Technology Development Guideline for Manufacturing and Testing of Rail Fastener Seminar

National Science and Technology Development Agency (NSTDA), Thailand Science Park, Pathumthani, Thailand，27-28 Sept. 2023

Design and Testing of Rail Fastener

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27 September 2023

Part One: Product Design

Design Team/Hardware/Software

Product Designers (R&D Engineers, Drawings)

Workstations

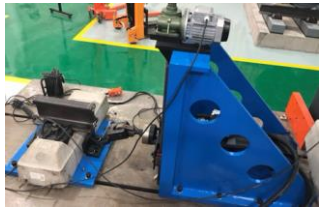
Software (ProE, Solidworks, FEA， CAD etc.)

* Ref. Pandrol PPT

Part Two: Product Testing

Test Team/Hardware/Software/Standard

- Engineers/Technicians
- Lab/Facility
- Software (Daq, Logger)
- Standards



* Ref. SUES CMA Lab

Part One: Product Design

1. Track Structure
2. Rail Fastenings
3. Effect of Rail Fastenings on Rail Roll
4. Low Noise and Vibration Fastenings
5. Stiffness Design

Part One: Product Design

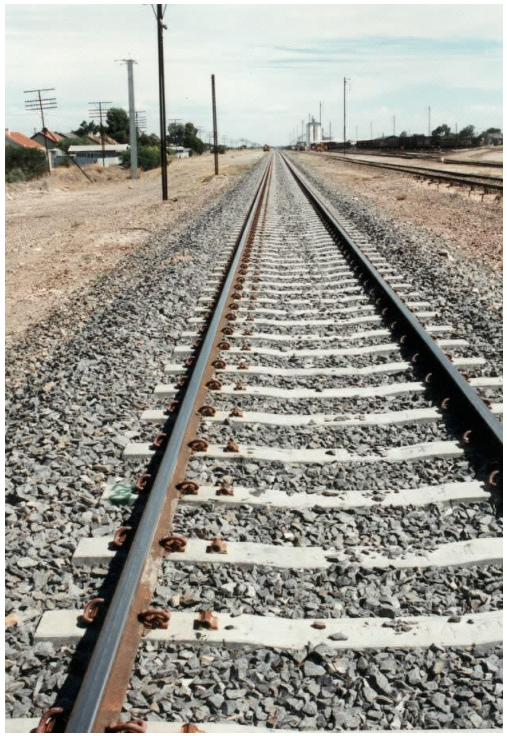
1. Track Structure

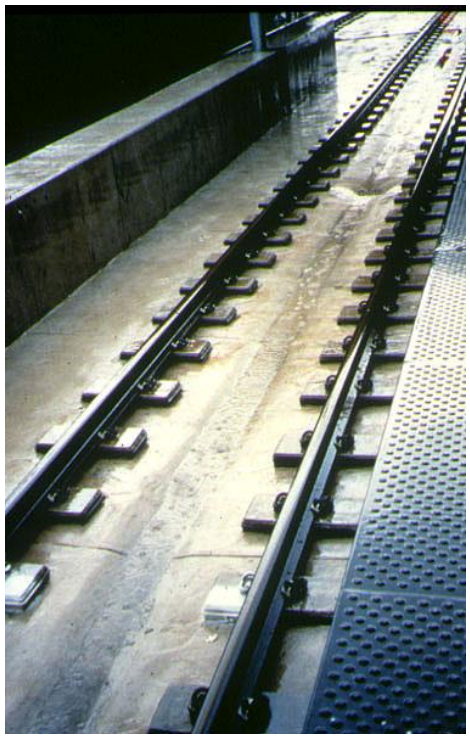
1. Track Structure

❖ Track Structure

What are the basic elements of the track structure?

❖ What different types of track exist?





1.1 Track structure – main features

- **Ballast**
  - Distribute load into subgrade
  - Provide resistance to lateral movement – buckling
  - Provide drainage
- **Sleepers**
  - Concrete, Steel, Wood, (Recycled materials …)
- **Rails**
  - Vignolles section
  - Continuously welded (Thermit, Flash butt)
  - Pre-stressed
- **Resilient fasteners …**

1.2 Track structure – other features

- Formation
  - drainage, ditches etc
- Switches & crossings
- Insulated joints
  - signalling blocks
- Expansion joints
  - bridges & viaducts
- Fishplated joints
  - still widely used in US
  - temporary joints
- Level crossings

1.3 Track structure – Track Types

- Ballasted Track
  - Resilience
  - Settlement
    - Tamping
  - Contamination
  - Drainage
  - Realignment
  - Ground settlement
  - Weight
  - Depth
- Non-Ballasted (Slab) Track
  - Higher construction cost
  - Lower maintenance (?)
    - lower cost
    - limited access time
  - Alignment
    - higher cant
    - higher lateral resistance
  - Applications
    - Tunnels
    - Bridges & viaducts
    - High speed
    - Urban environments

1.4 Non-ballasted track – requirements of fastening

- **Resilience**
  - at least equivalent of ballasted track
  - greater deflection for vibration reduction
- **Adjustment**
  - to facilitate construction
  - to allow for subsequent ground settlement / earthquakes

Part One: Product Design

1. Track Structure

2. Rail Fastenings

2. Rail Fastenings

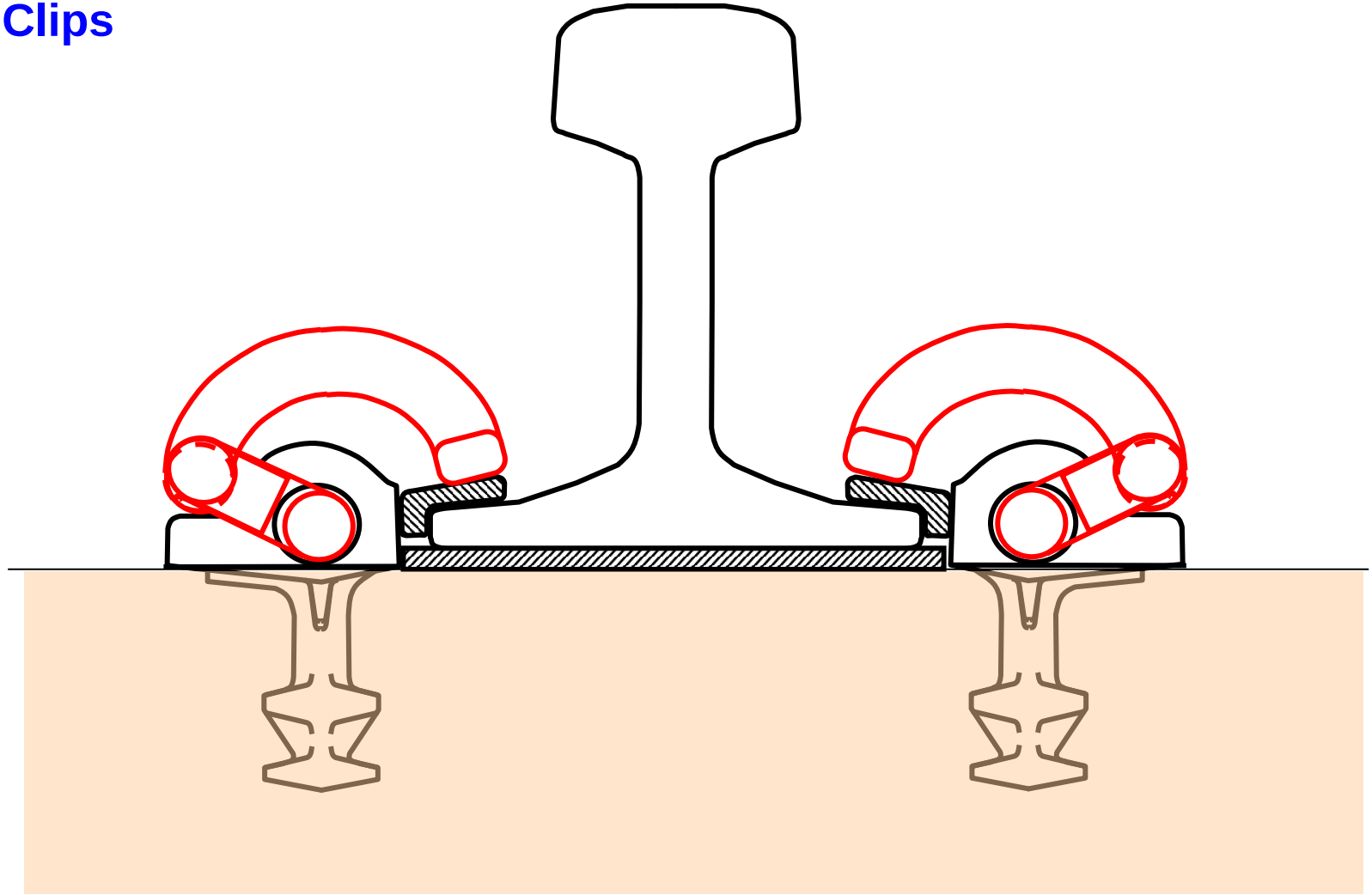
- Rail fastenings
  - What is a rail fastening?
  - What does a rail fastening do?
  - Specifying rail fastenings
  - How does a rail fastening work?
  - Types of rail fastenings
  - Successful rail fastenings

2.1 Requirements of a modern fastening system

- Transfer static loads from rail to track support
- Maintain track gauge and rail inclination
- Anchor rail to track support
  - … buckling
  - … pull-apart
- Provide electrical insulation … (steel, concrete)
- Attenuate dynamic forces … (concrete, steel)
- Facilitate maintenance of track
- Durability

2.2 Rail fastening system - Naming of parts

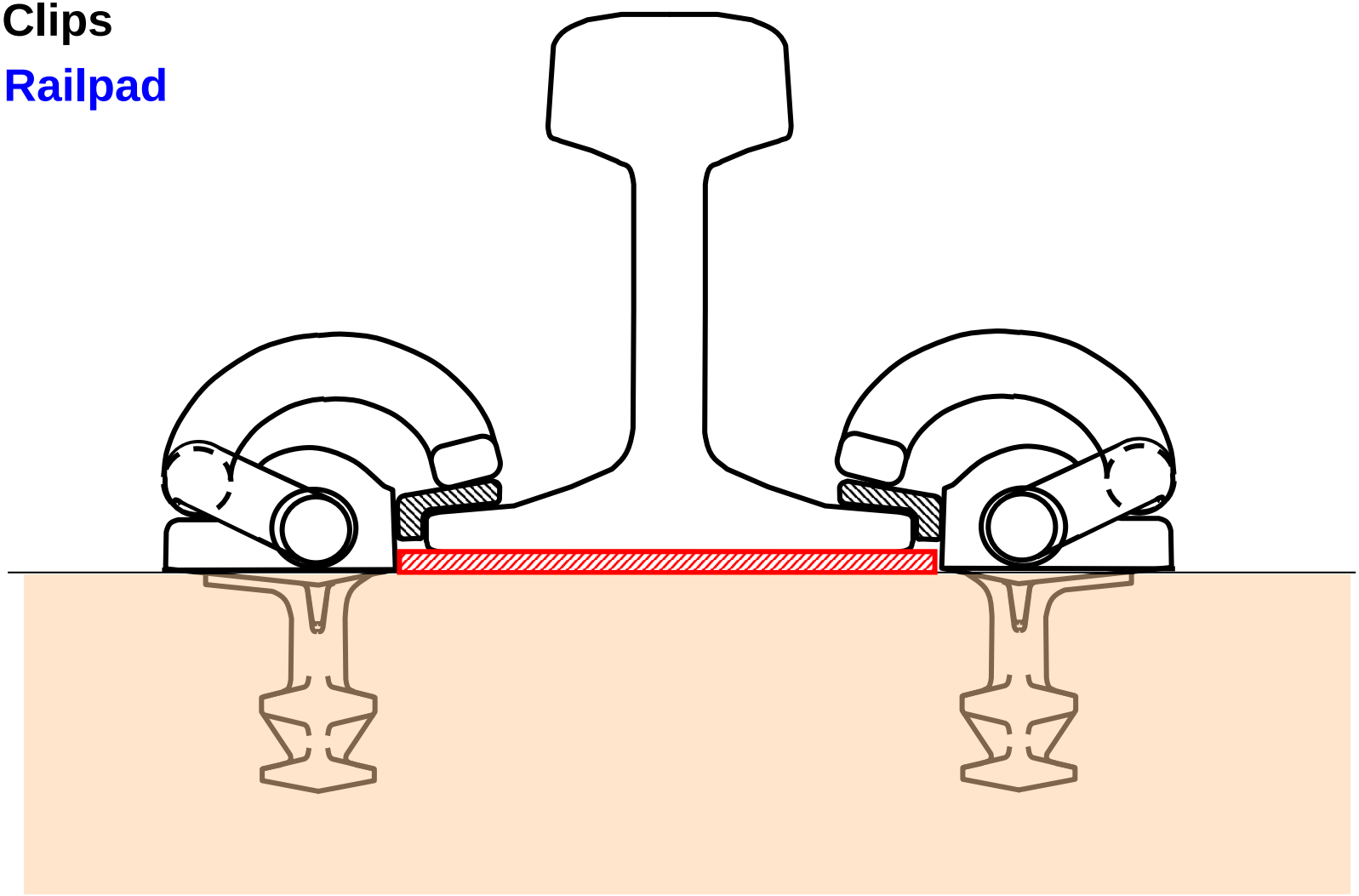
Clips



2.2 Rail fastening system - Naming of parts

Clips

+ Railpad

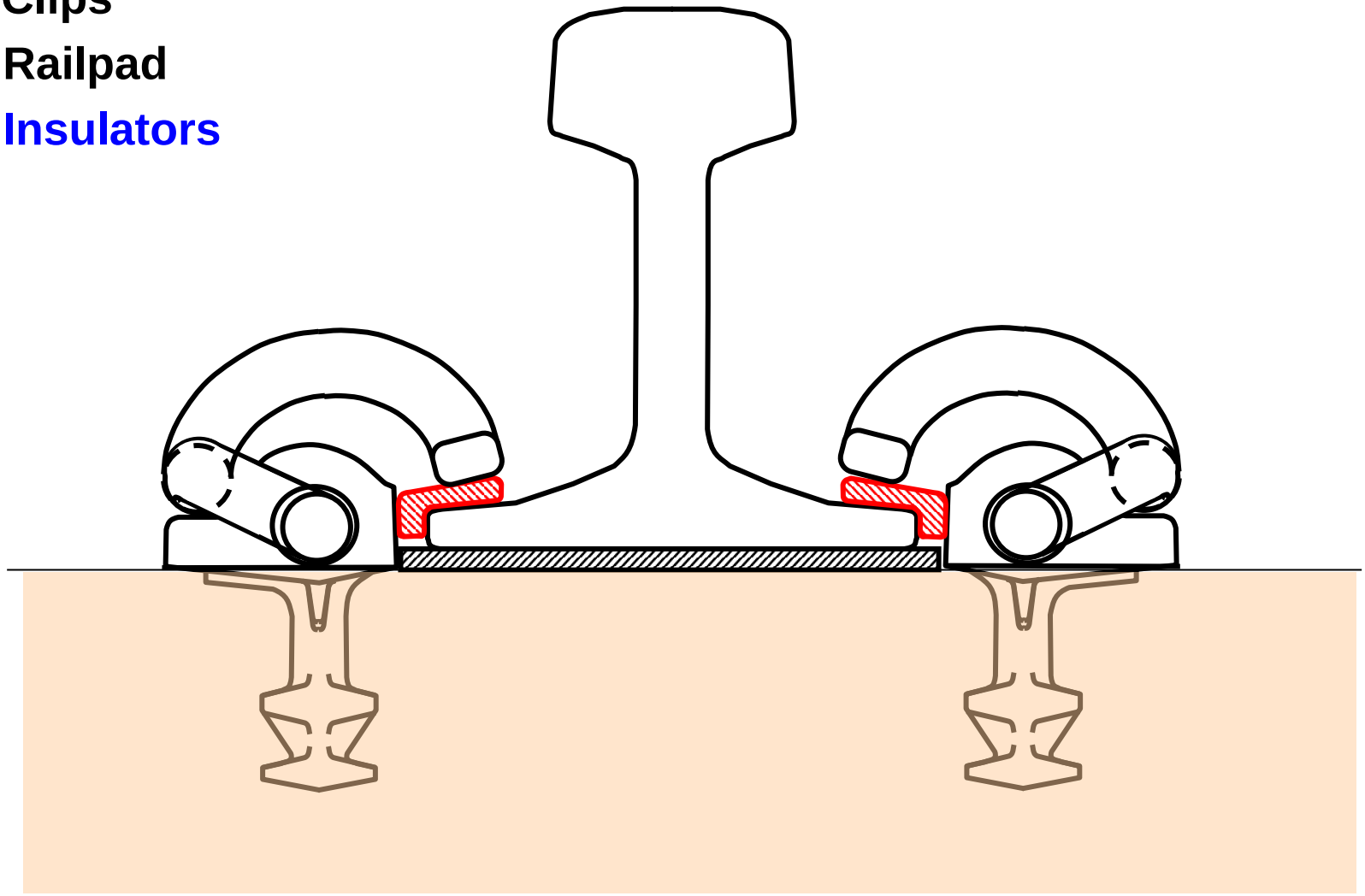


2.2 Rail fastening system - Naming of parts

Clips

+ Railpad

+ Insulators



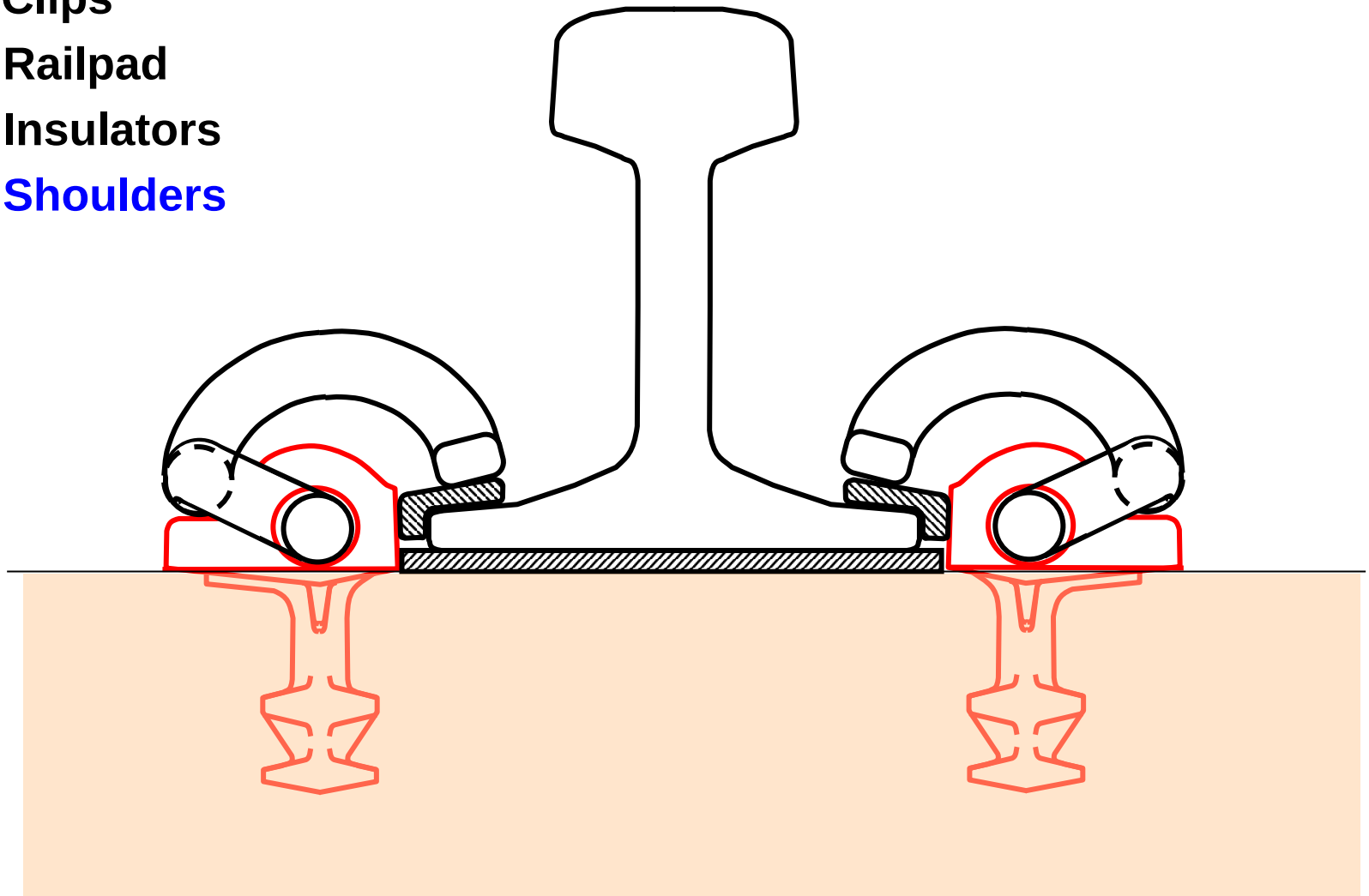
2.2 Rail fastening system - Naming of parts

Clips

+ Railpad

+ Insulators

+ Shoulders



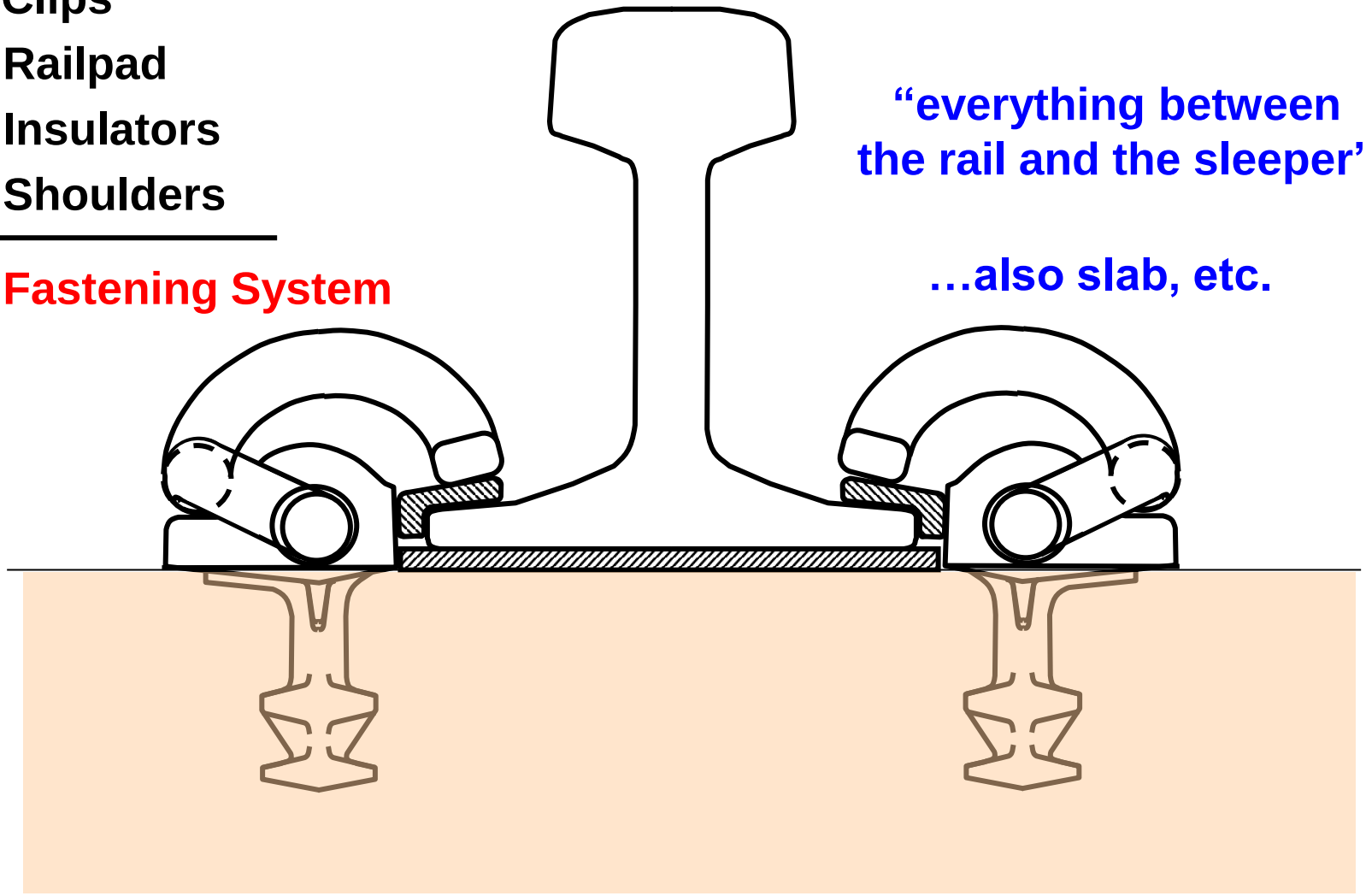
2.2 Rail fastening system - Naming of parts

Clips
+ Railpad
+ Insulators
+ Shoulders

= Fastening System

"everything between the rail and the sleeper"

…also slab, etc.



2.3 Specifications for fastening systems

CEN EN13481

Railway applications
- Track -
Performance requirements for fastening systems

- **Part 2 “Fastening systems for concrete sleepers”**
- **Part 3 “Fastening systems for wooden sleepers”**
- **Part 4 “Fastening systems for steel sleepers”**
- **Part 5 “Fastening systems for slab track”**

2.3 Specifications for fastening systems

CEN EN13146

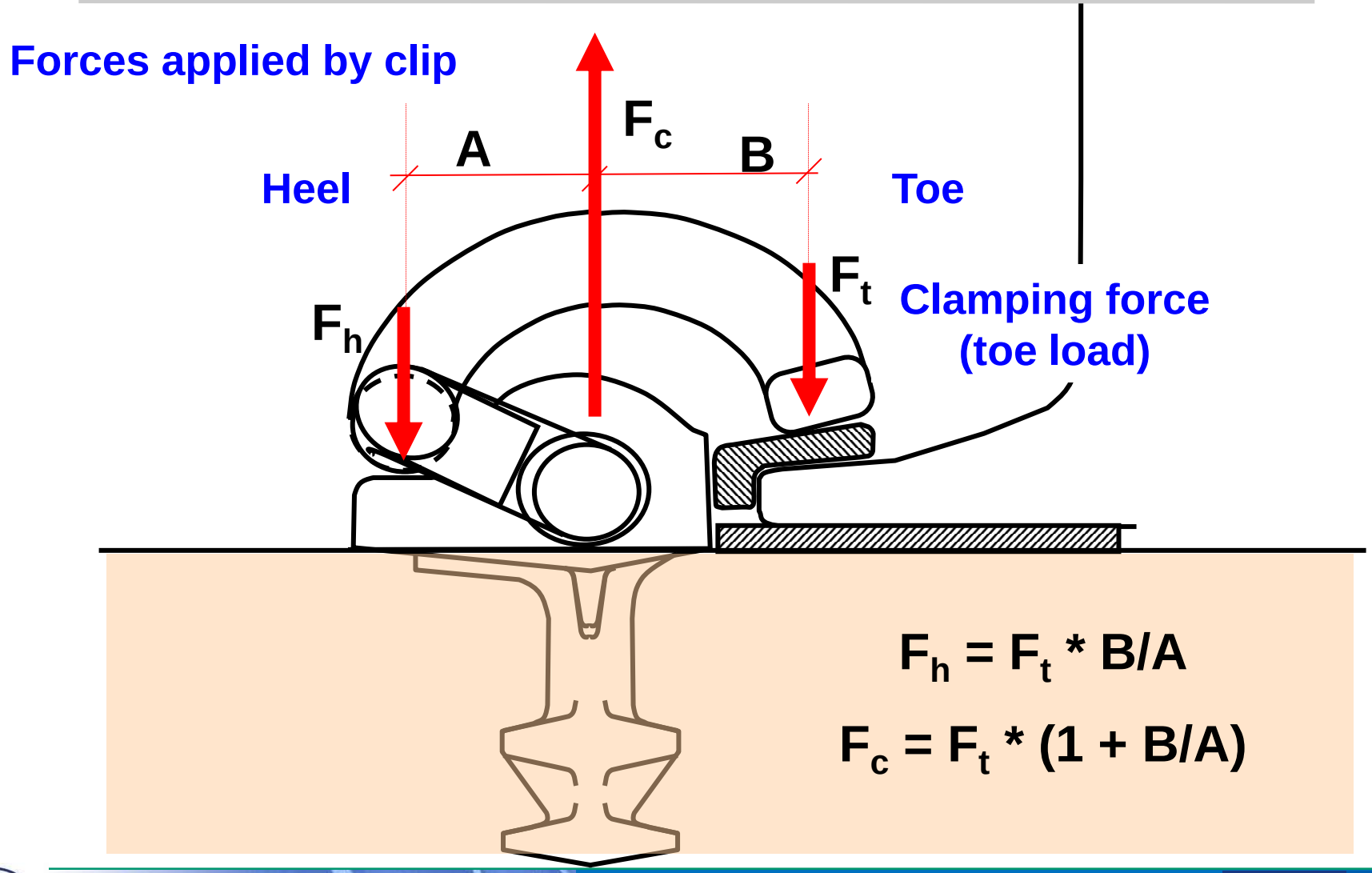
Railway applications
- Track –
- Test methods for fastening systems”

- **Part 1 “Determination of longitudinal rail restraint”**
- **Part 2 “Determination of torsional resistance”**
- **Part 3 “Determination of impact loads”**
- **Part 4 “Effect of repeated loading”**
- **Part 5 “Determination of electrical resistance”**
- **Part 6 “Effect of exposure to severe environmental conditions”**
- **Part 7 “Determination of clamping force”**
- **Part 8 “In service testing”**

2.3 Specifications for fastening systems

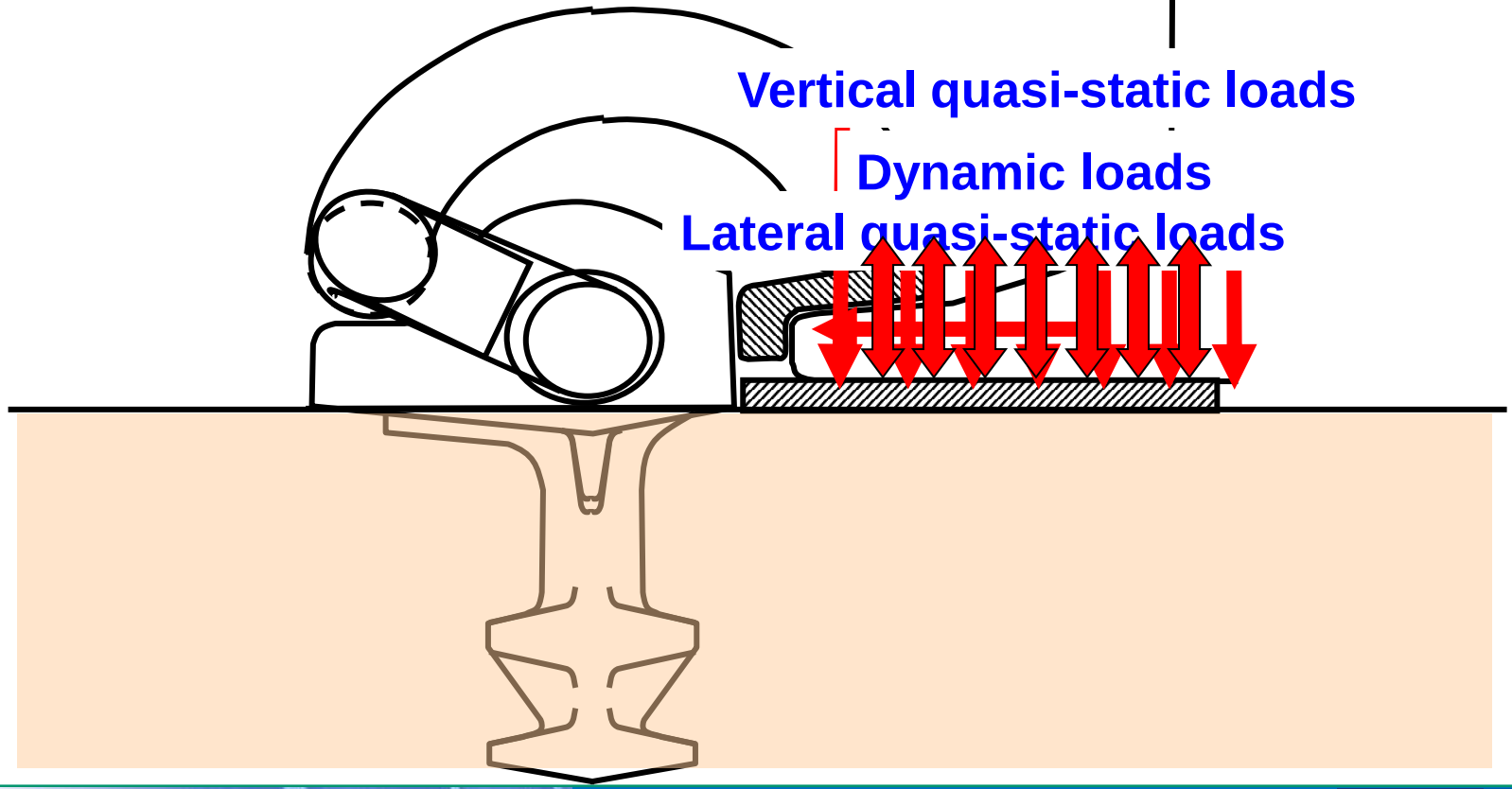
- Transfer static loads from rail to track support (Parts 3,4)
- Maintain track gauge and rail inclination (Parts 4,6)
- Anchor rail to track support
  - … buckling (Part 2)
  - … pull-apart (Parts 1,7)
- Provide electrical insulation … (steel, concrete) (Part 5)
- Attenuate dynamic forces … (concrete, steel) (Part 3)
- Facilitate maintenance of track (Part 8)
- Durability (Parts 4,6,8)

2.4 How do fastening systems work?



2.4 How do fastening systems work?

Forces applied through rail

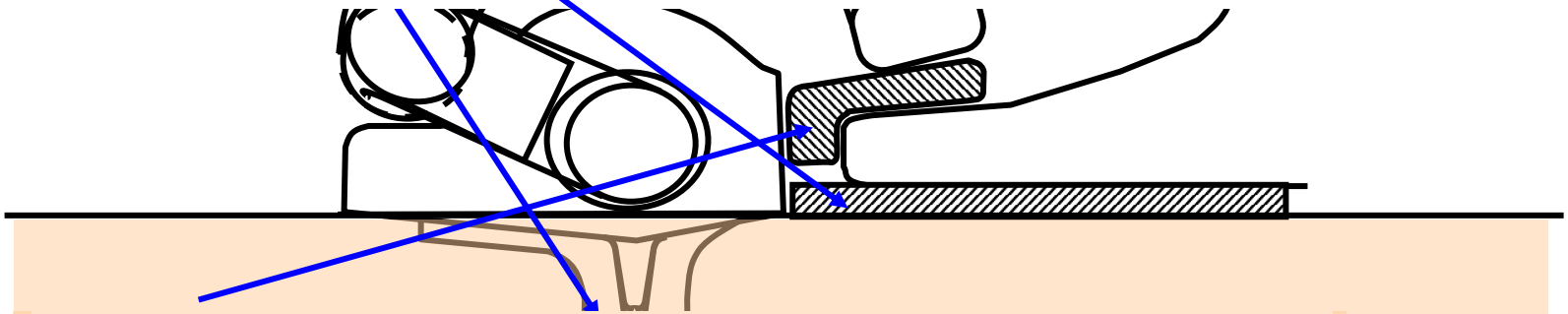


2.4 How do fastening systems work?

Shoulder : Reaction to clamping force
Transfers lateral loads to sleeper

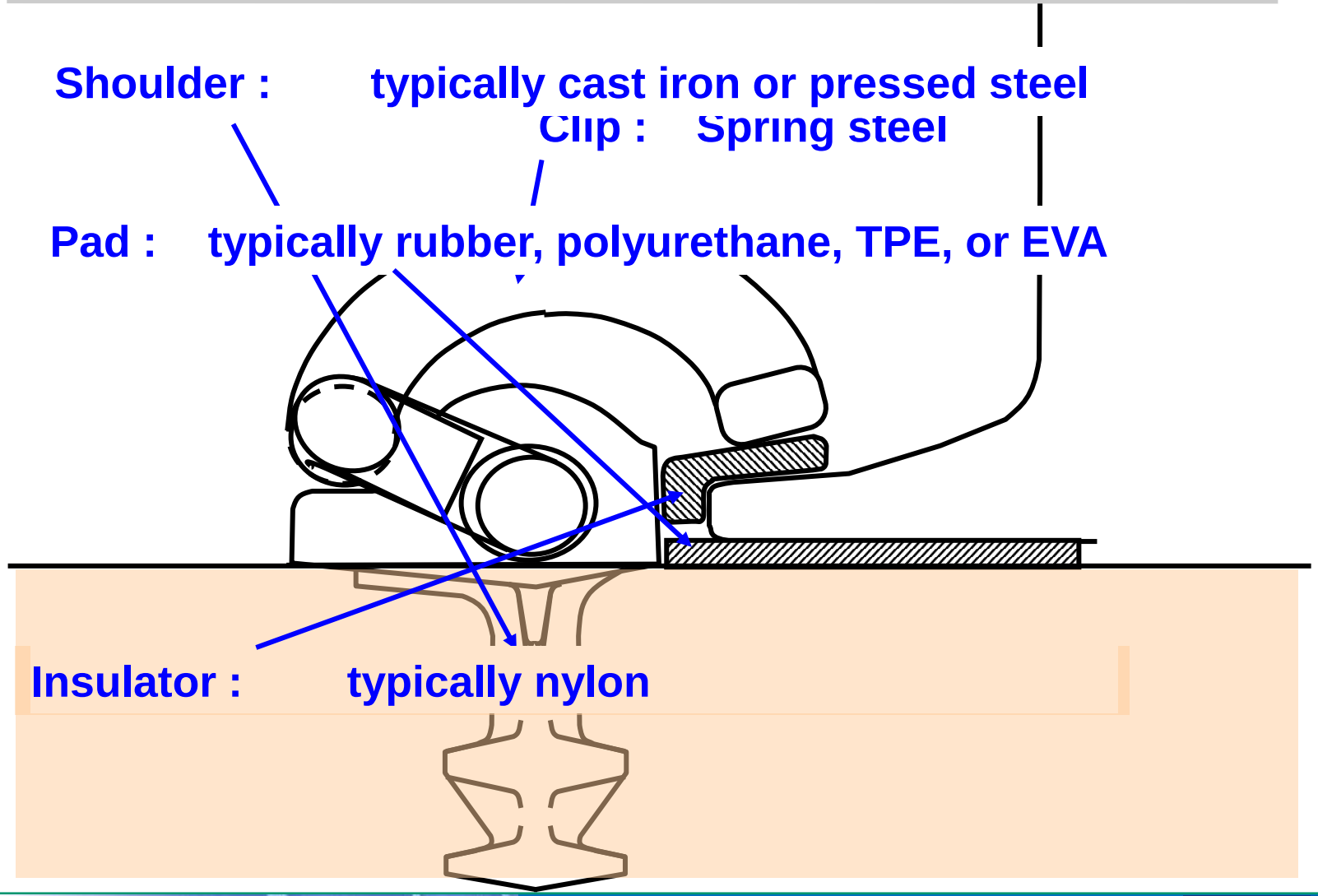
force

Pad : Transfers vertical / lateral loads to sleeper
Electrical insulator
Wear piece



Insulator : Transfers lateral loads to shoulder
Transfers clamping load to rail
Electrical insulator
Wear piece

2.4 How do fastening systems work?



2.5 Resilient clip types

	Coil spring type (Round bar)	Leaf Spring type (Flat bar / plate)
Threadless type	**Pandrol PR**	**Pandrol Safelok (US)**
	Pandrol 'e'	SHC (UK)
	Pandrol Fastclip	Mills (UK)
	FIST (South Africa)	Hey-back (Scandanavia)
	Lineloc (US)	Track-lok (Australia)
	Sidewinder (US)	DE (Netherlands)
Threaded type	**Vossloh**	**F type (Japan)**
		STEDEF (France)
		Nabla (France)

2.6 Distinguishes success from failure

Requirements of modern fastening systems

What distinguishes success from failure?

- Cost of fastening
- Rate of application
- Reduction of labour at application
- Low long term maintenance
- Ease of maintenance
- No weak points


45 MPH

Part One: Product Design

1. Track Structure

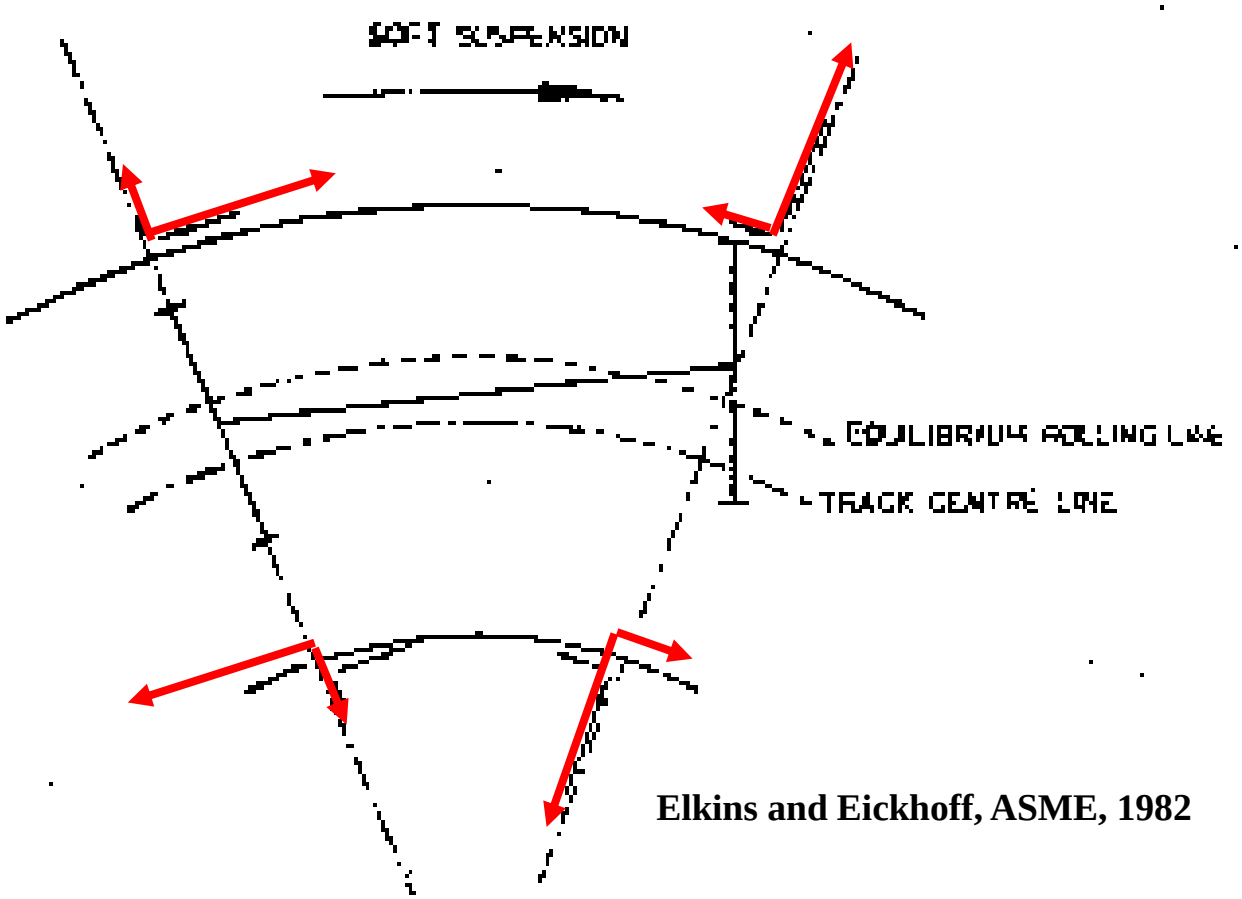
2. Rail Fastenings

3. Effect of Rail Fastenings on Rail Roll

3. Effect of rail fastenings on rail roll

- What causes rail roll?
- How much does the rail roll?
- Why is rail roll important?
- How can we reduce rail roll?

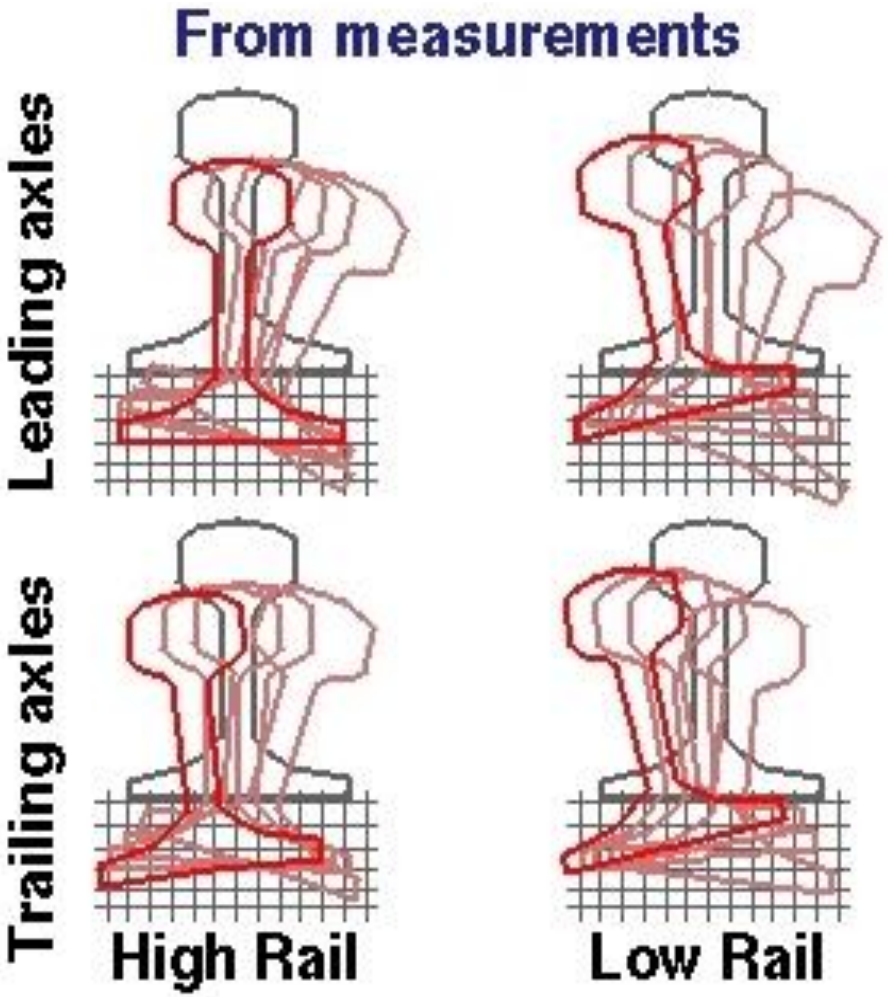
3.1 What causes rail roll?



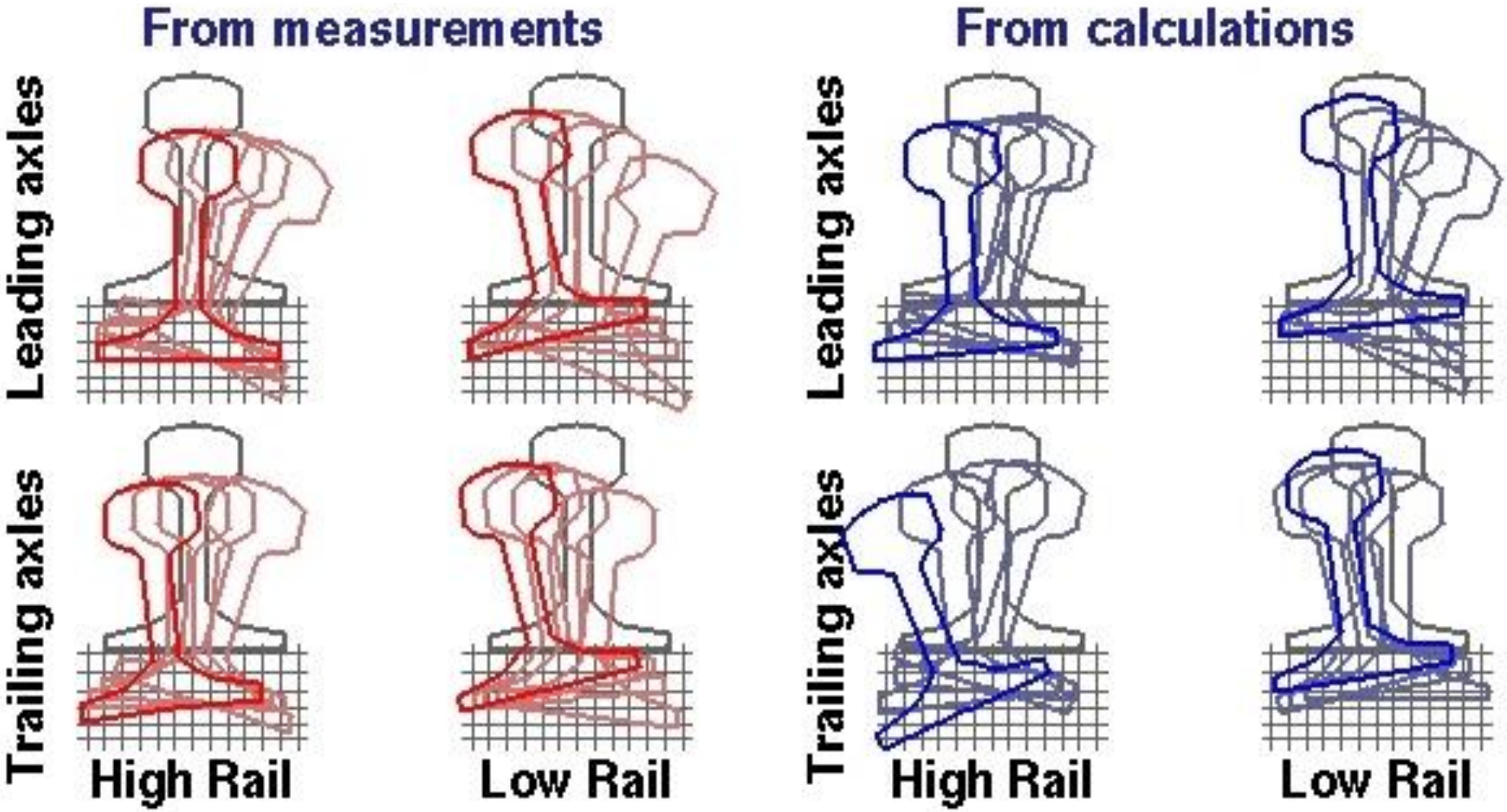
Elkins and Eickhoff, ASME, 1982

Equal and opposite forces applied to the track

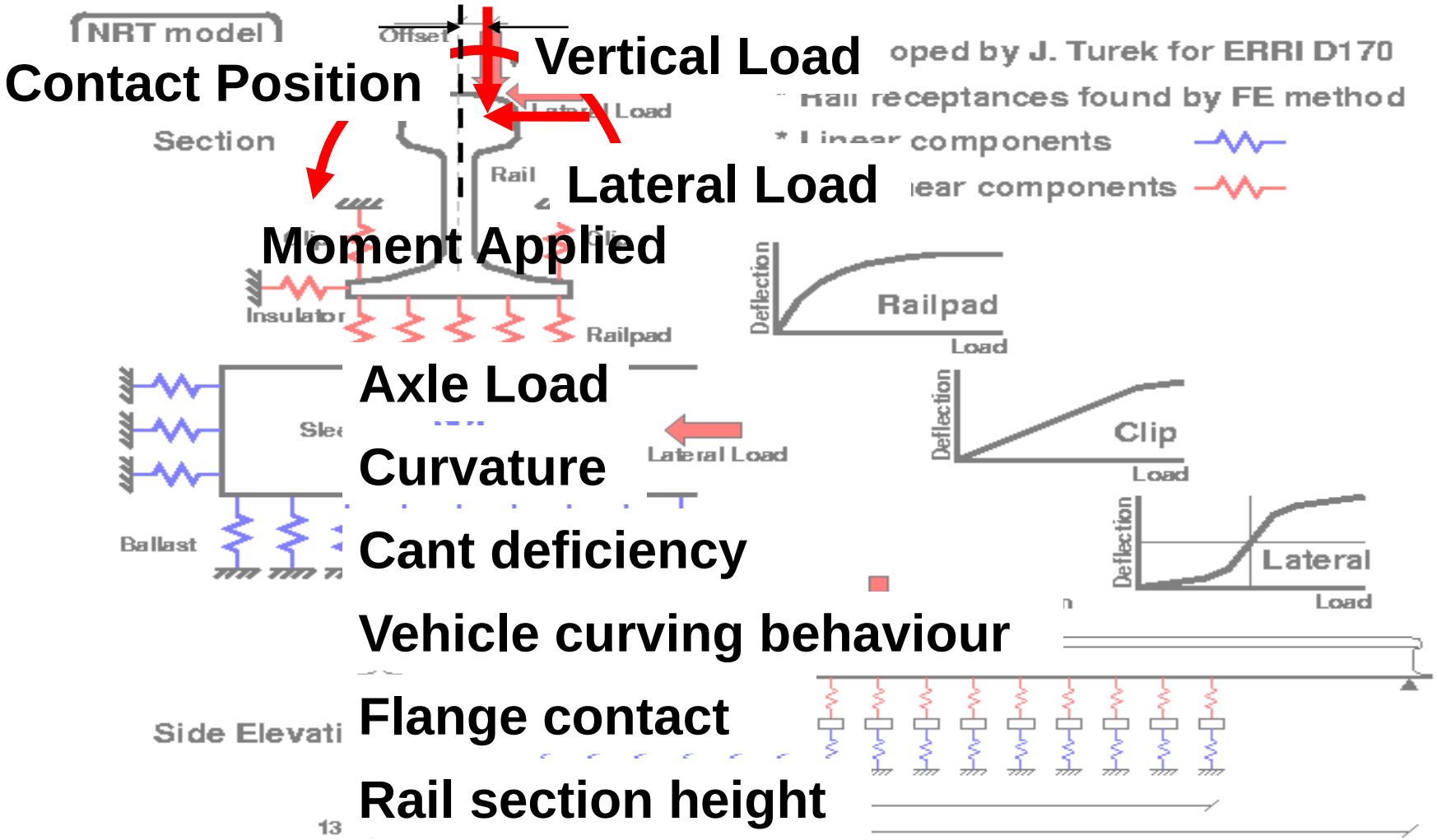
For Pendolino train ... to exaggerated scale!



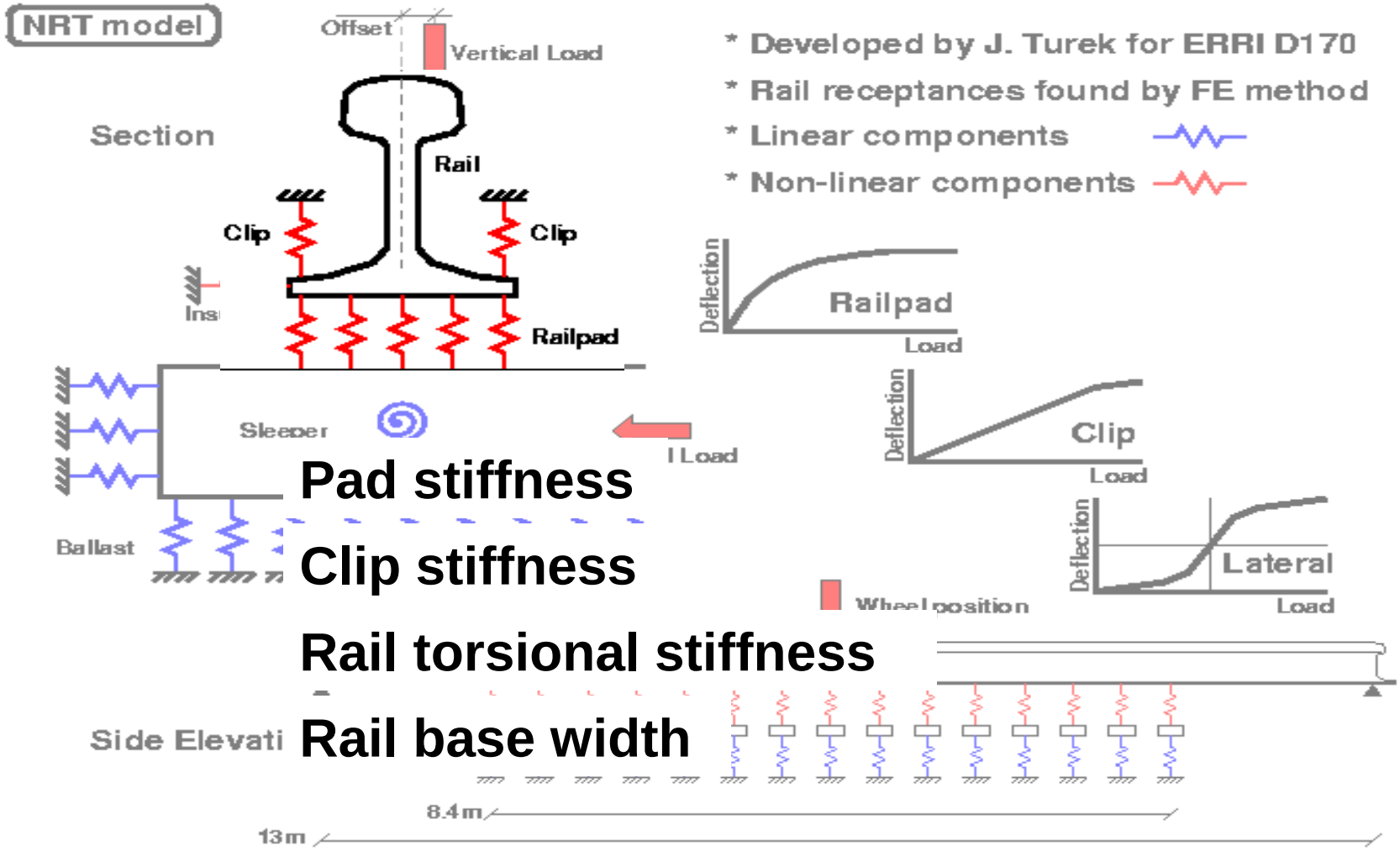
Prediction of rail roll



What causes rail roll?



3.2 How much does the rail roll?



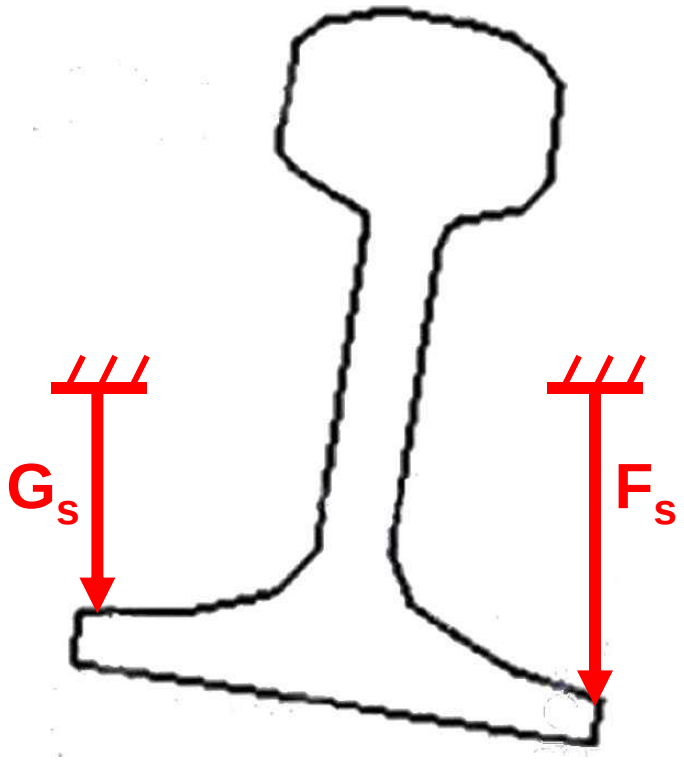
Pad stiffness

Clip stiffness

Rail torsional stiffness

Rail base width

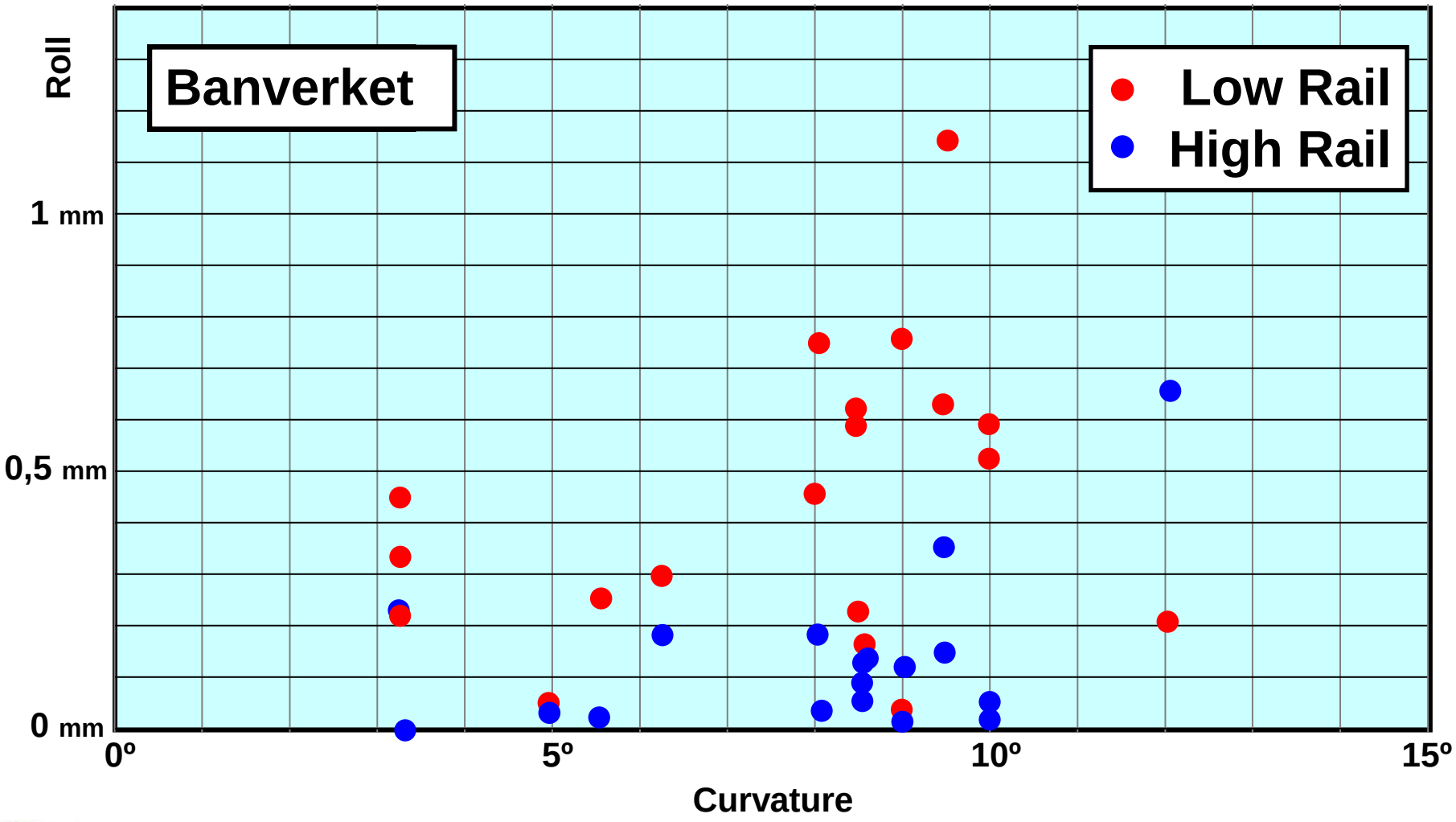
3.2 How much does the rail roll?



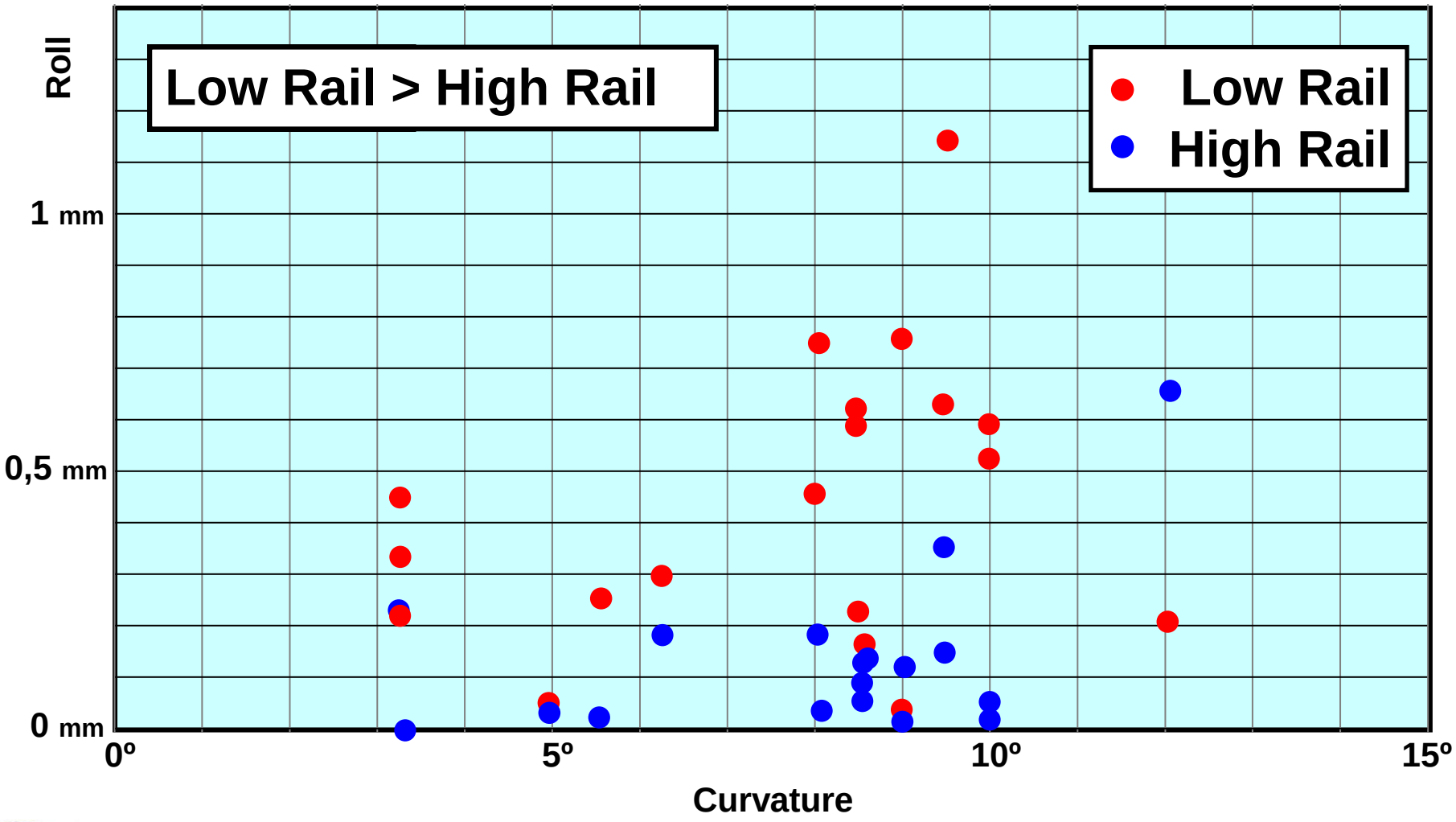
$$\text{Deflection} = (F_s + G_s) / 2$$

$$\text{Roll} = (F_s - G_s) / 2$$

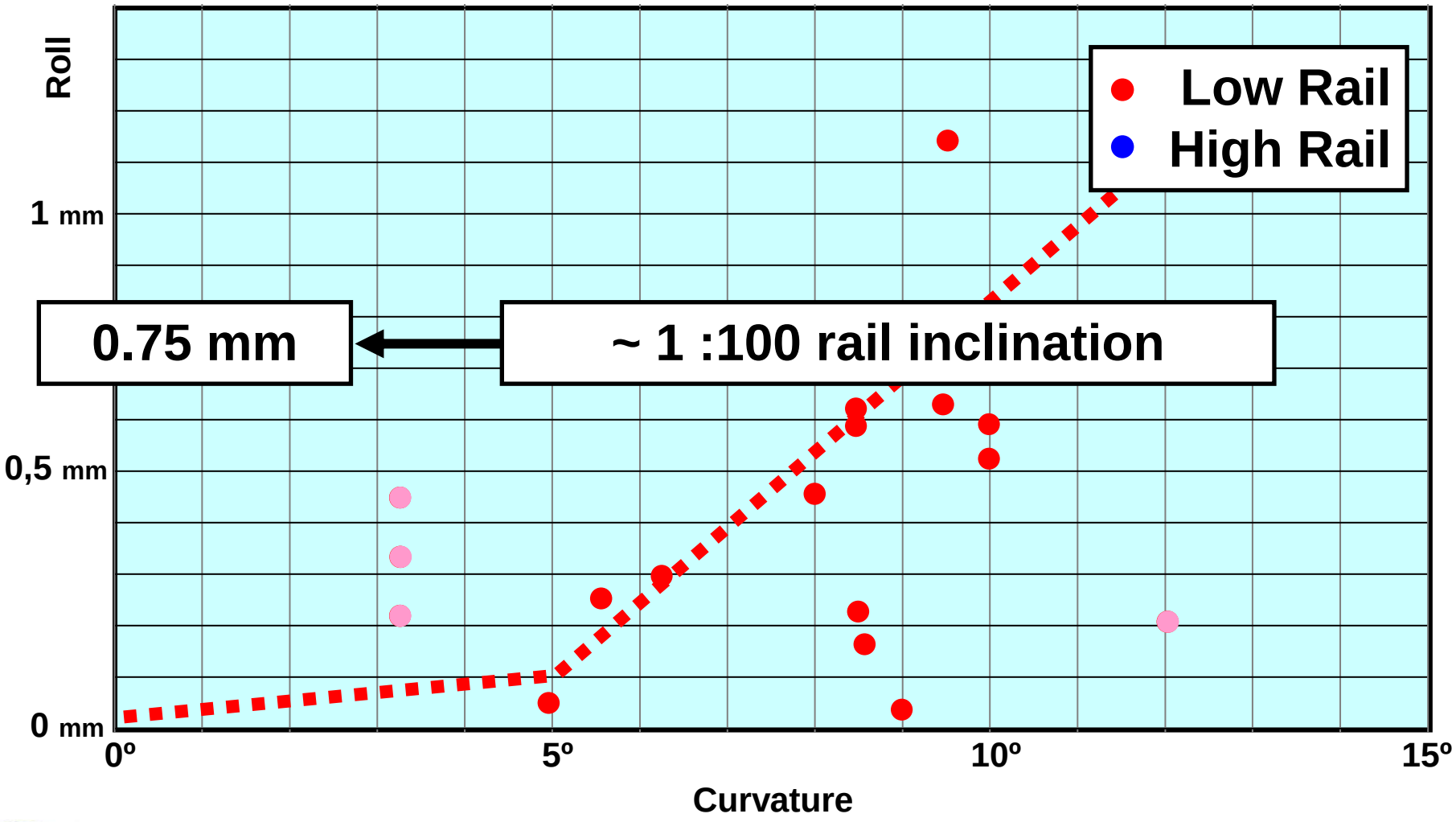
3.2 How much does the rail roll?



3.2 How much does the rail roll?



3.2 How much does the rail roll?



3.3 Why is rail roll important?

- Flange climb / Derailments
  - (in extreme cases!)
- Structure gauge
  - (in extreme cases!)
- Track damage
  - Insulators
  - Rail Seat Abrasion?
  - Rail gauge corner contact fatigue?
  - Corrugation development?

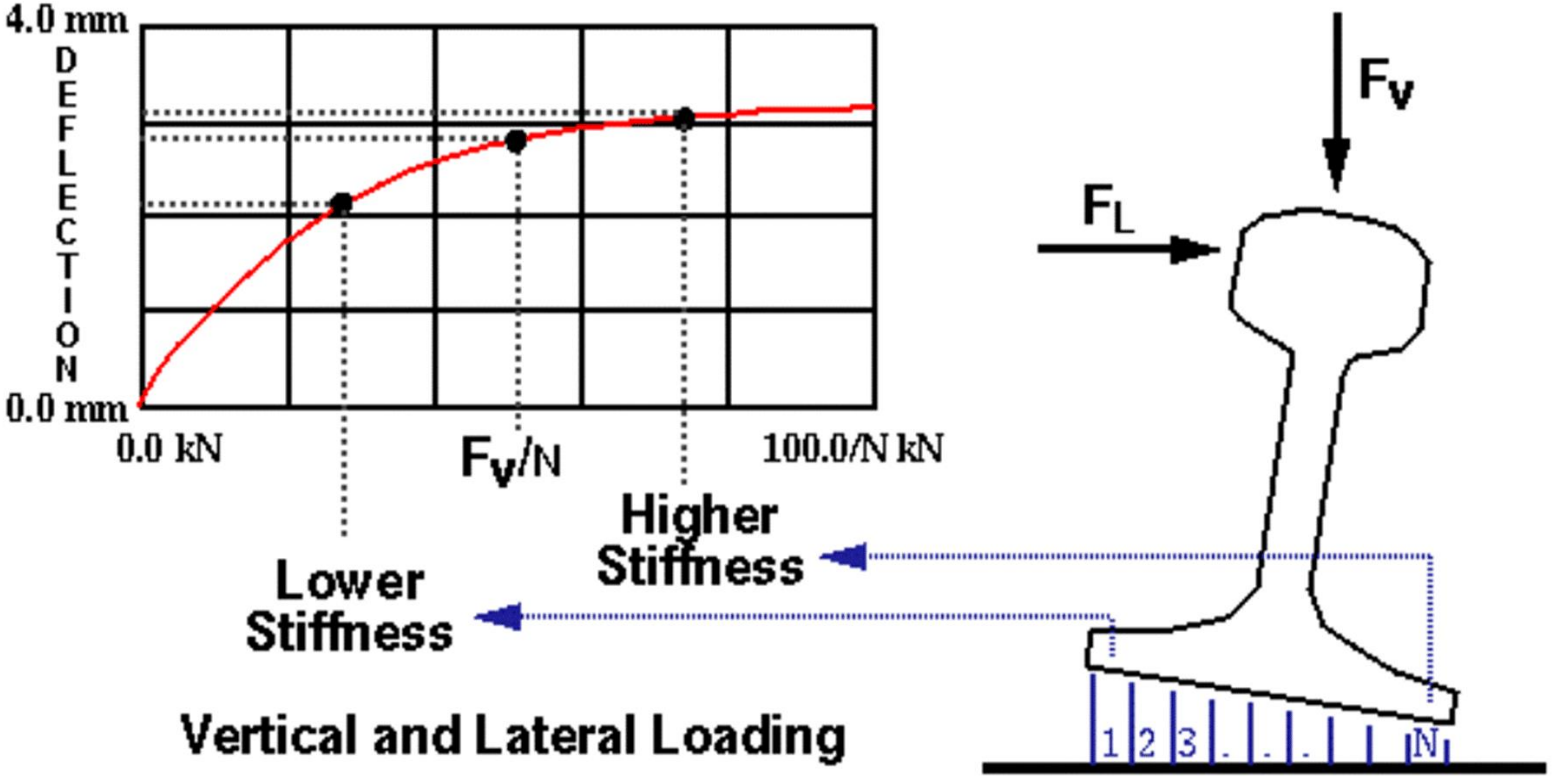
3.3 Why is rail roll important?

- Vehicle curving behaviour
- Limiting factor
  - assembly spacing
    - (also buckling / ballast loading / rail pull apart)
    - e.g. closer spacing on curves
  - track support stiffness

3.4 Can we reduce rail roll?

- Reduce applied moment?
- Non-linear pads
- … see also noise and vibration …

3.4 Can we reduce rail roll?



Non–linear pads reduce rail roll

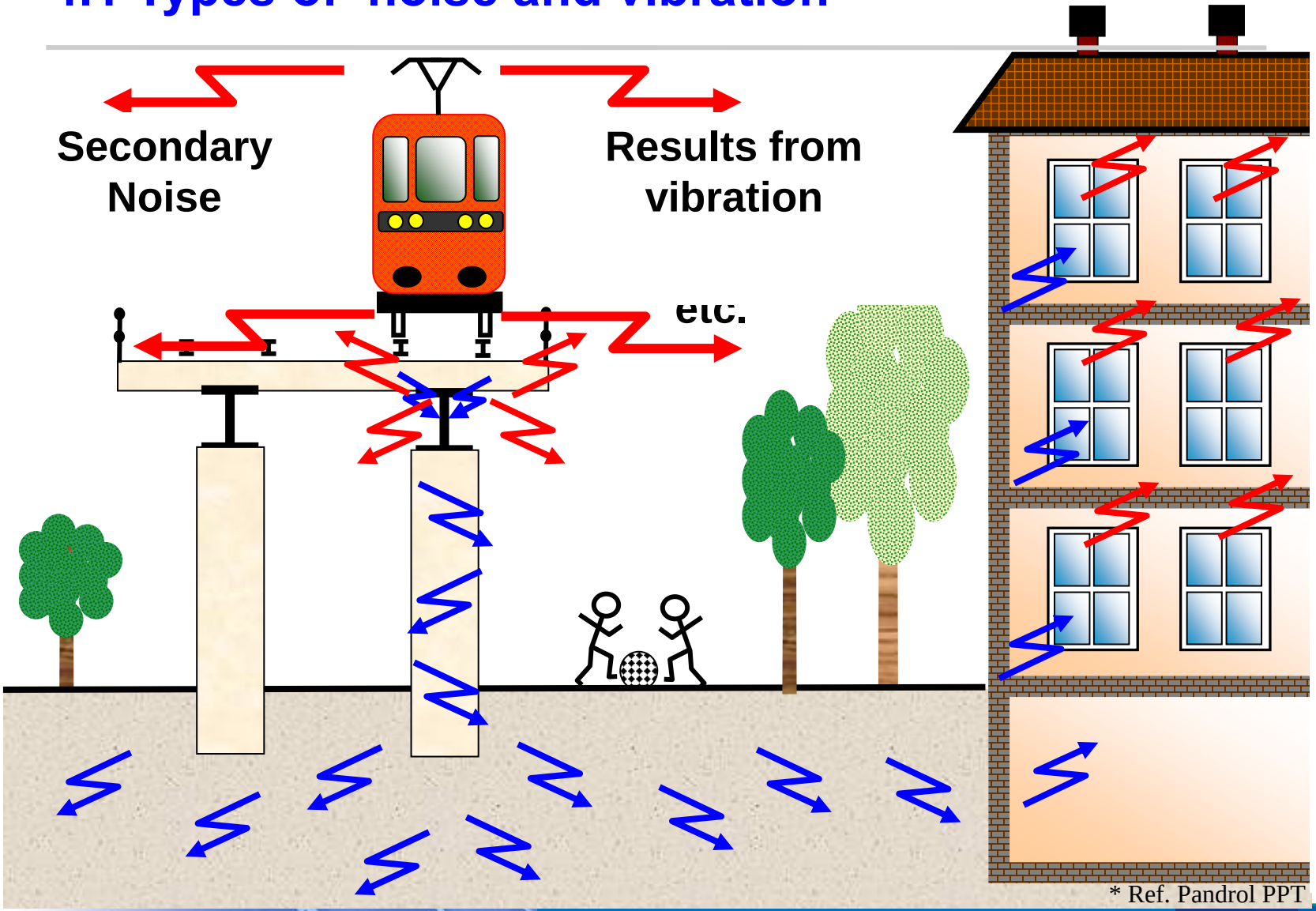
Part One: Product Design

1. Track Structure
2. Rail Fastenings
3. Effect of Rail Fastenings on Rail Roll
4. **Low Noise and Vibration Fastenings**

4. Low Noise and vibration fastenings

- Sources of noise and vibration
- Dealing with noise
- Dealing with vibration
- Design of noise and vibration reducing fasteners

4.1 Types of ‘noise and vibration’



* Ref. Pandrol PPT

4.2 Effects of track fastening on noise and vibration

Airborne Noise	Small effect : 1-2 dBA
Secondary Noise Vibration	Potentially large effect : 20-30 dBA

4.2 Effects of track fastening on noise and vibration

- **Rolling noise**
  - Wheel / rail roughness
  - Corrugation
  - Flats / joints

Fast

Fasteners have relatively small effect.
Generally try to reduce vibration from rail.
Increase decay rate so less rail vibrates.
Additional track dampers.
Increasing pad stiffness also increases decay rate.
… reduces noise emitted from rail
… but may increase sleeper vibration and noise.
… detrimental effect on sleeper / ballast life.
… and may affect long term roughness growth.

4.2 Effects of track fastening on noise and vibration

Secondary noise

Ground borne vibration

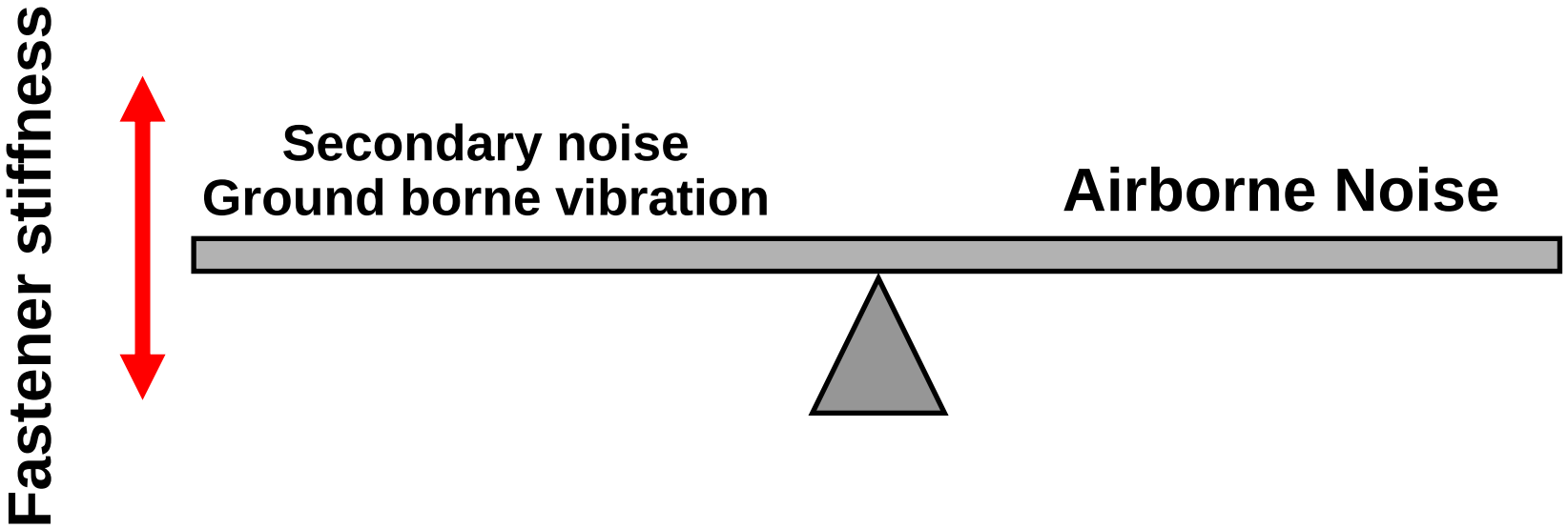
… both controlled by ‘isolating’ track from support

… rail fastener can have a relatively large effect

… control by increasing track mass (a lot …)

… or more practically by reducing fastener stiffness

4.2 Effects of track fastening on noise and vibration



Track

- At grade
- Bridges and viaducts
- Tunnels

} different balance?

4.3 Control of vibration through track support

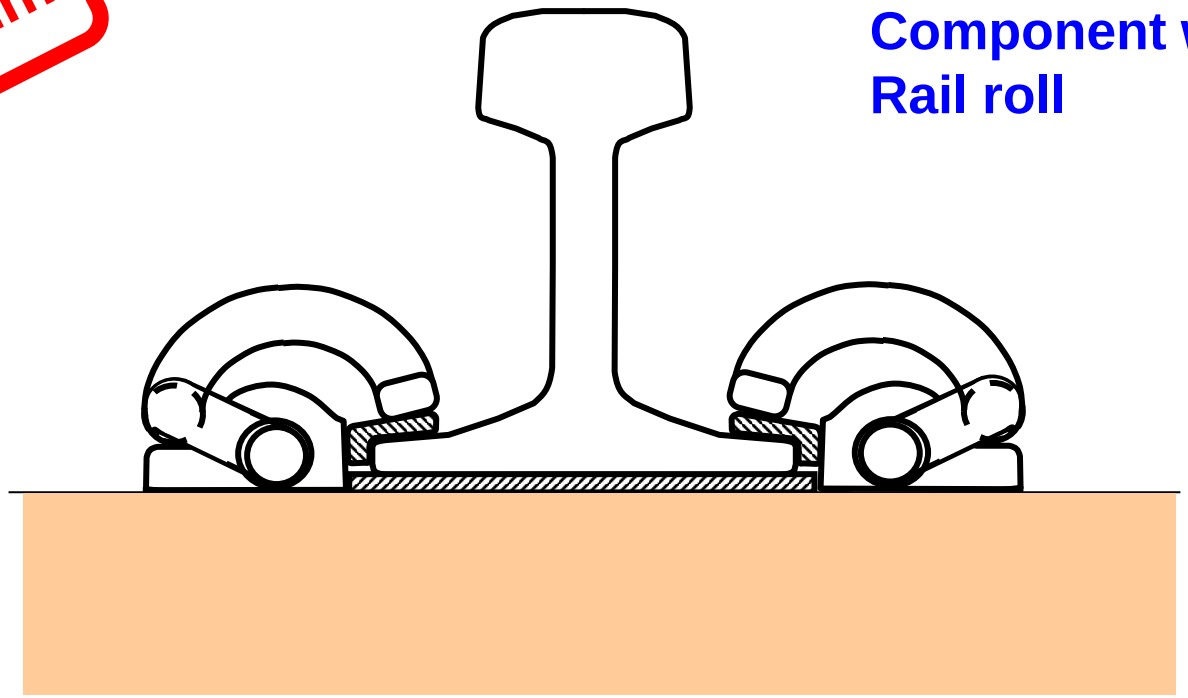
- **Increase track mass**
  - Need to add a lot of mass!
  - Floating slab track
  - Very expensive
- **Decrease track stiffness**
  - Increase fastener spacing
  - Decrease fastener stiffness
  - Limited by rail roll

4.3 Control of vibration through track support

Constraints on reducing fastener stiffness

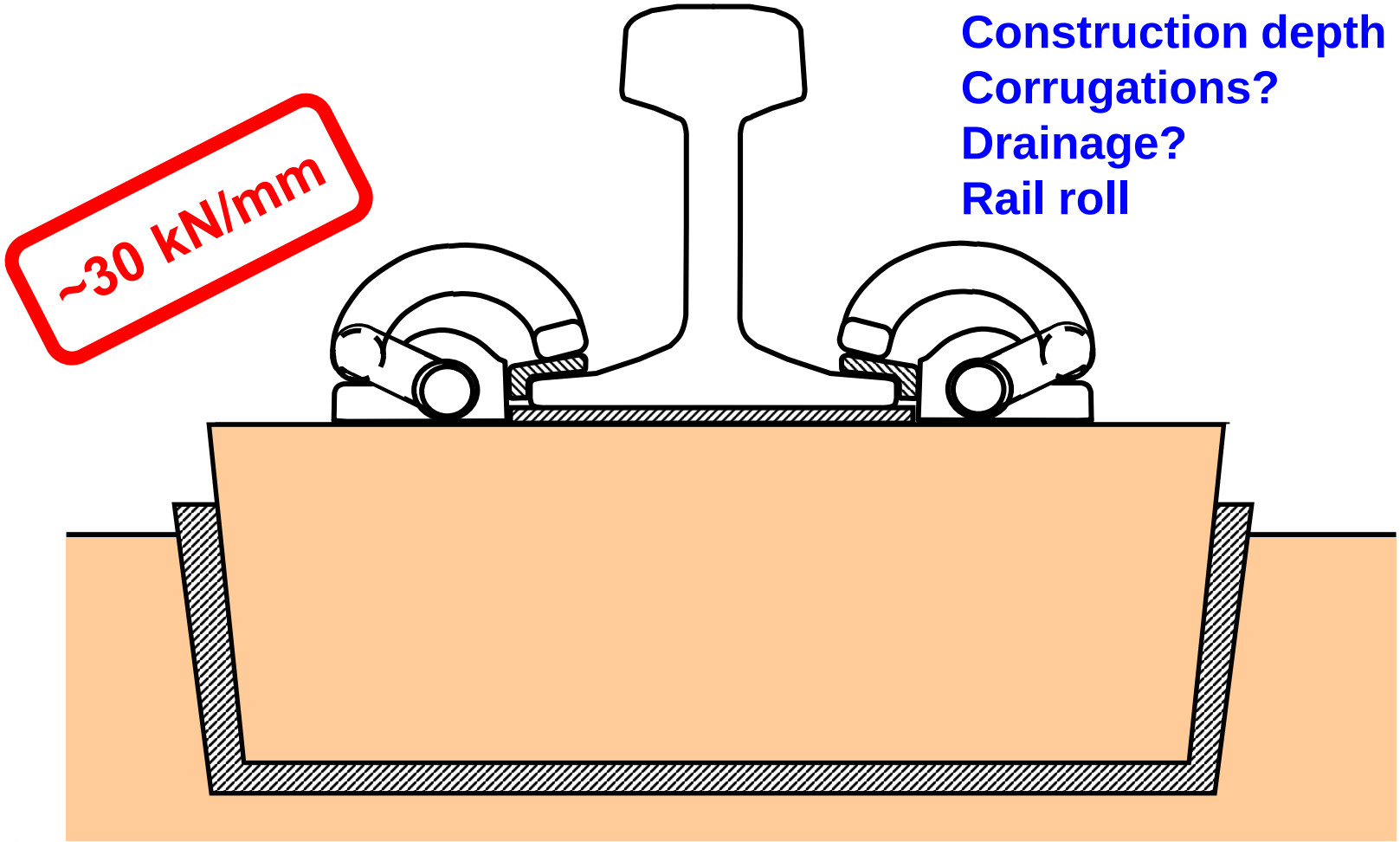
~45 kN/mm

Fastener fatigue limit
Component wear
Rail roll



4.3 Control of vibration through track support

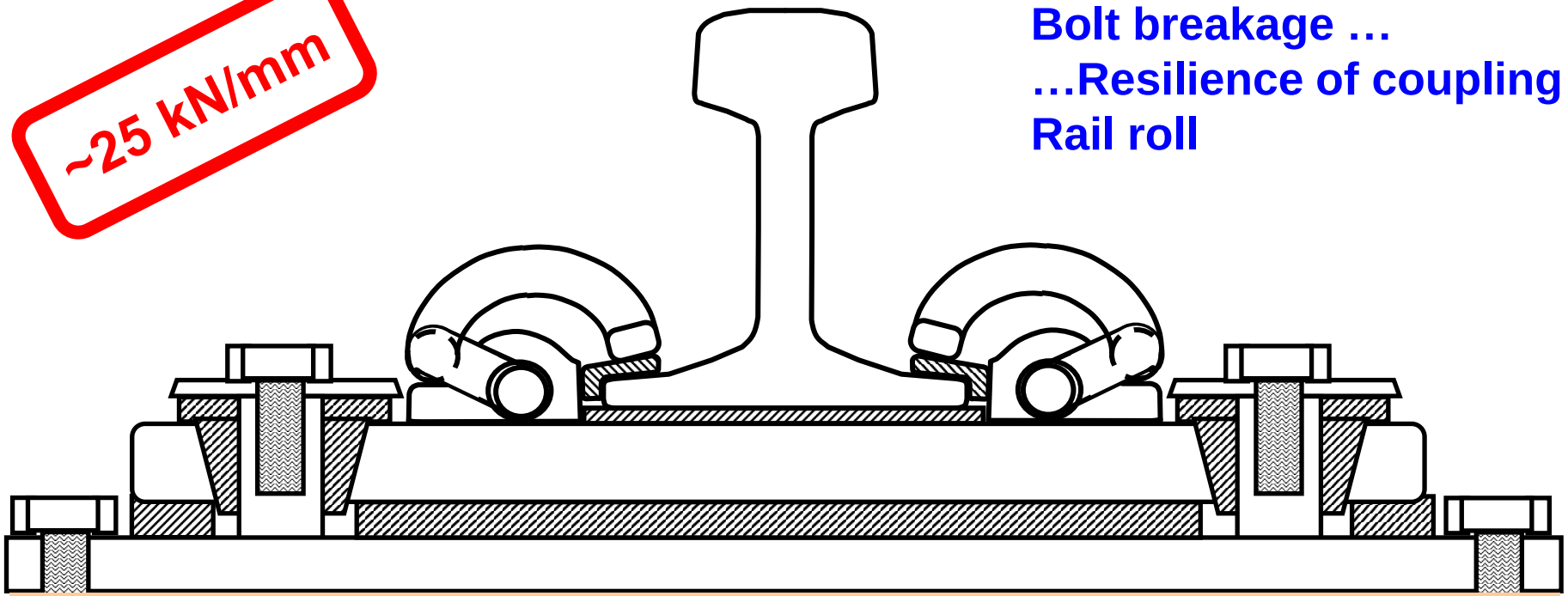
Constraints on reducing fastener stiffness



4.3 Control of vibration through track support

Constraints on reducing fastener stiffness

~25 kN/mm



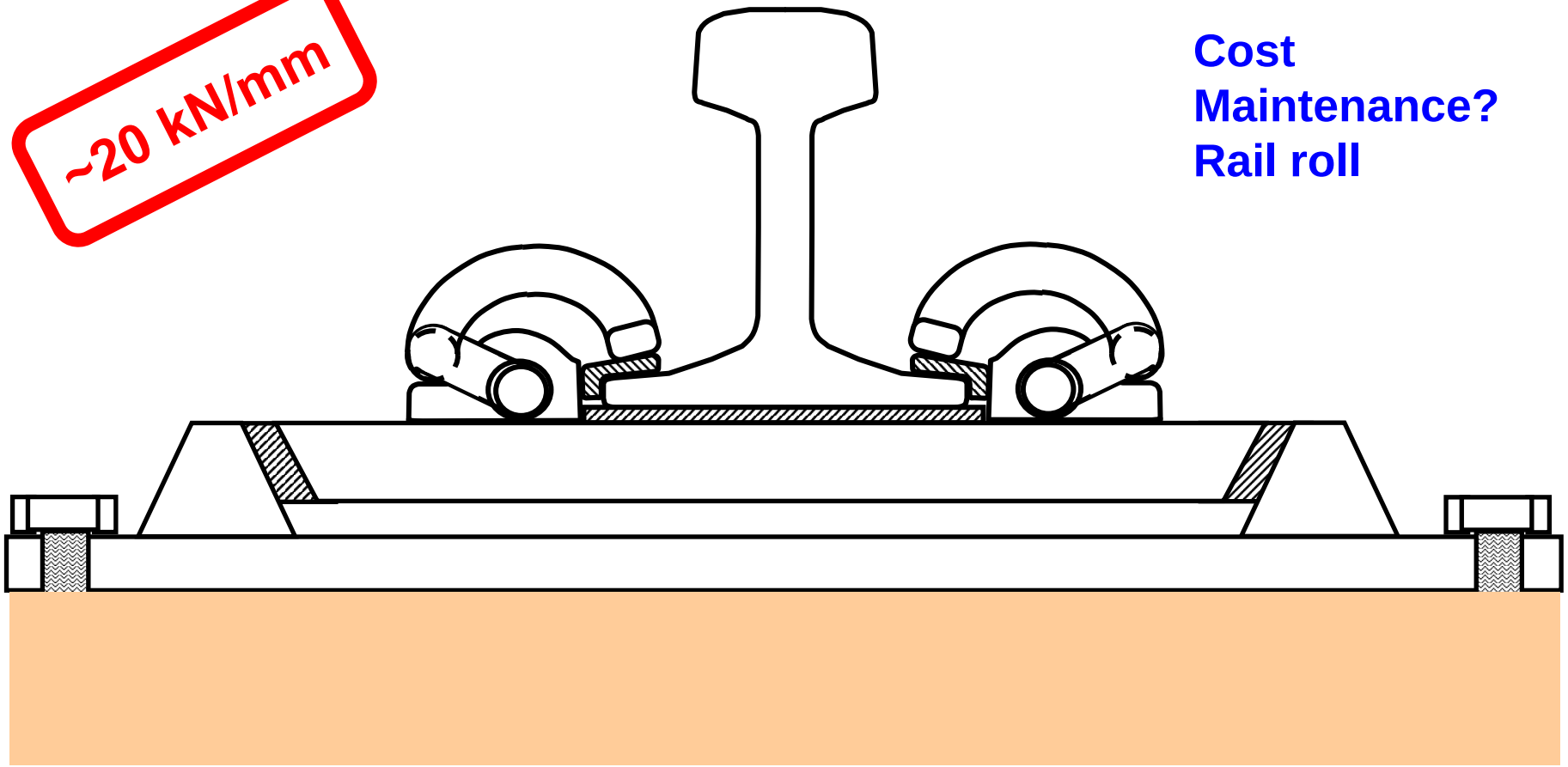
Bolt breakage …
…Resilience of coupling
Rail roll

* Ref. Pandrol PPT

4.3 Control of vibration through track support

Constraints on reducing fastener stiffness

~20 kN/mm



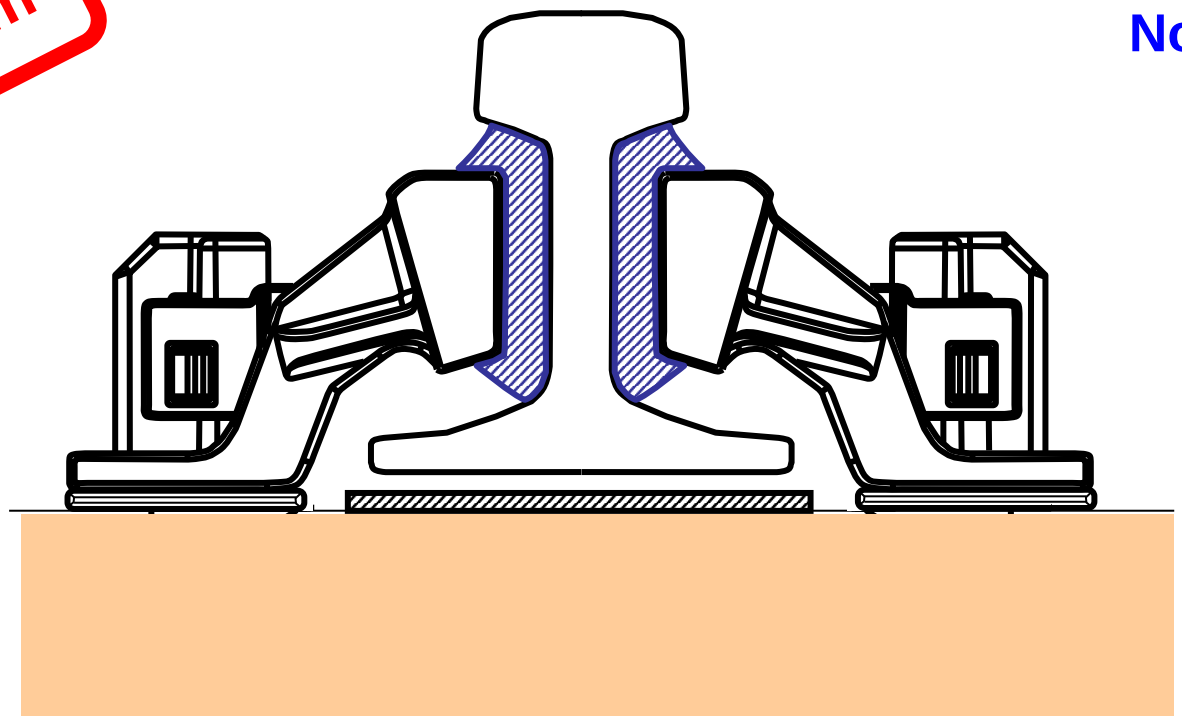
Cost
Maintenance?
Rail roll

4.3 Control of vibration through track support

Constraints on reducing fastener stiffness

~5 kN/mm

Cost
Novelty



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Part One: Product Design

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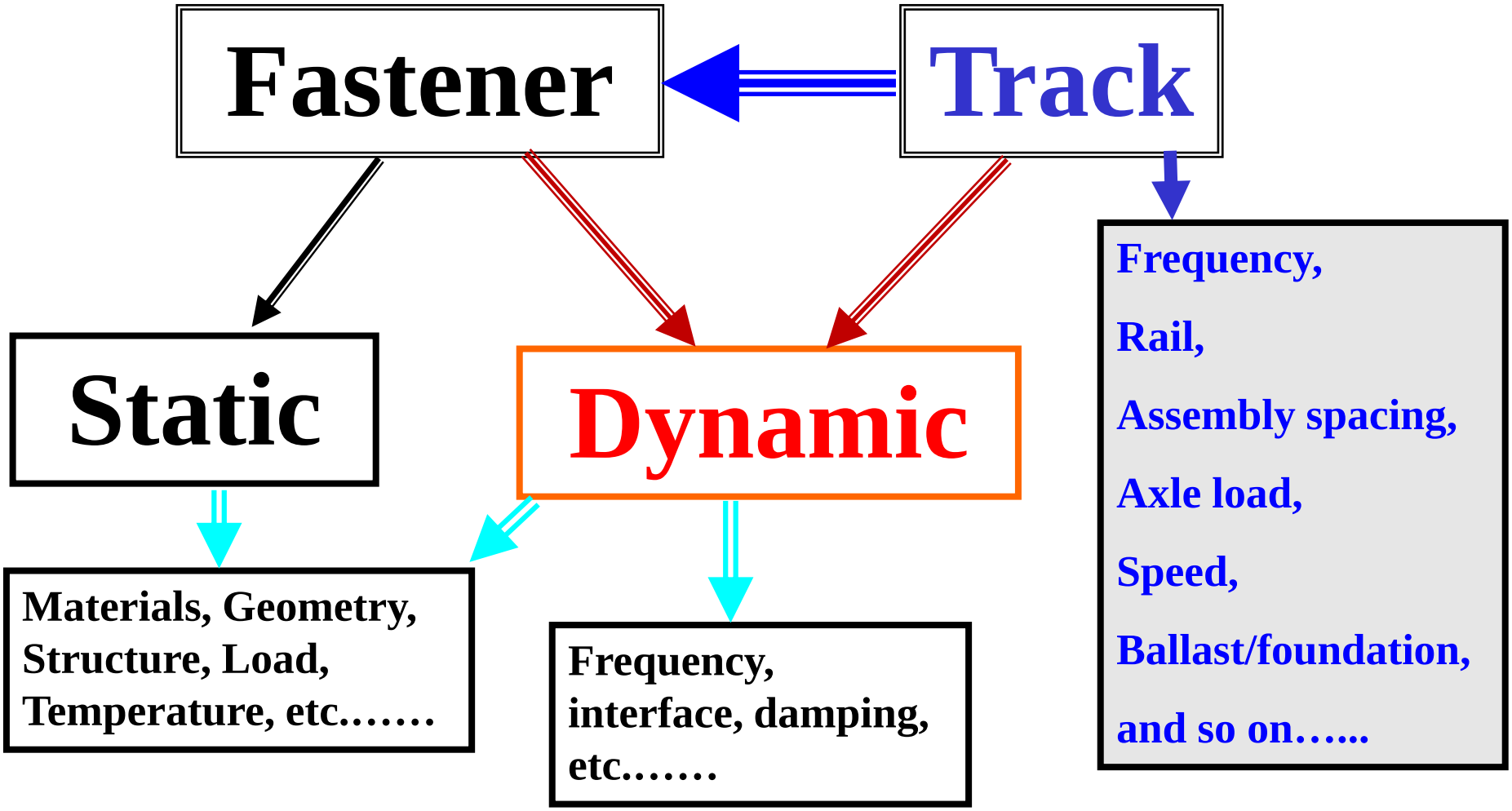
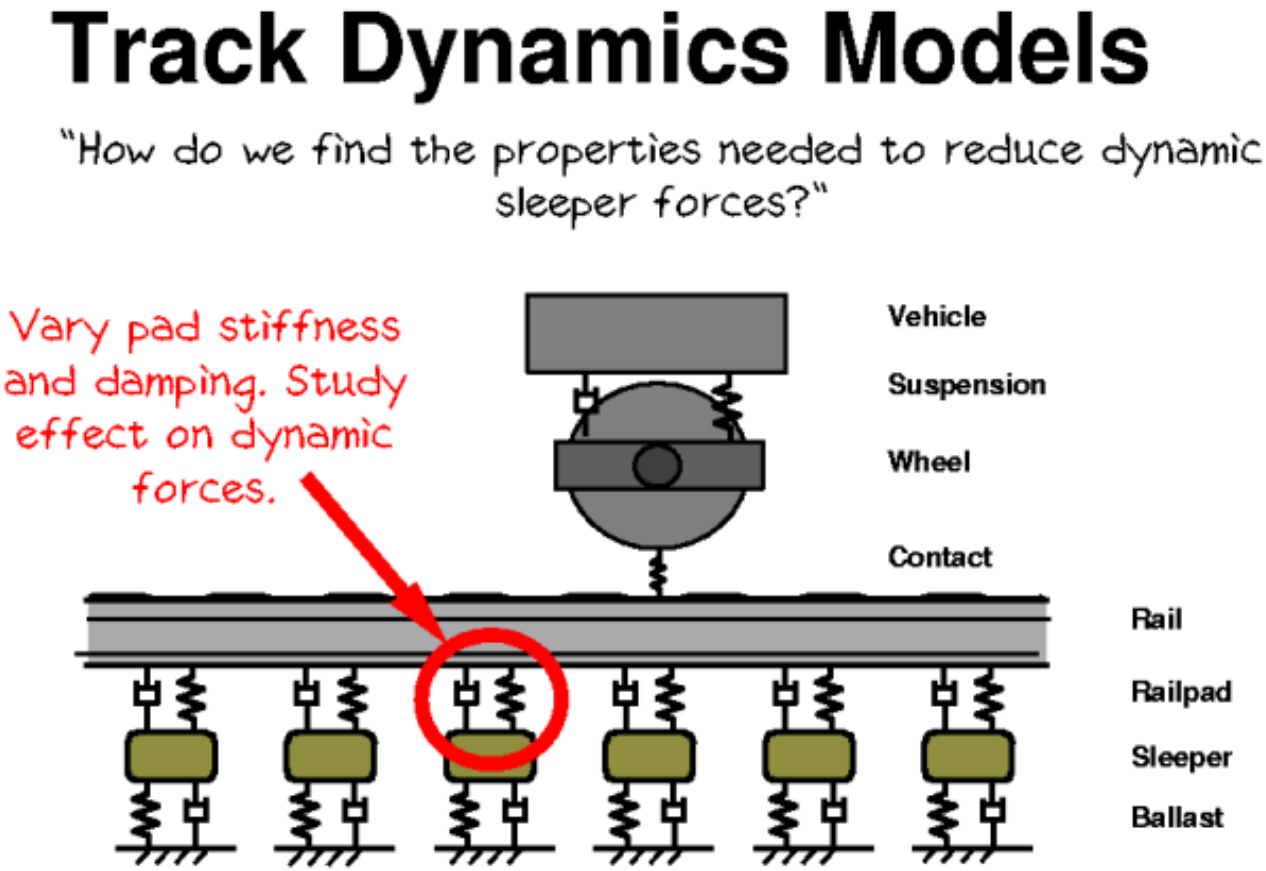
3. Effect of Rail Fastenings on Rail Roll
4. Low Noise and Vibration Fastenings
5. **Stiffness Design**

5. Stiffness Design



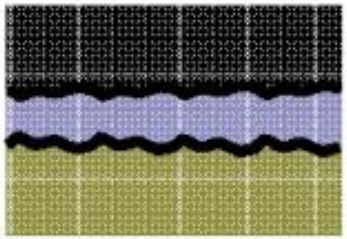
5.1 Track models



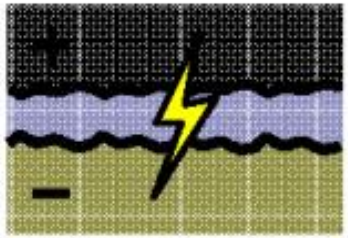
5.2 Stiffness and damping

Railpad Functions

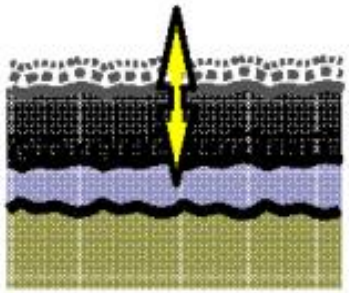
Conformity



Electrical Isolation



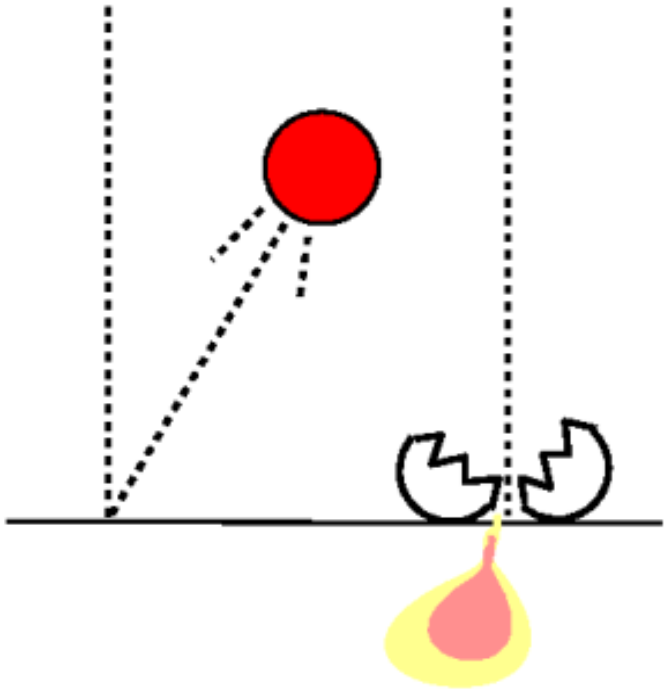
Mechanical Isolation



5.2 Stiffness and damping

Resilience

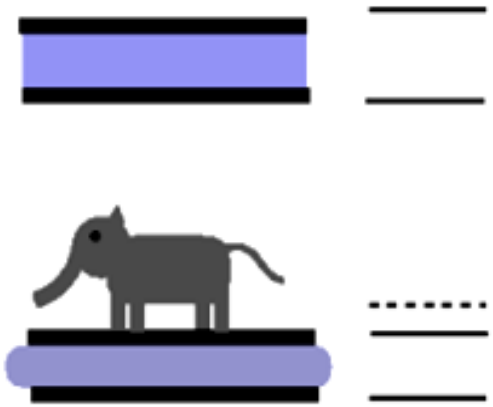
"Ability to recover from deflection"

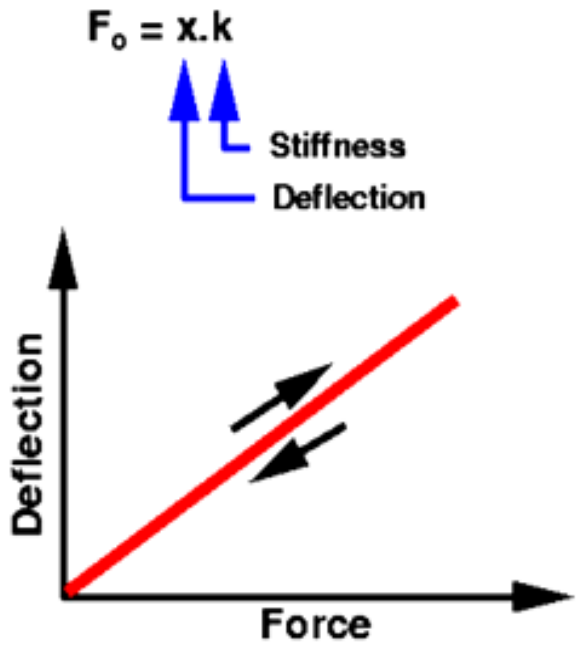


5.2 Stiffness and damping

Stiffness

"Resistance to deflection"

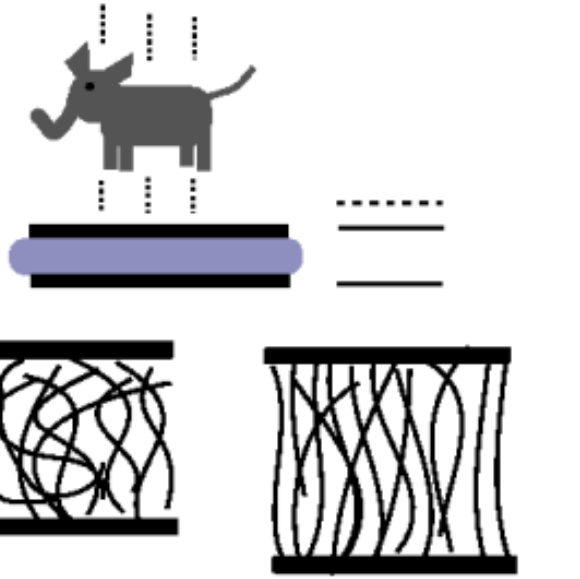




5.2 Stiffness and damping

Dynamic Stiffness

"Resistance to dynamic deflection"



Time required to stretch chains

$F_o.\sin(\omega t) = x.k'$

Dynamic Stiffness

Deflection

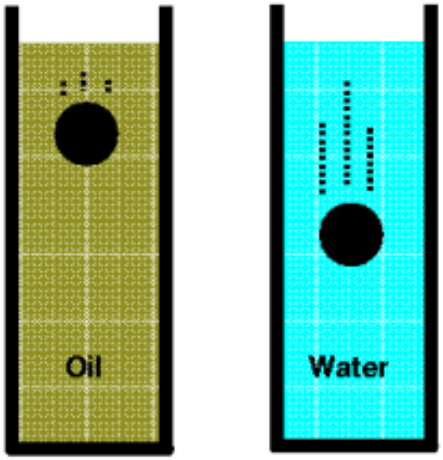
$x = X_o.\sin(\omega t)$

Dynamic Stiffness > Static Stiffness

5.2 Stiffness and damping

Damping

"Resistance to speed of deflection"



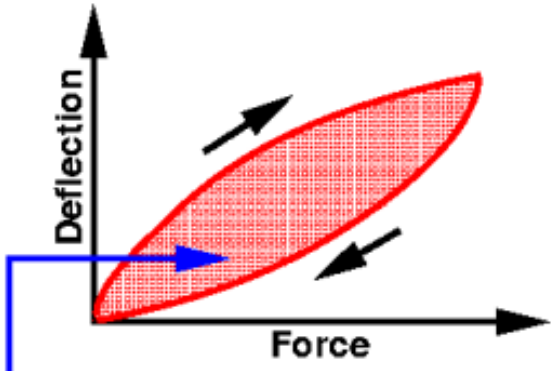
$F_o.\sin(\omega t) = x.k' + x'.c$

Damping constant

Velocity

$x = X_o.\sin(\omega t + \phi)$

Phase



$W_d = \pi.c.\omega.X_o^2$

Energy absorbed per cycle

5.3 Effects on stiffness and damping

Track Dynamic Force to Sleeper/Slab/Ballast ?

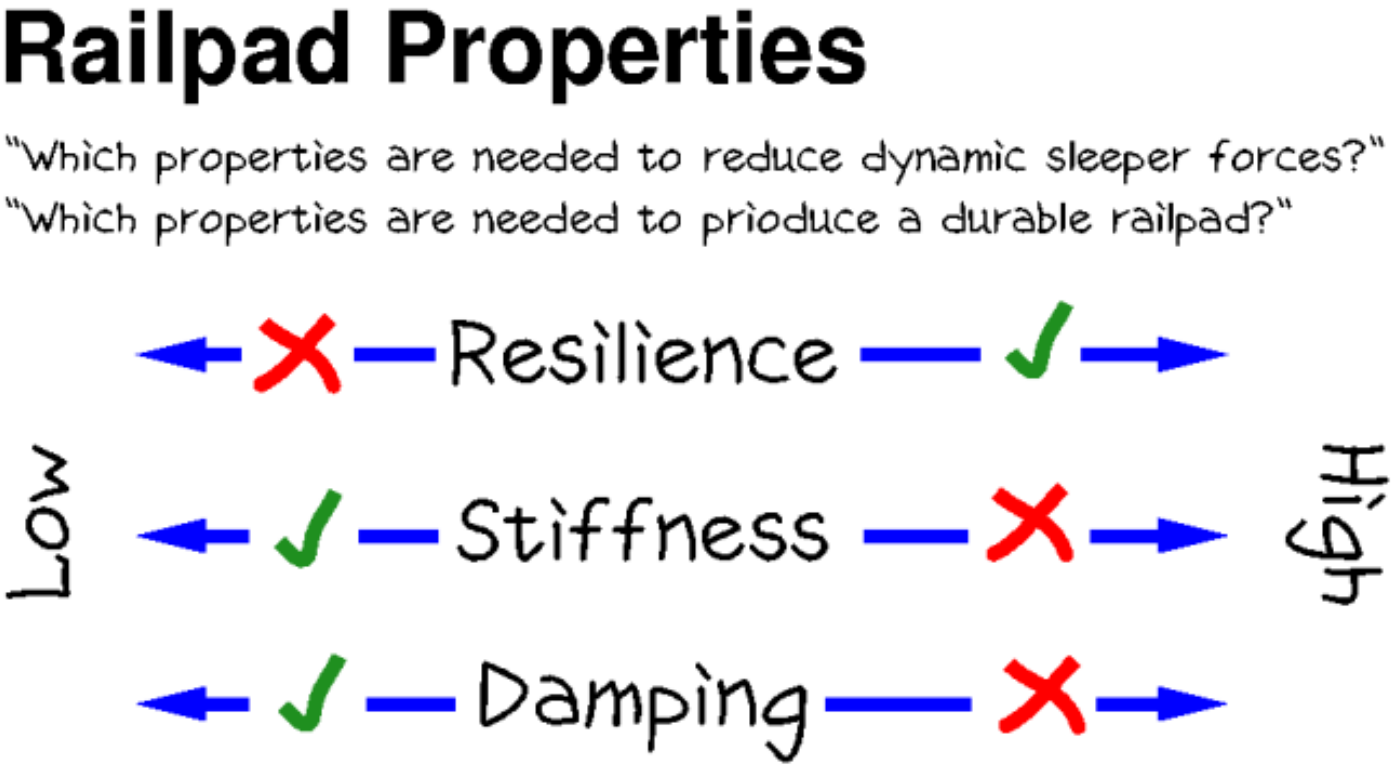
Sleeper/Slab/Ballast Vibration and Noise ?

Track Vibration decay Rate ?

Wheel /Rail Roughness Growth ?

Wheel/Rail Interaction Force ?

5.3 Effects on stiffness and damping



5.3 Effects on stiffness and damping

Constraints

Lower stiffness => Lower forces

Reduced sleeper strains

Reduced sleeper strains

Reduced contact forces

BUT

Rail Roll must be limited

Pads become more expensive

Assembly becomes more expensive

Fatigue limit of clips must not be exceeded

Assembly must be designed for larger movements

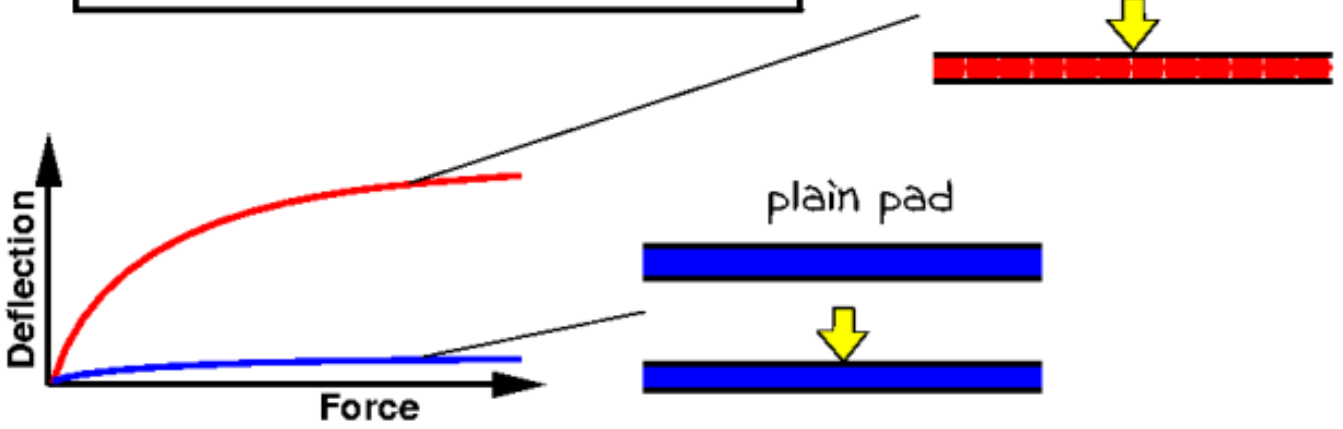
10mm thick pad is a good compromise

5.4 Non-linear pad

Natural Rubber Railpads

"How do we achieve the required properties?"

Natural rubber => high resilience
+ selected fillers => low damping
but rubber is incompressible so :
+ shaped pad => low stiffness



5.4 Non-linear pad

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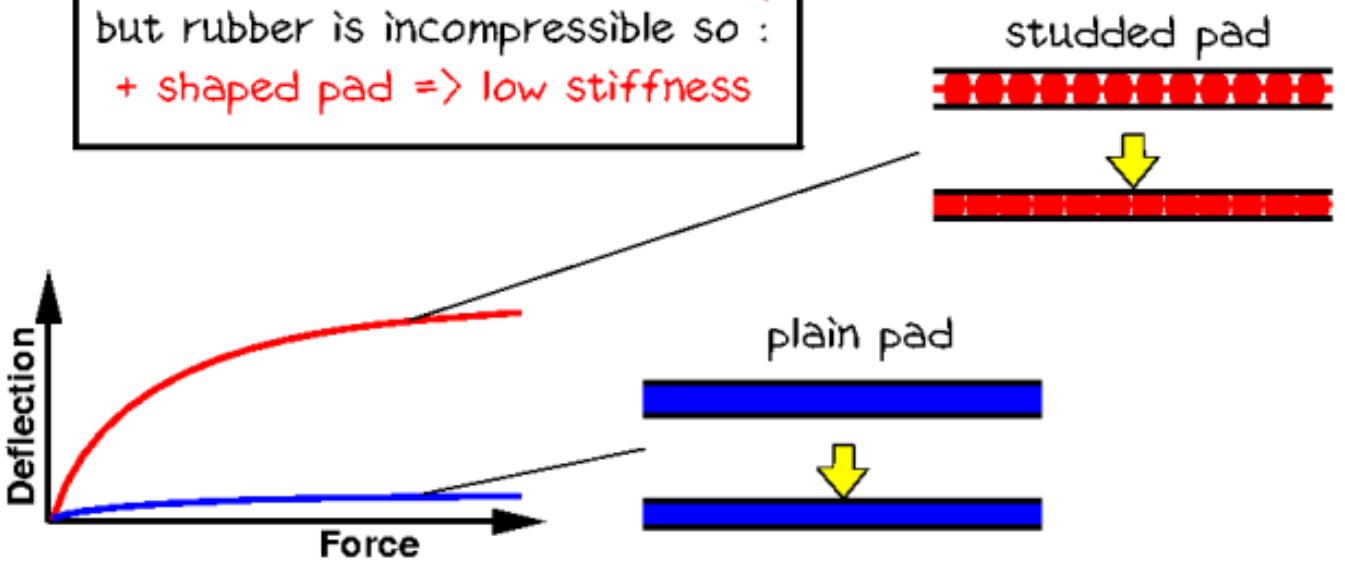
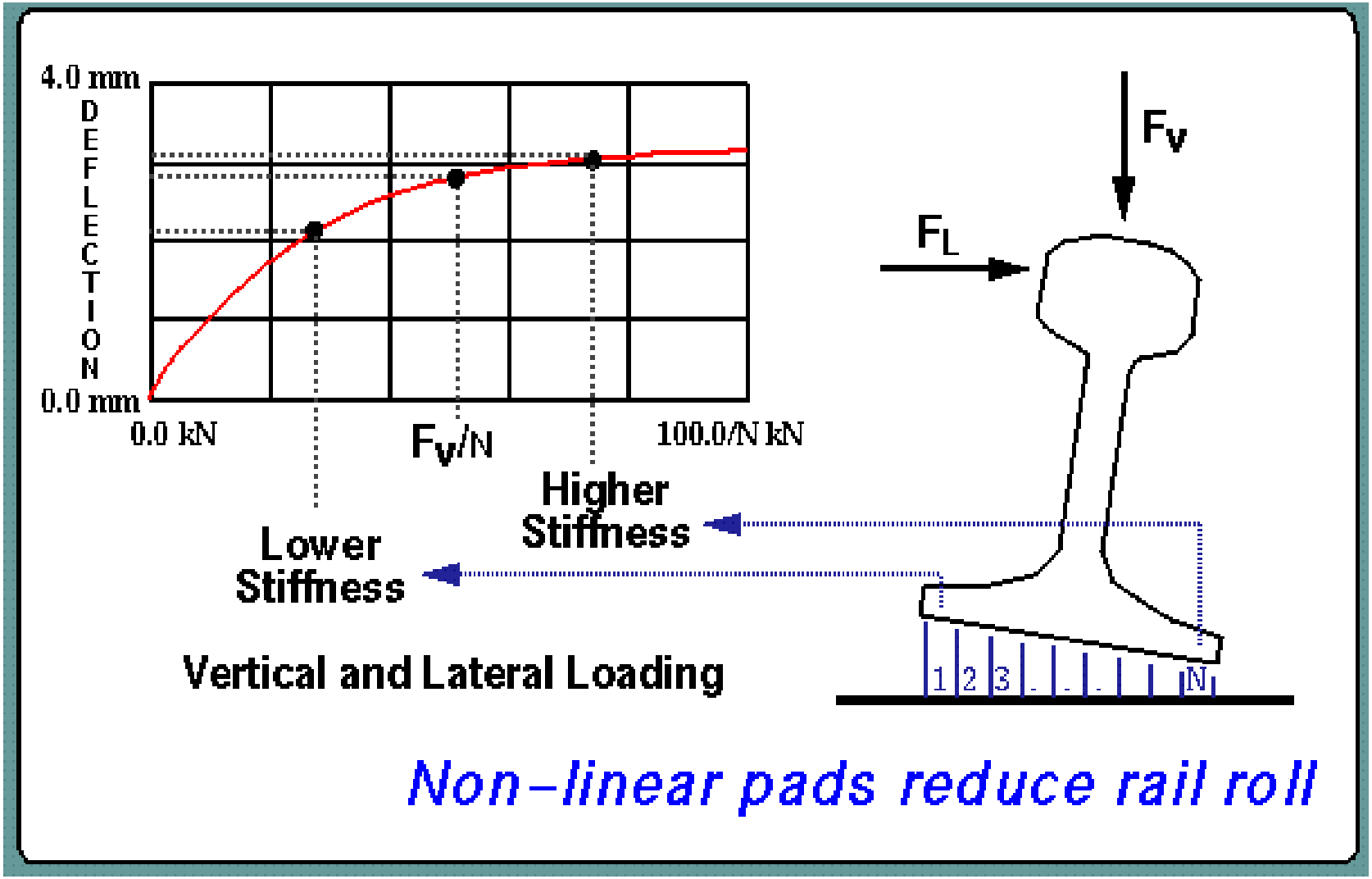


System Stiffness Design : Track and Fastener



Non–linear pads reduce rail roll

5.4 Non-linear pad

Nonlinear Pad

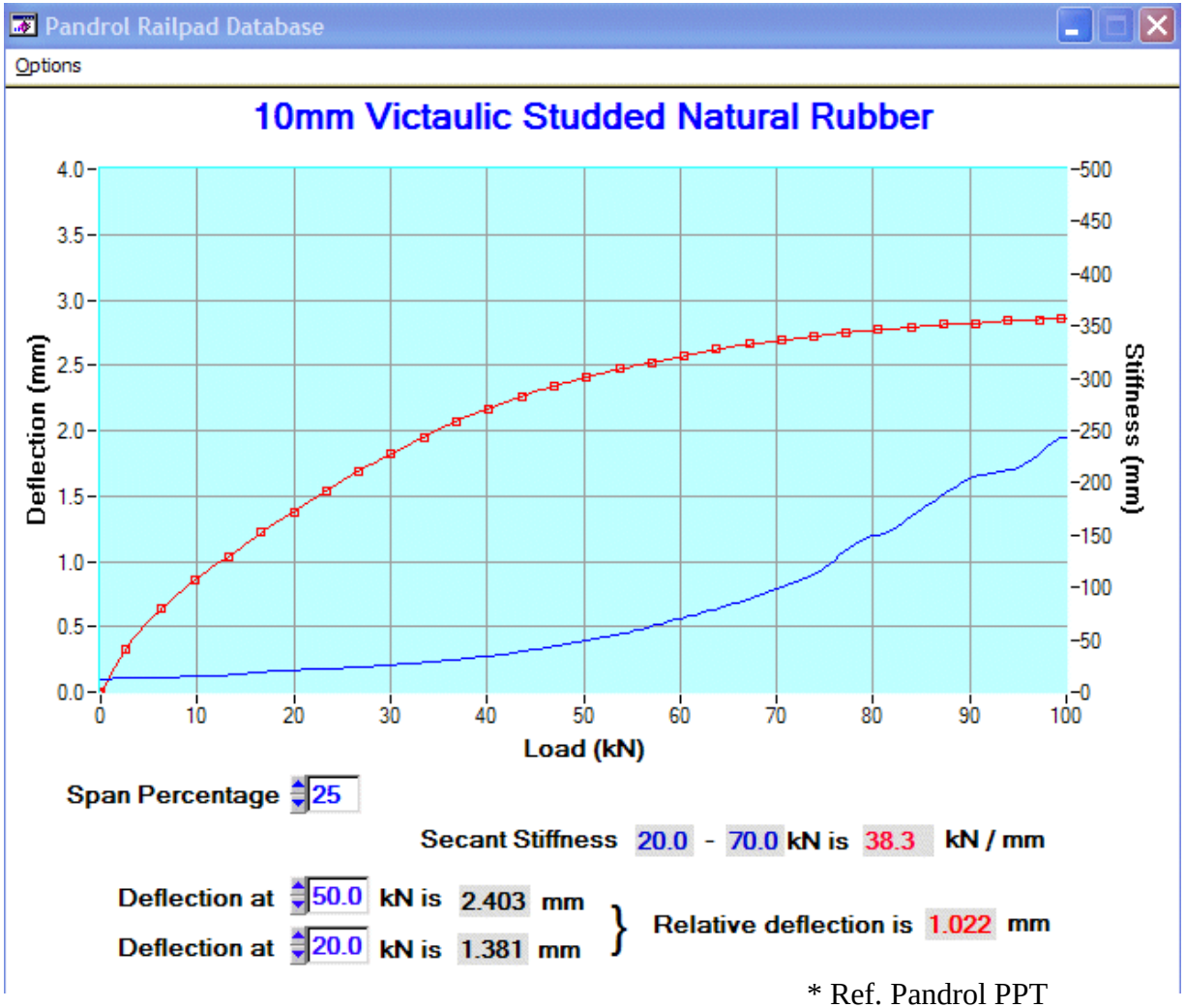
Secant Stiffness:

$K_{20\text{-}70}$=38 kN/mm

Tangent Stiffness:

K_{20} =21 kN/mm

K_{70} =104 kN/mm

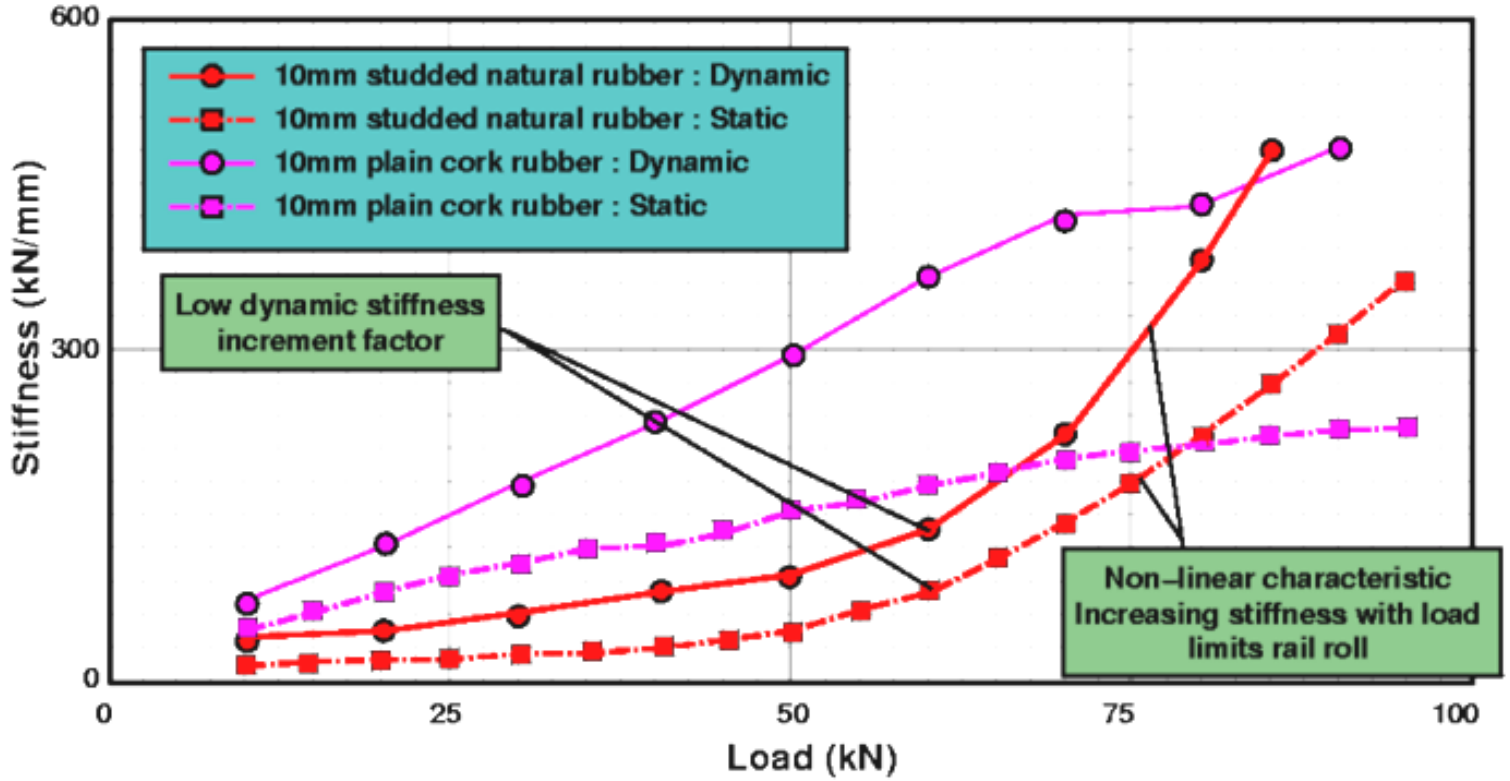


* Ref. Pandrol PPT

5.4 Non-linear pad

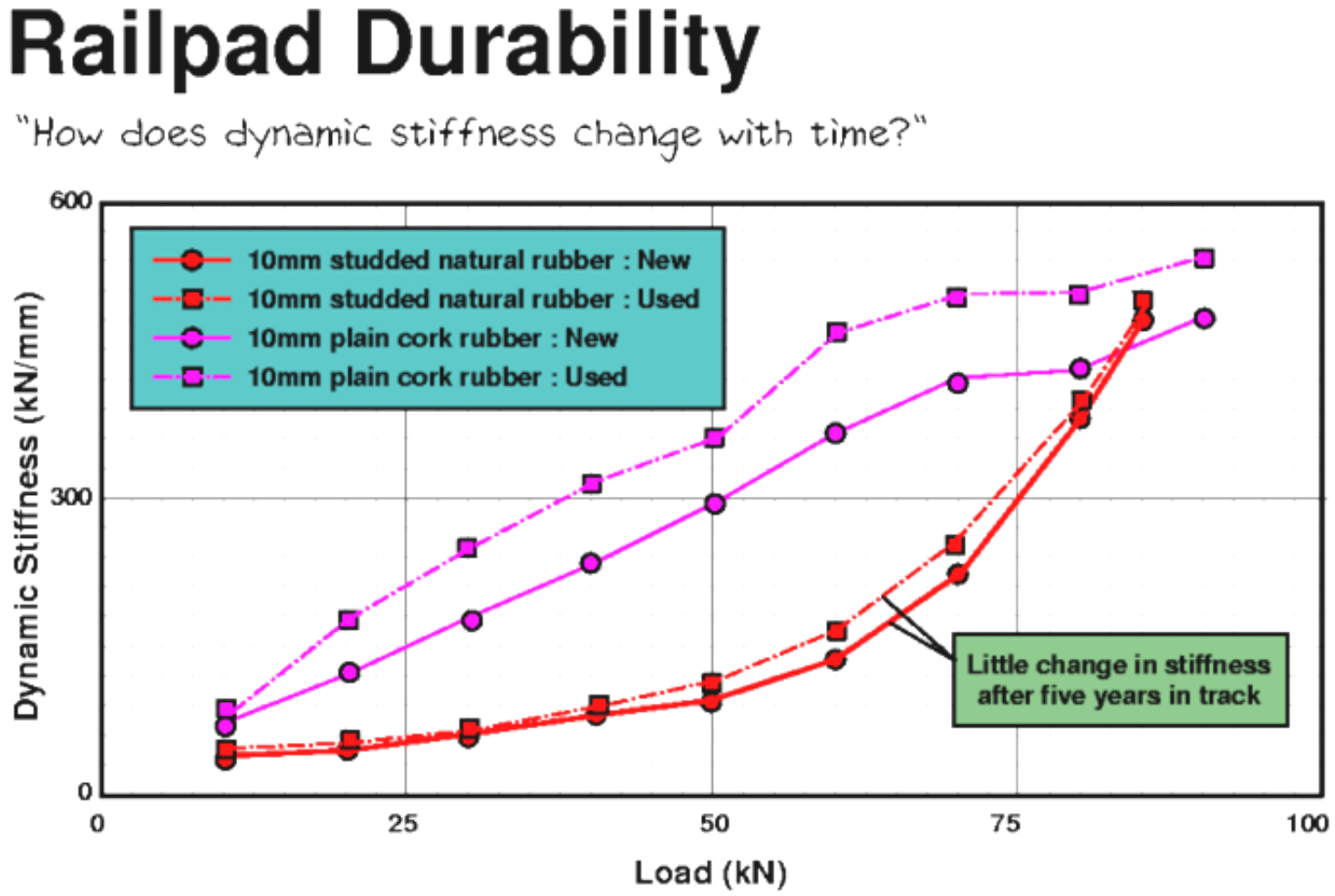
Railpad Stiffness Characteristics

"What features does a good railpad's characteristic exhibit?"



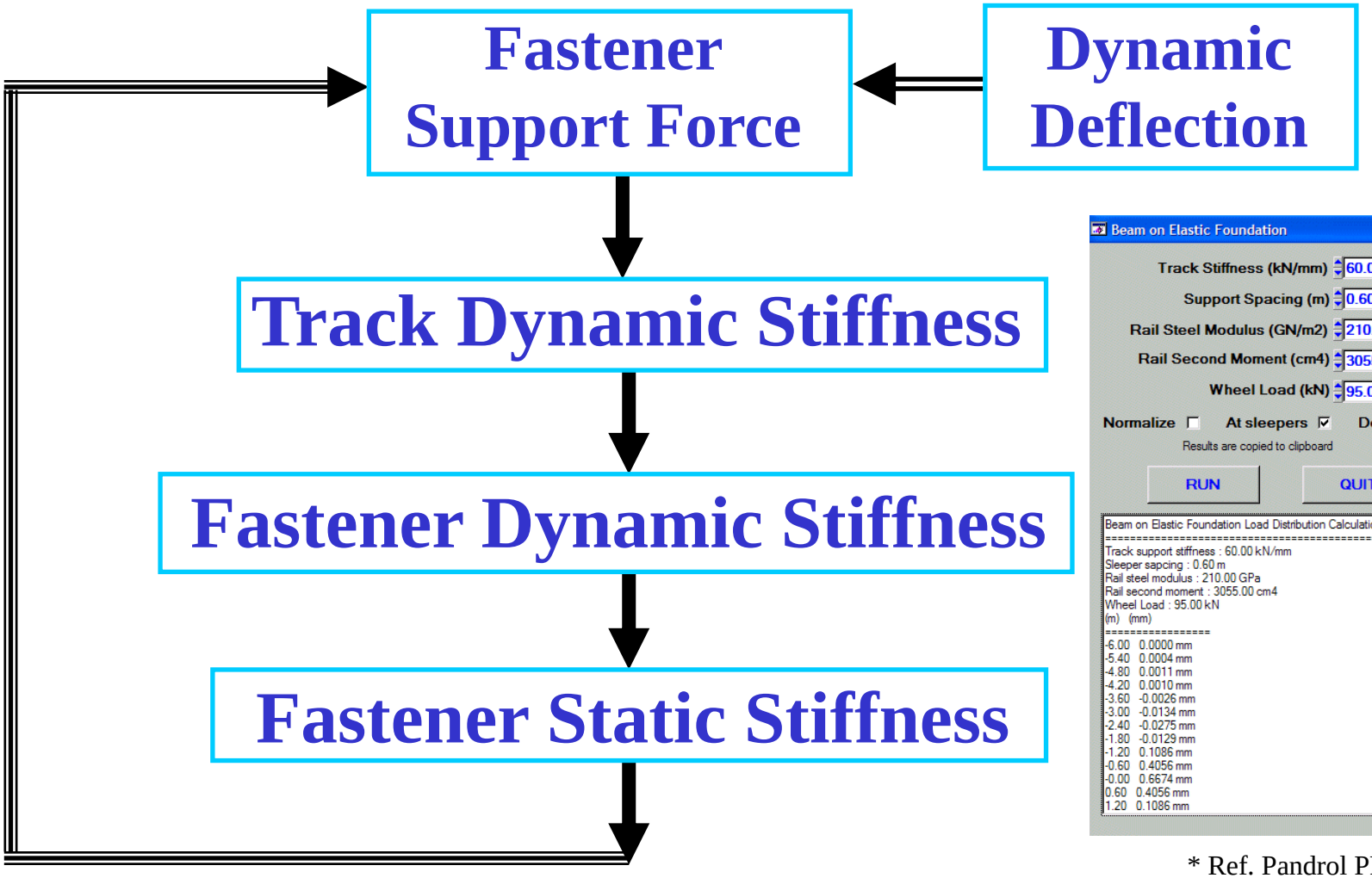
* Ref. Pandrol PPT

5.4 Non-linear pad



* Ref. Pandrol PPT

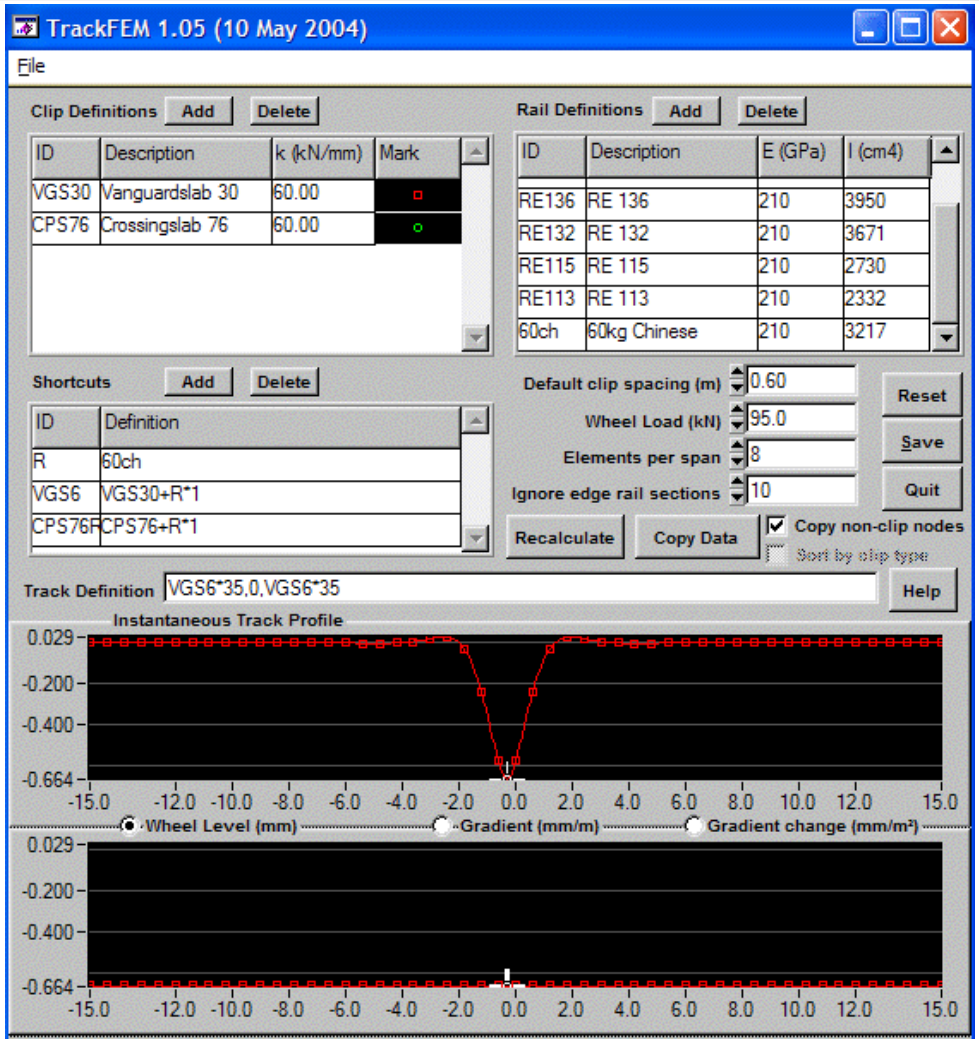
5.5 Fastening stiffness design



* Ref. Pandrol PPT

5.5 Fastening stiffness design

Stiffness Design Tool



* Ref. Pandrol PPT

Part Two: Product Testing

1. CEN standards
2. Lab test - case
3. Site test - case

Part Two: Product Testing

1. CEN standards

1. CEN Standards – rail fastening

EN13146_1_
EN13146_2_
EN13146_3_
EN13146_4_
EN13146_5_
EN13146_6_
EN13146_7_
EN13146_8_

EN13481_1_
EN13481_2_
EN13481_5_
EN13481_6_
EN13481_7_
EN13481_8_

1.1 Longitudinal rail restraint

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13146-1

November 2002

ICS 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 1: Determination of longitudinal rail restraint

1.2 Torsional resistance

EUROPEAN STANDARD **EN 13146-2**

NORME EUROPÉENNE

EUROPÄISCHE NORM

ICS 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 2: Determination of torsional resistance

Applications ferroviaires - Voie - Méthodes d'essai pour les systèmes de fixation - Partie 2: Détermination du couple d'encastrement

Bahnanwendungen - Oberbau - Prüfverfahren für Schienenbefestigungssysteme - Teil 2: Ermittlung des Verdrehwiderstandes

1.3 Attenuation

EUROPEAN STANDARD **EN 13146-3**

NORME EUROPÉENNE

EUROPÄISCHE NORM

ICS 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 3: Determination of attenuation of impact loads

Applications ferroviaires - Voie - Méthodes d'essai pour les systèmes de fixation - Partie 3: Détermination de l'atténuation des forces d'impact

Bahnanwendungen - Oberbau - Prüfverfahren für Schienenbefestigungssysteme - Teil 3: Bestimmung der Dämpfung von Stoßlasten

1.4 Repeated loading

EUROPEAN STANDARD **EN 13146-4**

NORME EUROPÉENNE

EUROPÄISCHE NORM

ICS 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 4: Effect of repeated loading

Applications ferroviaires - Voie - Méthodes d'essai pour les systèmes de fixation - Partie 4: Effets produits par des charges répétitives

Bahnanwendungen - Oberbau - Prüfverfahren für Schienenbefestigungssysteme - Teil 4: Dauerschwingversuch

1.5 Electrical resistance

EUROPEAN STANDARD **EN 13146-5**

NORME EUROPÉENNE

EUROPÄISCHE NORM

ICS 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 5: Determination of electrical resistance

Applications ferroviaires - Voie - Méthodes d'essai pour les systèmes de fixation - Partie 5: Détermination de la résistance électrique

Bahnanwendungen - Oberbau - Prüfverfahren für Schienenbefestigungssysteme - Teil 5: Bestimmung des elektrischen Widerstandes

1.6 Environmental conditions – salt spray

EUROPEAN STANDARD **EN 13146-6**

NORME EUROPÉENNE

EUROPÄISCHE NORM

ICS 19.040; 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 6: Effect of severe environmental conditions

Applications ferroviaires - Voie - Méthodes d'essai pour les systèmes de fixation - Partie 6: Effet résultant de conditions environnantes rigoureuses

Bahnanwendungen - Oberbau - Prüfverfahren für Befestigungssysteme - Teil 6: Auswirkung von starken Umwelteinflüssen

1.7 Clamping force

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13146-7

ICS 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 7: Determination of clamping force

Applications ferroviaires - Voie - Méthodes d'essai pour les systèmes de fixation - Partie 7: Détermination de l'effort d'application au patin du rail

Bahnanwendungen - Oberbau - Prüfverfahren für Schienenbefestigungssysteme - Teil 7: Bestimmung der Spannkraft

1.8 In service testing

EUROPEAN STANDARD **EN 13146-8**

NORME EUROPÉENNE

EUROPÄISCHE NORM

ICS 93.100

English version

Railway applications - Track - Test methods for fastening systems - Part 8: In service testing

Applications ferroviaires - Voie - Méthodes d'essai pour les systèmes de fixation - Partie 8: Essai en service

Bahnanwendungen - Oberbau - Prüfverfahren für Schienenbefestigungssysteme - Teil 8: Betriebserprobung

1.9 Performances

EN13481_1_

EN13481_2_

EN13481_5_

EN13481_6_

EN13481_7_

EN13481_8_

1.9 Performances – Concrete sleepers

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13481-2

ICS 93.100

English version

Railway applications - Track - Performance requirements for fastening systems - Part 2: Fastening systems for concrete sleepers

Applications ferroviaires - Voie - Prescriptions de performance pour les systèmes de fixation - Partie 2: Systèmes de fixation des traverses en béton

Bahnanwendungen - Oberbau - Leistungsanforderungen für Schienenbefestigungssysteme - Teil 2: Befestigungssysteme für Betonschwellen

1.9 Performances - Slab

EUROPEAN STANDARD **EN 13481-5**

NORME EUROPÉENNE

EUROPÄISCHE NORM

ICS 93.100

English version

Railway applications - Track - Performance requirements for fastening systems - Part 5: Fastening systems for slab track

Applications ferroviaires - Voie - Prescriptions de performance pour les systèmes de fixation - Partie 5: Systèmes de fixation des voies sur dalle

Bahnanwendungen - Oberbau - Leistungsanforderungen für Schienenbefestigungssysteme - Teil 5: Befestigungssysteme für feste Fahrbahnen

1.9 Performances - Attenuation

EUROPEAN PRESTANDARD **ENV 13481-6**

PRÉNORME EUROPÉENNE

EUROPÄISCHE VORNORM

ICS 93.100

English version

Railway applications - Track - Performance requirements for fastening systems - Part 6: Special fastening systems for attenuation of vibration

Applications ferroviaires - Voie - Prescriptions de performance pour les systèmes de fixation - Partie 6: Systèmes de fixation spéciaux pour atténuation des vibrations

Bahnanwendungen - Oberbau - Leistungsanforderungen für Schienenbefestigungssysteme - Teil 6: Spezielle Besfestigungssysteme zur Minderung von Schwingungen

1.9 Performances Switches/check rails

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13481-7

ICS 93.100

English version

Railway applications - Track - Performance requirements for fastening systems - Part 7: Special fastening systems for switches and crossing and check rails

Applications ferroviaires - Voie - Prescriptions de performance pour les systèmes de fixation - Partie 7: Systèmes de fixation pour appareils de voie, contre-rails et rails de sécurité

Bahnanwendungen - Oberbau - Leistungsanforderungen für Befestigungssysteme - Teil 7: Spezielle Befestigungssysteme für Weichen und Kreuzungen sowie Führungsschienen

1.9 Performances – Heavy axle loads

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13481-8

ICS 93.100

English Version

Railway applications - Track - Performance requirements for fastening systems - Part 8: Fastening systems for track with heavy axle loads

Applications ferroviaires - Voie - Prescriptions de performance pour les systèmes de fixation - Partie 8: Systèmes de fixation des voies pour des charges à l'essieu lourdes

Bahnanwendungen - Oberbau - Leistungsanforderungen für Schienenbefestigungssysteme - Teil 8: Befestigungssysteme für Strecken mit hohen Radsatzlasten

Part Two: Product Testing

1. CEN standards

2. Lab test - case

2. CEN Lab tests - example

* Ref. Pandrol Report 2005

Part Two: Product Testing

1. CEN standards

2. Lab test - case

3. Site test - case

3. Site tests - example

* Ref. SUES CAM Lab Report 2018

8th IWRN, UK 2004

14th IWRN, PRC 2022

Thanks !