Track stiffness variations

This is a well known problem especially at transitions from:

- Slab track to Ballasted track
- Tunnels to Ballasted track
- Bridges to Ballasted track
- S&C to plain line
Maintenance issues

Stiffness variations

- Stiffness variations
- Dynamic load
- Wear on track components
Is there an optimal stiffness?

The required stiffness of the track, in total is limited by a requirement of a maximum deflection off the rail: ~< 2.3 mm (NB, North America ~< 5mm)

- Higher axle loads and/or speed needs a stiffer track, due to higher dynamic forces
- A stiff track structure leads to a higher load at each fastening point and on the rail
- A soft track distributes the load over more fastening points but is less stable.
- The stiffness needs to be independent of temperature, speed of the train and constant over time.

The aim is to reduce the stiffness on the stiffer track structure and foremost to build a smooth transition zone to the track with lower stiffness.
Zimmerman calculations

One way of calculate the total stiffness that is required:

Track with low stiffness, rail deflection around 3.3 mm

Track with high stiffness rail deflection around 0.4 mm
Vertical deflection of the track structure
Rail deflection of slab track and ballasted track under dynamic load

**Deflection of Rail**

**Ballasted Track**
- 0.05 - 0.35 mm
- 0.3 - 0.7 mm

**Slab Track**
- 0.8 - 1.5 mm
- 0.05 - 0.2 mm

- Deflection of Fastening System
- Deflection of ballast and track formation
- Deflection of concrete slab and track formation
How to change the stiffness of a track structure

Lowering the total stiffness: Tunnels and bridges with concrete deck and ballast

- Fastening systems with high flexibility and low stiffness
- USP
- Ballast mats (some maintenance restrictions)
Transition with large step in stiffness of track

No transition zone, situation as built

Slab track / S&C / Tunnel / Bridge etc.

Ballasted track
Transition zone with step change in stiffness along the track structure

With transition zone, as built

Slab track / S&C / Tunnel / Bridge etc.

Transition zone

Ballasted track
Transition with large step in stiffness of track
After some time maintenance is required

Slab track / S&C / Tunnel / Bridge etc.  Ballasted track
Transition with large step in stiffness of track
Maintenance or upgrading of track

Slab track / S&C / Tunnel / Bridge etc.

Transition zone

Newly Ballasted track
How to change the stiffness of a track structure

Lowering the total stiffness: **Switch**

- To even out the stiffness variations, the stiff track can be made less stiff and the ballasted track can be made stiffer. In most cases, a combination of this is done.

- Switches: USP, Under Sleeper Pads in combination with rail pads with different pad stiffness.
How to change the stiffness of a track structure

Lowering the total stiffness: Switch

2.1.2. Tungrotsplatta typ P2

SKL 12 clip

SKL 14 clip

4,5 mm mellanlägg
För 2 mellanlägg, total
Statisk styvhet: 60 kN/mm
How to change the stiffness of a track structure

Lowering the total stiffness: Slabtrack

- Fastening system with high flexibility
- Use railpads and/or intermediate pads with different stiffness
How to change the stiffness of a track structure

Lowering the total stiffness: Steel bridge deck with wooden sleepers

- High stiffness, noise and vibration problems
How to change the stiffness of a track structure
DFF 300 LT for wooden sleepers on steelbridge

- High elasticity
- Low stiffness
- Low toe load
How to change the stiffness of a trackstructure
Make the ballasted track structure stiffer

- This is a more challenging task!

- Some different methods are available, but most of them have some restrictions when it comes to maintenance.

- Ballast gluing of the complete ballast layer or only the shoulders
  - Difficult to do, time consuming, environmentally questionable
  - Tamping is not possible, have to be "re-glued"

- Larger sleepers, twin sleepers or even larger sleeper frames
  - Works well but are difficult to lay in track and tamp
  - Non standard sleepers

- Angled concrete plate after/before bridge construction
  - Difficult to maintain, not possible to tamp, high wear on ballast
How to change the stiffness of a track structure

Ballast glueing
How to change the stiffness of a track structure

Gradual change of stiffness with USP, Ballast mat and Rail pads
How to change the stiffness of a track structure
Gradual change of stiffness with USP, Ballast mat and Rail pads
How to change the stiffness of a track structure
Gradual change of stiffness with: Larger sleeper stiff track construction
Simplified transition zone with standard components

Practical approach to the task

1. A steady, gradual approximation of the structure and behaviour of stiffness of both types of superstructure.
2. A continuous approximation of the behaviour of settling of both types of superstructure. This area cannot be completely maintenance free and it (as well as the directly adjacent ballast track) can and has to be upgraded occasionally by simple measures.
3. Simple, repeatable (as often as required) correct-ability of the temporal changes in the trackstructure and substructure.
4. **Exact definition of properties and their long-term compliance in practice** by using clearly definable elements (steel construction, elastomers)
Simplified transition zone with standard components
Component details

- **Exact definition of properties and their long-term compliance in practice**
- Damping / Elastic material properties need to be designed for load and climate:
  - Frequency independent: Ratio between Static and Dynamic stiffness has to be low close to ~1,1 is preferred
  - Dynamic stiffness should be temperature independent
- Wear resistant and the dynamic stiffness should not be depending on shapes or voids, it should be a material specific behaviour
- Water resistant
Simplified transition zone with standard components
Steel frame with Elastomer
Simplified transition zone with standard components
Steel frame in position
Simplified transition zone with standard components
Sleepers is placed on steel frame
Simplified transition zones with standard components

Snow and ballast arrives at the same time
Simplified transition zone with standard components

Ballast in place
Universal transition Module

Main benefits

> Durable and reliable structure properties concerning settlements and stiffness by using time and load resistant elements (steel and elastic pads).

> Compensation of settlements in both: super- and substructure

> Independently usable on any kind of slab track type

> The length can be chosen to suit the specific project

> Few amount of single elements and hence sources or error

> Advantages of pre-fabrication quality

> Usage of conventional track construction methods

> Easy correction of construction failures and operation defects

> Unrestricted involvement in additional track equipment (e.g. guard rails)

> Less stress on the elastic elements due to the deployment of the stresses over a larger area
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Thank you for your Attention

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