrete-plate sleepers

- provides continouos support for the track,
- very sensitive to bad subbalast condition
- impossible to exchange without demolition



Steel sleepers





- low mass
- easy assembly
- recyclable
- suffer from rusting
- conduct electricity

Steel Y-shaped sleepers

- more uniform load distribution,
- better dynamic performance,
- reduced volume of ballast required,
- lower acoustic emission.





Plastic composite sleepers

source:
www.rti-railroad-tie.com



The 50+ year extended life span of composite crosstie provides significant cost savings.

Composite ties are completely compatible with wood tie rail systems. Unlike chemically treated wood sleepers, composite railroad ties do not conduct electricity. They have virtually no moisture content, and although they possess AREMA compliant strength. They do not rely upon any conductive steel or concrete components for structural strength as do some other composite sleepers. Composite ties are electrically non-conductive thereby diminishing railroads' problems with stray current corrosion and interference with proper track circuit and signalling operation. Composite crossties do not require any pre-drilling of holes prior to spiking (cut or screw spikes) and do not/will not crack or split during any type of conventional mechanical or manual spiking.

Ballast

Ballast layer rests on a trackway (the upper surface of ground formation) formed in a way to enable the removal of ground water and rain water which soaks trough the ballast. The ballast is tightly compacted or tamped around the sleepers to keep the track precisely levelled and aligned. The width and thickness of the ballast layer are dependent on the line category.

The best material for ballast is crushed stone, produced from crushing hard rocks resistant to crushing, scratching and atmospheric weathering, e.g. granite, porphyry, basalt, gneiss and marble. The characteristic for crushed stone is that the grains of 30-60 mm diameter have sharp edges which enable mutual blocking of their position and keeping a proper profile of the track pavement. It is proved that resistance against the horizontal movement of sleepers in ballast made of sand is a half of that offered by gravel ballast. After certain period of operation ballast has to be cleaned from litter and natural dirt: organic ground, leaves etc. Dirt can diminish the effect of friction between grains.



Role of ballast

- Load transfer from the sleepers (one wheel loads consecutively 3-5 sleepers only), spreading it through the ballast and transfer to the trackway uniformly spread. Interaction between vehicles and the track should cause elastic deformation only. Elastic ballast layer enables the calm running of wheels and extends the sleepers durability.
- Fast soaking through and transport of precipitation water to the sides of the trackway to keep the formation as dry as possible.
- Damping of impulses generated by wheels – the ballast should be an elastic material with resilience characteristics.
- Keeping the sleepers in their position in 3D. The passing vehicle, besides the vertical forces, loads rails with longitudinal forces (creeping) and transversal forces e.g. by hunting of boogies or centrifugal force on curved section s of the track.

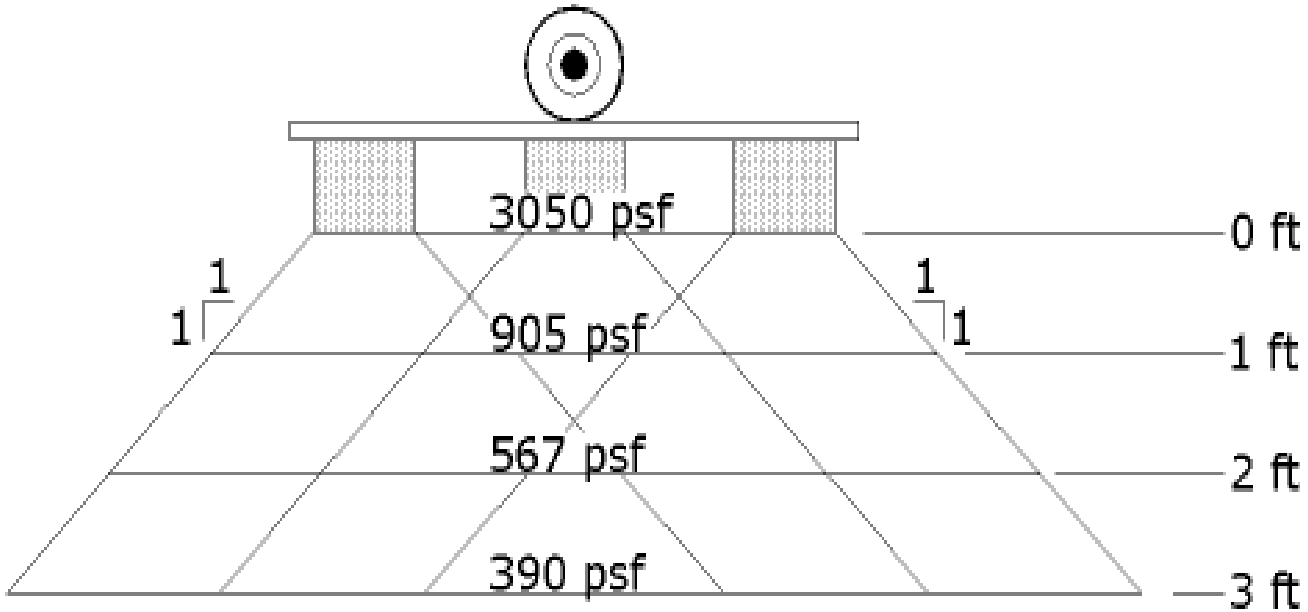
Cleaning of the ballast

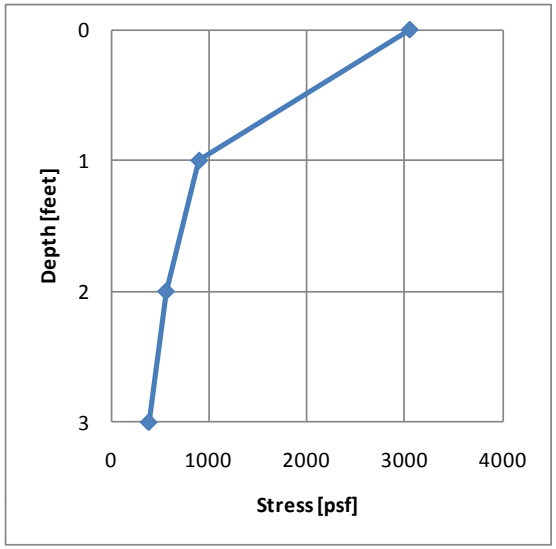


For cleaning, devices called ballast cleaner machines are used which process the gravel integrating old and new material, builds it in and tamps to the required geometry of the track.



Load transfer through the ballast





Track class

Track class	Allowable speed [km/h]	Allowable locomotive axle load [kN]	Allowable wagon axle load [kN]	Intensity of traffic [Tg/year]
0	200	221	140	up to 25
1	100 120 140 160	221 210 210 205	221 205 190 140	not specified
2	80 100 120	221 210 205	221 205 190	16-25
3	70 80	221 210	221 205	9-15
4	60 70	221 210	221 205	4-8
5	30 40	221 210	221 205	up to 3

Construction standard

Pavement construction standard describes minimal technical requirements for construction materials for the given track class:

- type of rails,
- type of sleepers,
- type of fastening,
- maximum sleeper spacing
- minimum ballast layer thickness under the sleepers

as well as technical parameters of materials.

In every class a few construction standards can be used. Standards should be used at the construction of new tracks, rebuilding and modernization taking into account the track class required by operation conditions. The track qualified as a specific construction class should be built with requirements of the given class or higher.

Example of construction standard

Construction standards for the track class 0

Variant No.	Rail type	Sleepers type	Maximum sleepers spacing [m]	Fastening type	Minimum ballast layer thickness under the sleepers [m]
0.1	New UIC60 for v>200 km/h	PS-93 PS-94	0,60	SB type	0,35
0.2	New UIC60 for v>200 km/h	I/B, II/B hard	0,60	Skl type K-type	0,30

On Polish Railways the standard "D1 - Warunki techniczne utrzymania nawierzchni na liniach kolejowych" proposes for every class from 2 to 6 variants.