INTRODUCTION TO PERMANENT WAY ENGINEERING

Day 2
JKR Railway Engineering Course
Feb 2019

Presented by
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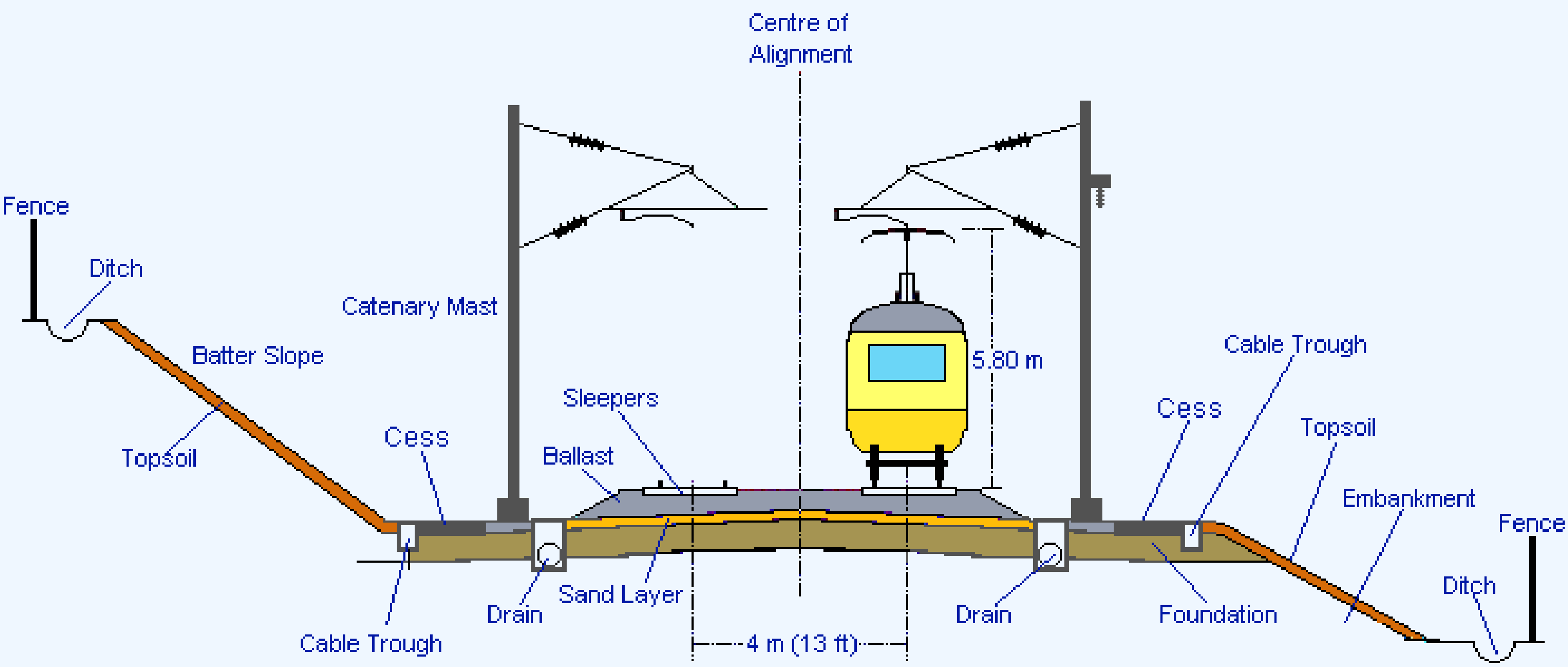
Outline

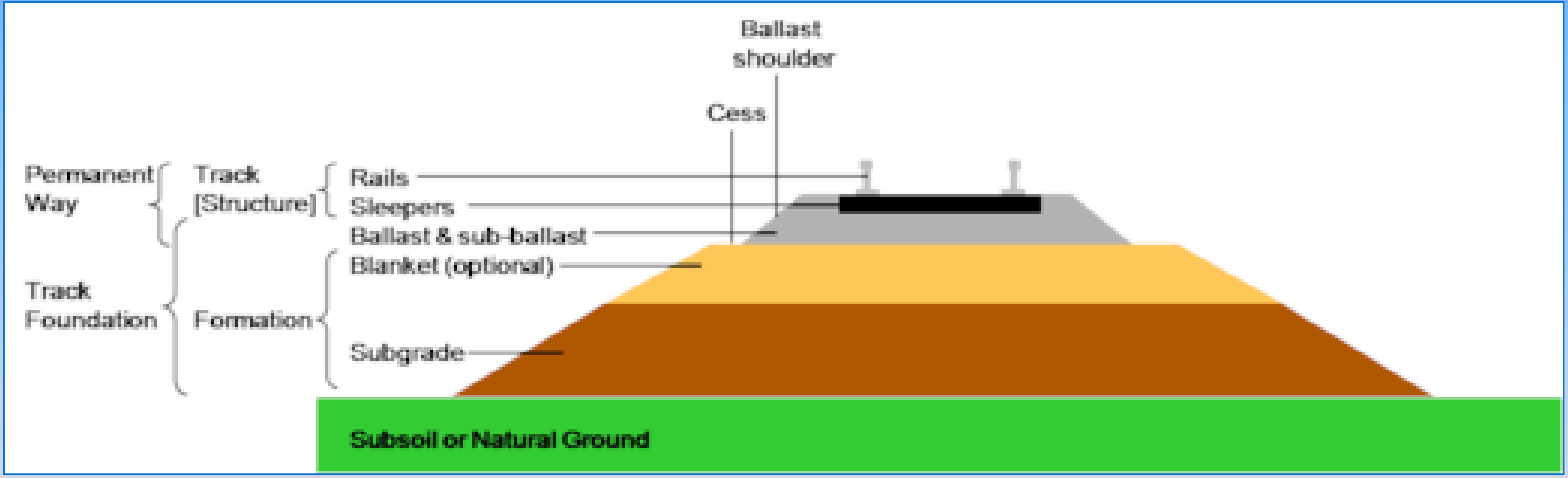
- Wayside Infrastructure
- Permanent Way and its Function
- Wheel Rail Interface
- Brief description of components
- Track Quality
- Track Maintenance

Wayside Infrastructures



Cross Section of Double Track Railway Alignment showing names of principal parts of construction

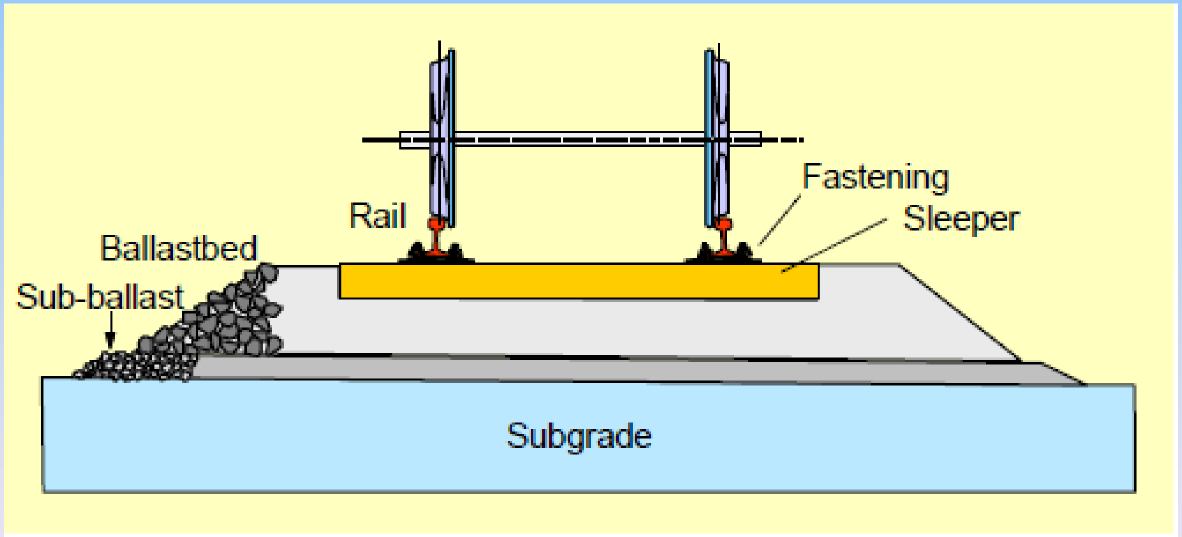
The Permanent Way



The Track Function

- To transfer train loads to the formation

- To guide the wheel



The Track Function

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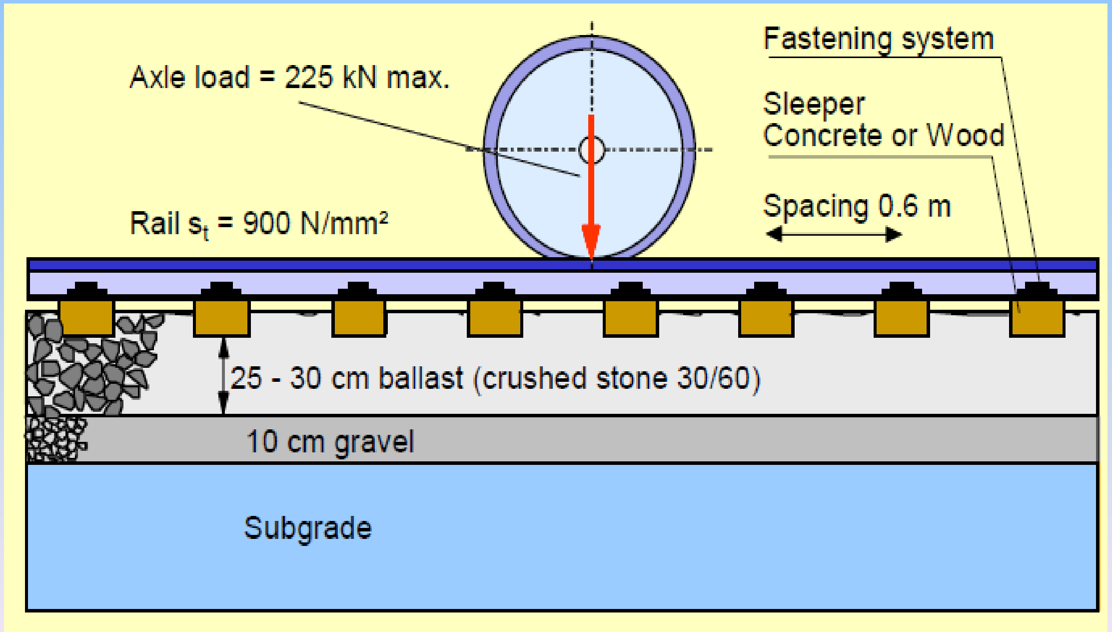


Loads on the track

- Vertical
- Horizontal – transverse and parallel to the track
- Unevenly distributed between the two rails
- The forces comprises quasi-static & dynamic forces

Loads on the Track

Quasistatic

- gross loads,
- centrifugal and centering forces in curves and turnouts
- loads from cross winds

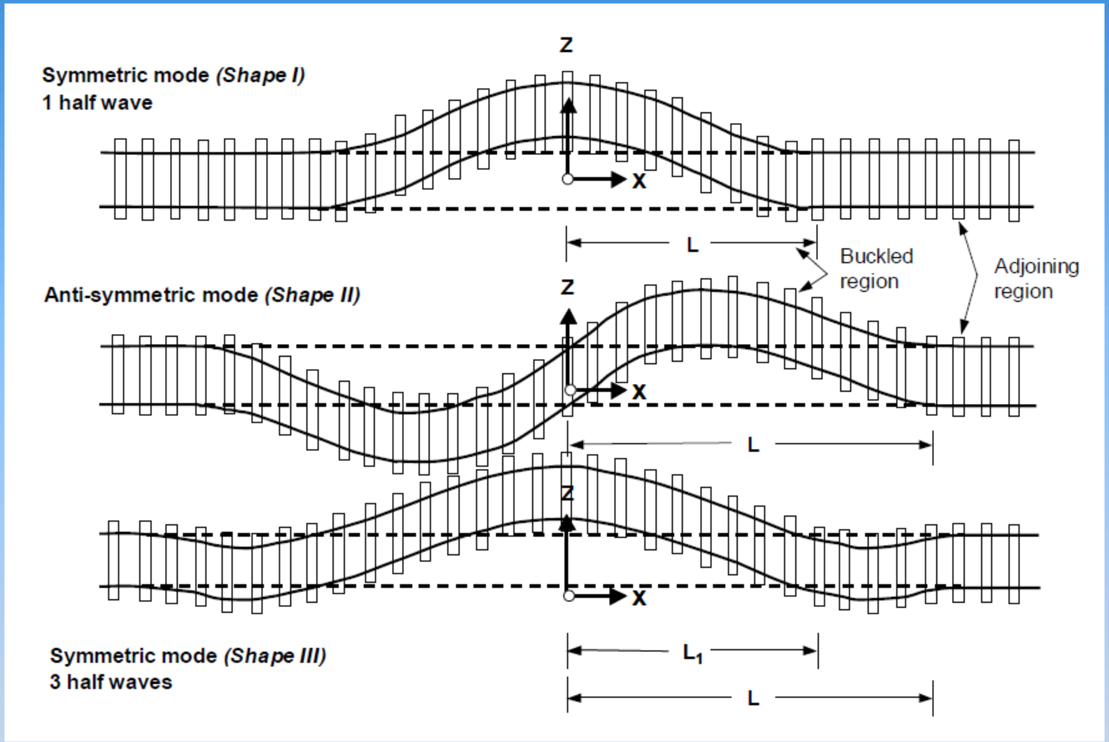
Dynamic

- vertical and horizontal track irregularities
- irregular track stiffness due to varying track structure characteristics and settlement of ballast bed and formation
- discontinuities at joints, welds and turnouts
- irregular rail running surface eg. Corrugations
- vehicle or wheel defects eg. Flats, hunting, vibrations

Thermal

- longitudinal tensile and compressive forces
- track buckling

Track buckling



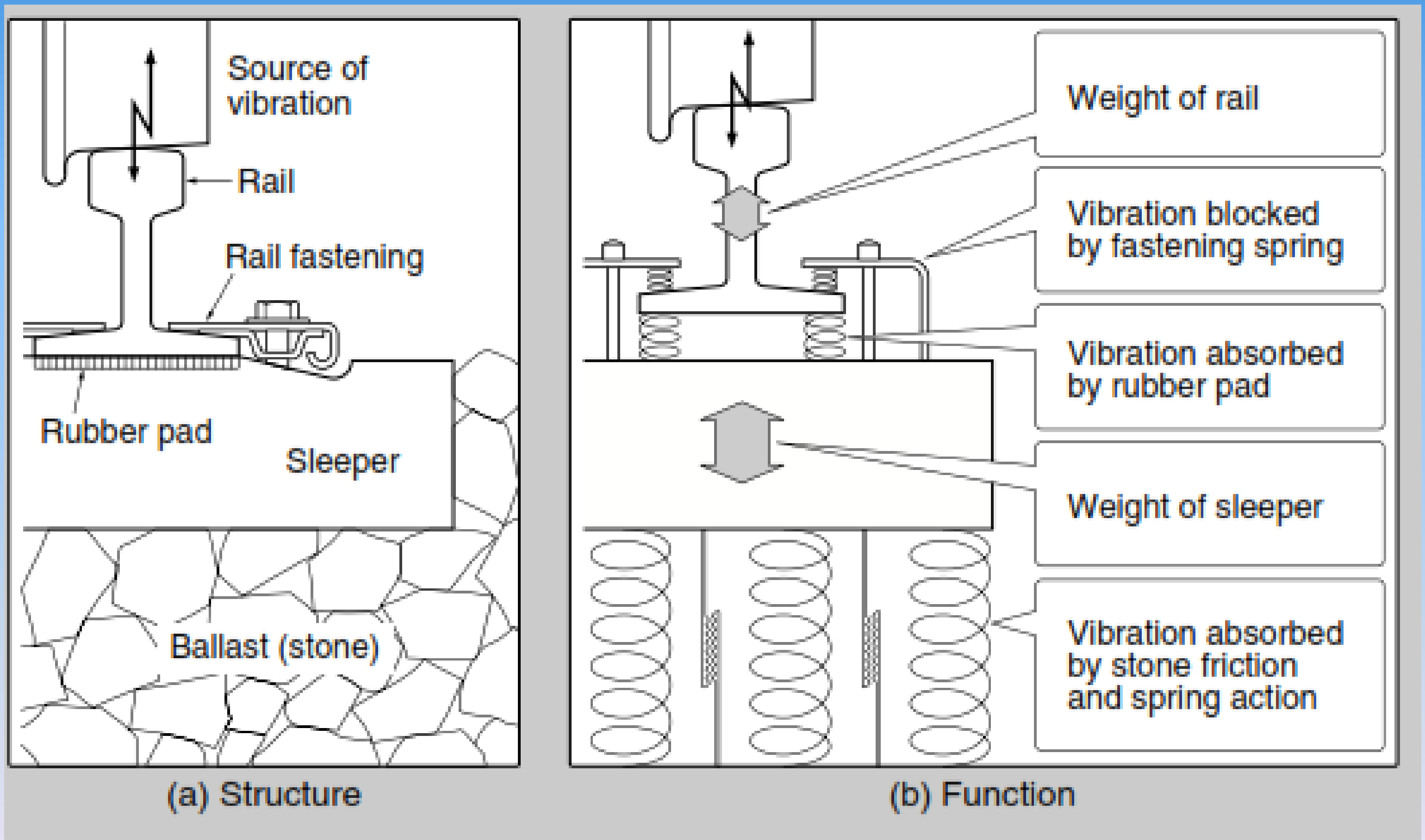
Continuous welded rails must undergo destressing operations after installations & if disturbed during maintenance operations such as tamping or ballast cleaning

The Track Function

Requirements:

1. **Adequate Strength**
2. **Provide minimal environmental impact - noise and ground vibration.**
3. **Optimised Life Cycle cost – Long lasting**
4. **Easy to maintain**

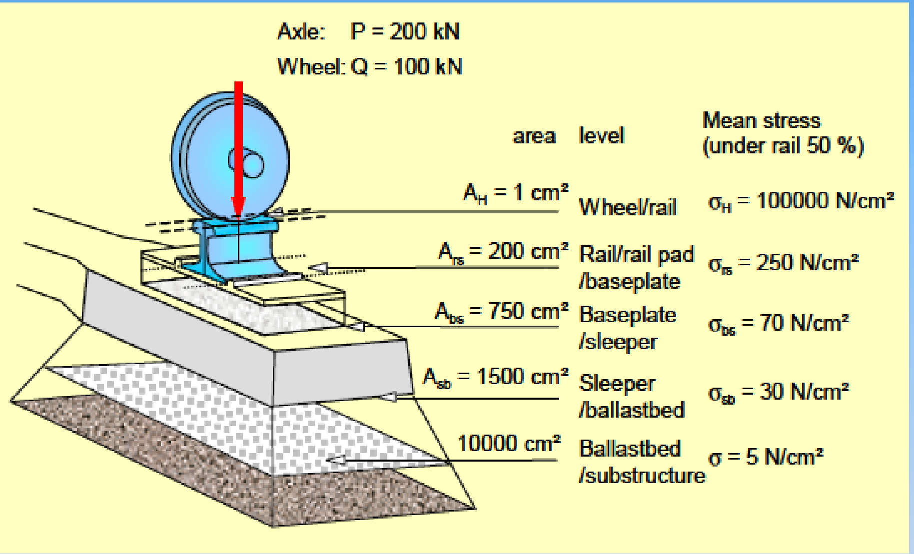
The Railway Track Structure



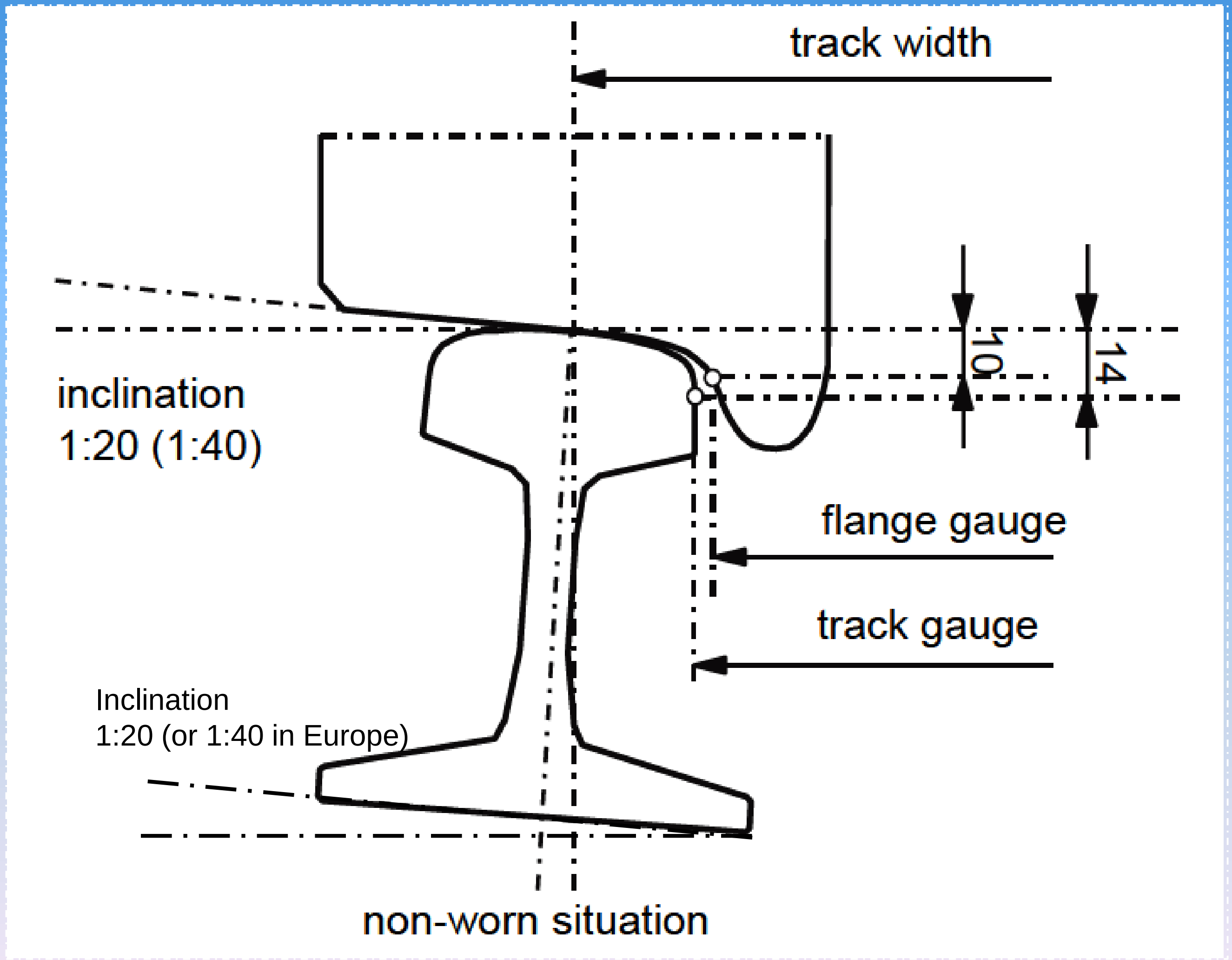
Load bearing function of the track

The load transfer works on the principle of stress reduction - layer by layer.

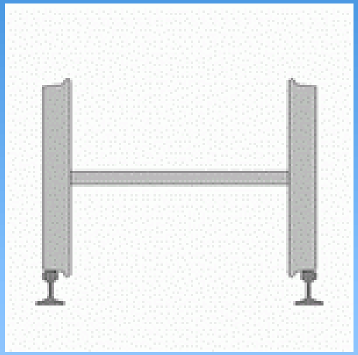
1. **The greatest stress occurs between wheel and rail and is in the order of 30-100 kN/cm2**
2. **Between rail and sleeper the stress is two orders smaller and diminishes between sleeper and ballast bed down to about 30 N/cm2.**
3. **Finally the stress on the formation or substructure is only about 5 N/cm2.**

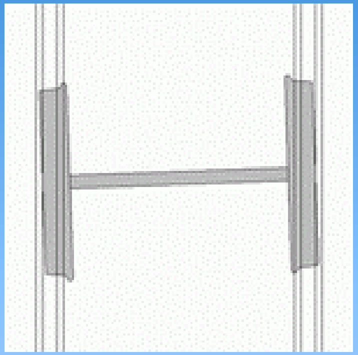


Wheel (flange) and Track Gauge



Behaviour of the Wheelset on the Track



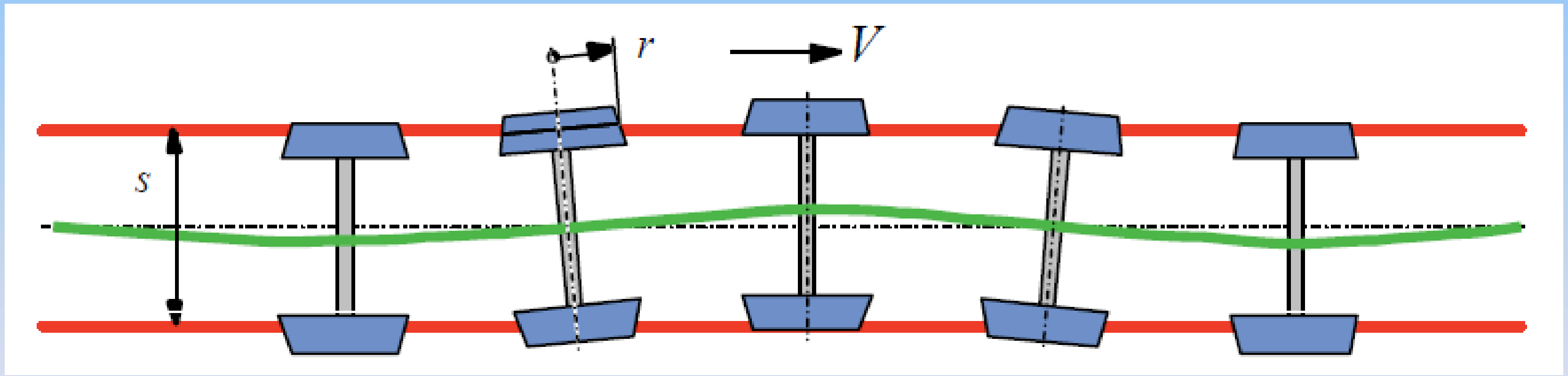


Klingel's study - sinusoidal movement

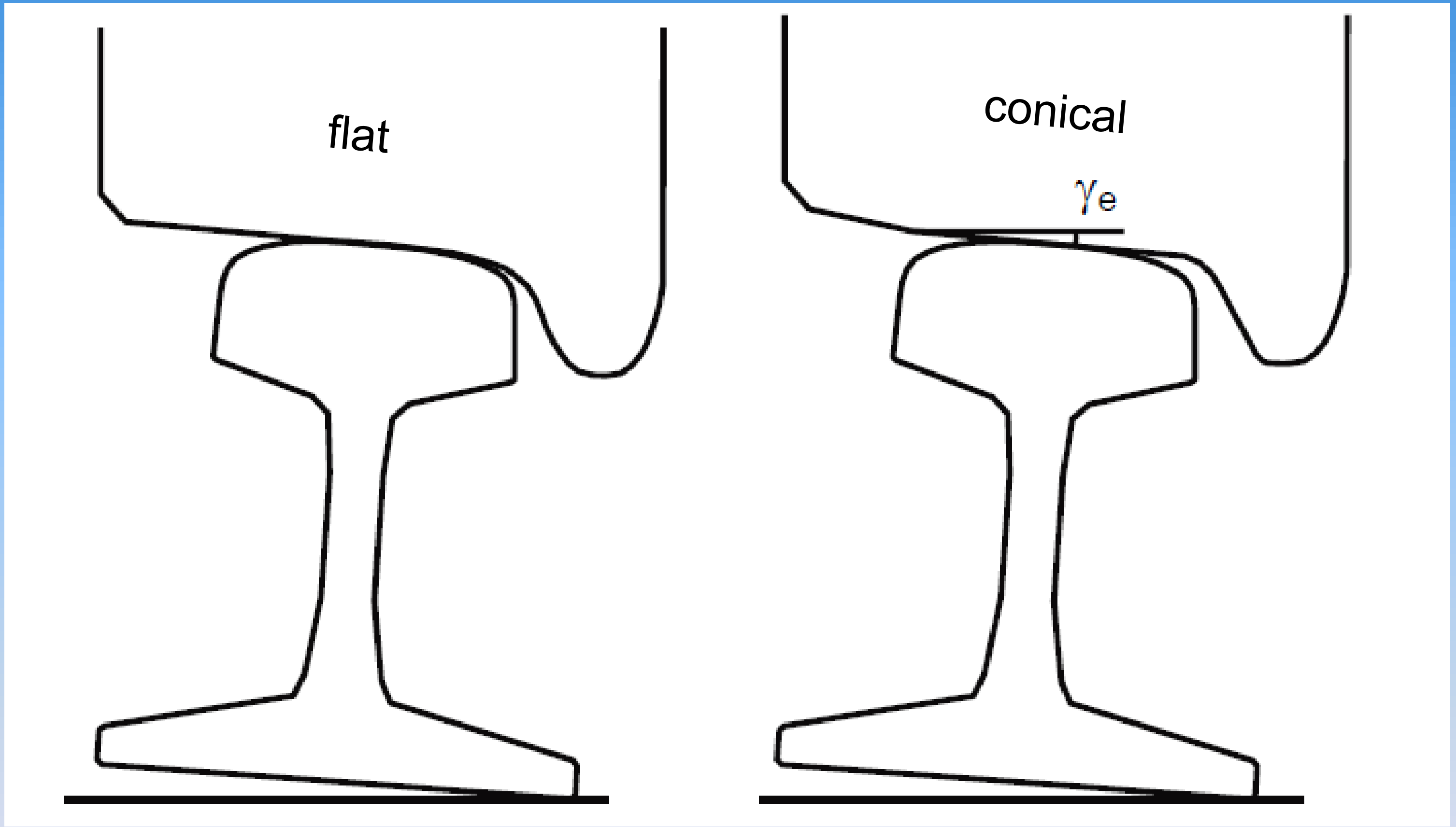
$$L_k = 2\pi\sqrt{\frac{rs}{2\gamma}}.$$

$$f = \frac{V}{L_k}.$$

Wavelenth, L_k
Wheel radius r
Wheelset conicity γ
Distance bet. contact points s
Speed V



The conical wheel profile



Modern wheel sets has conical wheel profile,
a curvilinear shape that matches the rail head profile

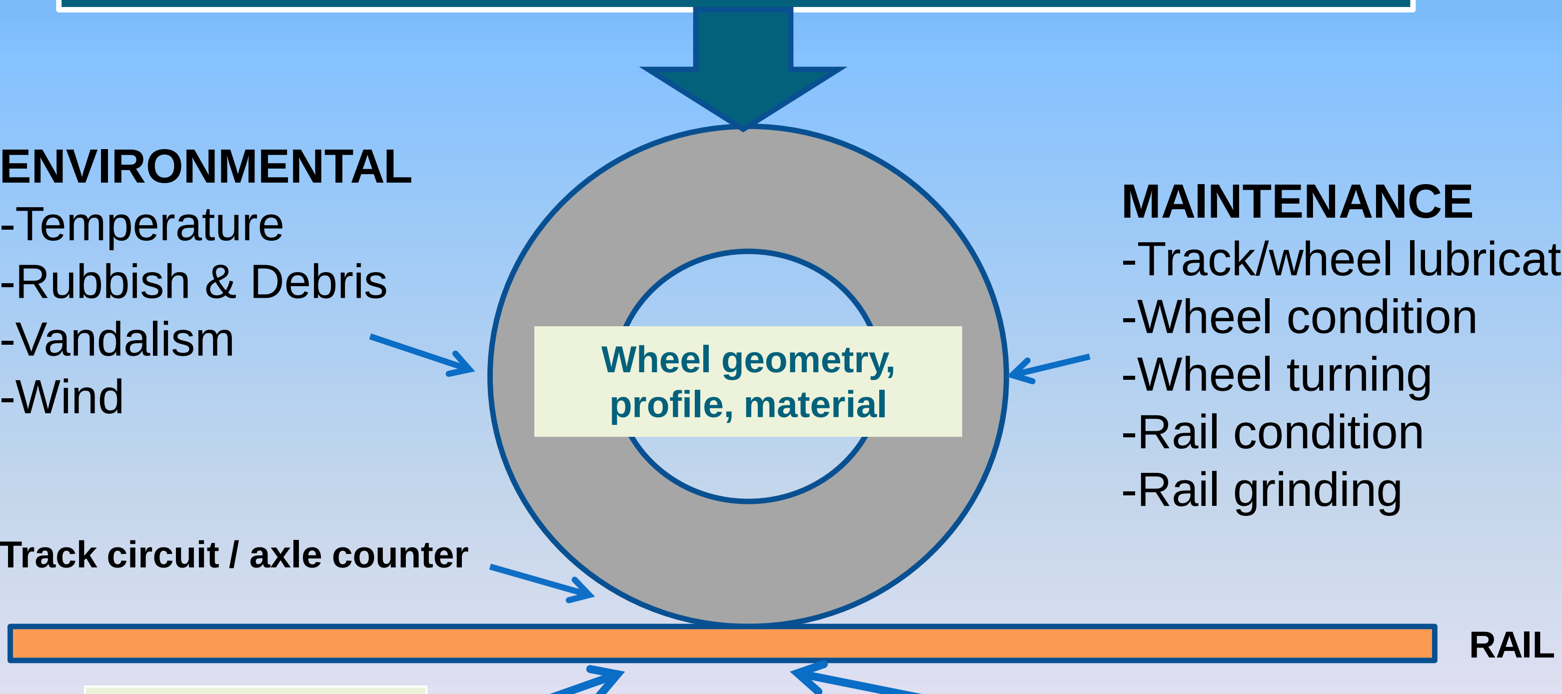
WHEEL-RAIL INTERFACE

Train Aspects

PHYSICAL ASPECTS
- -Train formation
- -Suspension system
- -Axle load
- -Running gear steering
- -Traction type

OPERATIONAL ASPECTS
- -Velocity
- -Length of train
- -Frequency of operation
- -Traffic pattern
- -Volume

ENVIRONMENTAL
- -Temperature
- -Rubbish & Debris
- -Vandalism
- -Wind



MAINTENANCE
- -Track/wheel lubrication
- -Wheel condition
- -Wheel turning
- -Rail condition
- -Rail grinding

Track circuit / axle counter

Rail geometry, profile, material

Track geometry, profile, material

Classification of Lines

- **UIC guideline – UIC Leaflet 700 and 714**
- **Equivalent Tonnage T_f = $(T_p \times V/100) + (T_g \times P_c/18D)$**

T_p = Real load for daily passenger traffic (tonnes)

V = Maximum permissible Speed in km/h

T_g = Real load for daily freight traffic (tonnes)

P_c = Maximum axle load with wheels of diameter D (tonnes)

D = Minimum wheel diameter (m)

UIC Classification of Lines

Tracks are usually classified into four categories, depending on train speed, as follows:

- **High speed tracks (V > 200 km/h),**
- **Rapid speed tracks (140 km/h < V < 200km/h)**
- **Medium speed tracks (100 km/h < V < 140km/h)**
- **Low speed tracks (V < 100 km/h)**

Type of Tracks

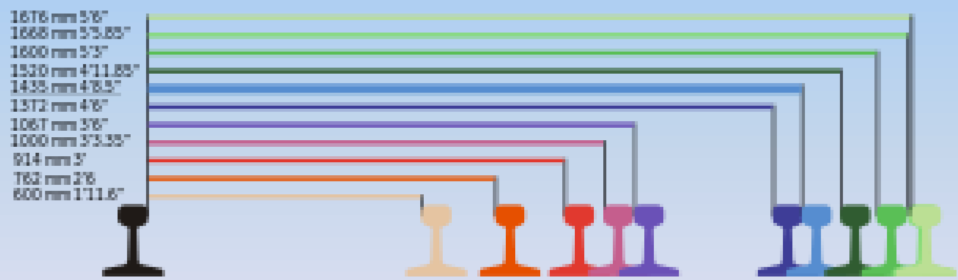
Ballastless Track (Slab Track)

Ballasted Track

- ➡ Slab track capital cost ~ 30-60% more than ballasted track.
- ➡ Maintenance costs can be reduced by 3 to 5 times that of ballasted track

Broad gauge	
Breitspurbahn	3,000 mm (118.1 in)
Brunel	2,140 mm (84.3 in)
Indian	1,676 mm (66.0 in)
Iberian	1,668 mm (65.7 in)
Irish	1,600 mm (63.0 in)
Russian	1,520 mm (59.8 in)
Standard gauge (Stephenson)	
	1,435 mm (56.5 in)
Medium gauge	
Scotch	1,372 mm (54.0 in)
Cape	1,067 mm (42.0 in)
Metre	1,000 mm (39.4 in)
Narrow gauge	
Three foot	914 mm (36.0 in)
Bosnian	760 mm (29.9 in)
Minimum gauge	
Fifteen inch	381 mm (15.0 in)

Track Gauge



http://en.wikipedia.org/wiki/Track_(rail_transport)

Track Components

1. Ballast & Sub-ballast
2. Rails
3. Track Sleepers
4. Rail Fastenings
5. Switches & Crossings (Turnouts)

Track components –features		
Components	**Before modernization**	**After Modernization**
RAILS	Jointed with fishplates	Continuously welded to eliminate all fish-plated joints
	Medium Manganese	Superior grade with higher hardness
SLEEPERS	Timber or Metal sleepers	Mostly Concrete sleepers
FASTENINGS	Rigid type	Elastic type
BALLAST	Graded stone ballast	
	Limited ballast cushion	Increased ballast cushion
	Moderate Ballast profile Less quantity needed	Larger ballast profile More quantity needed
Sub – Ballast	Not required	Required
Inspection, Monitoring Maintenance	Mostly Manual	Fully Mechanized
Speed Potential of track	LIMITED	HIGH

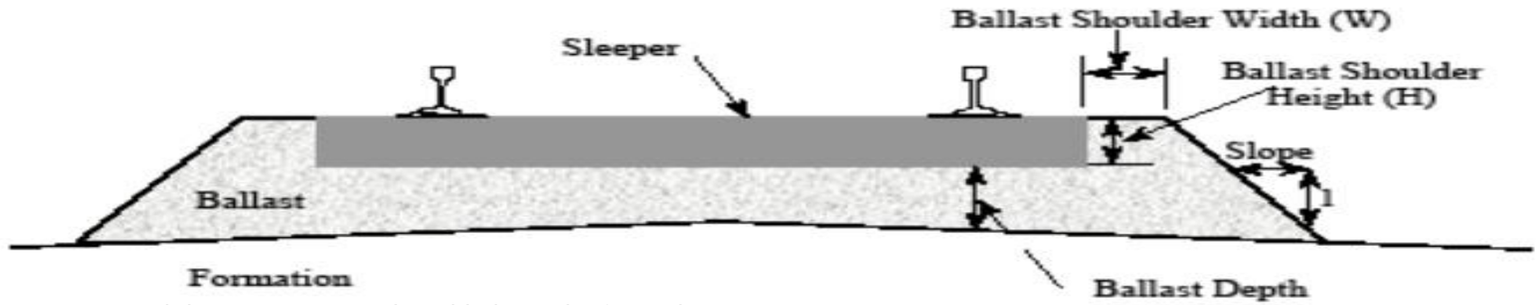
Ballast

Provide uniform support and alignment stability to the track structure.

Provide elasticity and void space to allow runoff of water

- Clean, hard, dense, angular **granite** to grading specification
- High wear and abrasive qualities
- High internal shearing & compressive strength
- High resistance to temperature changes, chemical attack, exhibit a high electrical resistance and low absorption properties

Typical Ballast Profile



Capping Layer or Sub ballast layer may be laid above the formation layer

	MAIN LINES		SIDINGS	
Type of Lines	Nominal ballast depth (mm)	Shoulder width (mm)	Nominal ballast depth (mm)	Shoulder width (mm)
Heavy Haul	300	400	250	200
Interstate Lines	250	400	150	200
Light weight Lines	150	400	150	150

Note: Factors to consider in determining the profile are speeds and axle loads

Track lateral displacement

The total resistance to lateral displacement is made up of the following portions:

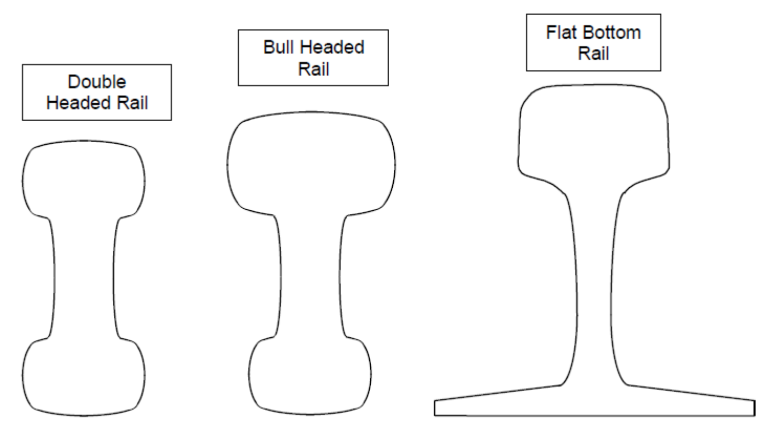
- Sleeper underside friction 45-50%
- Sleeper-end resistance 35-40%
- Long-side resistance of sleeper 10-15%

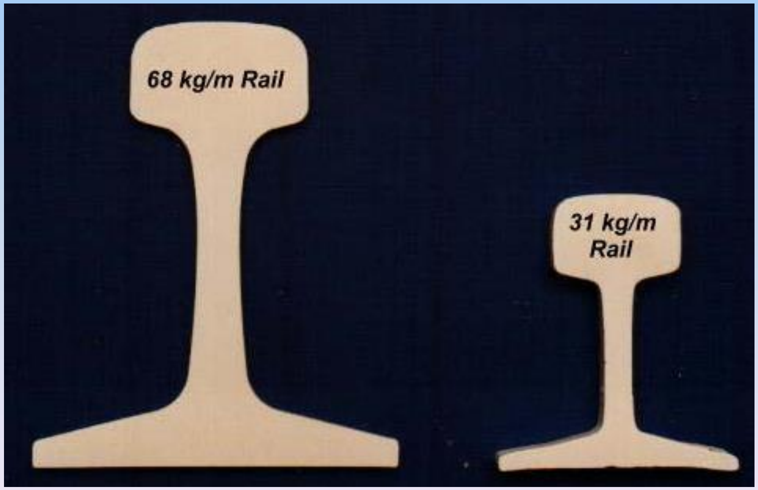
Resistance to Lateral Displacement

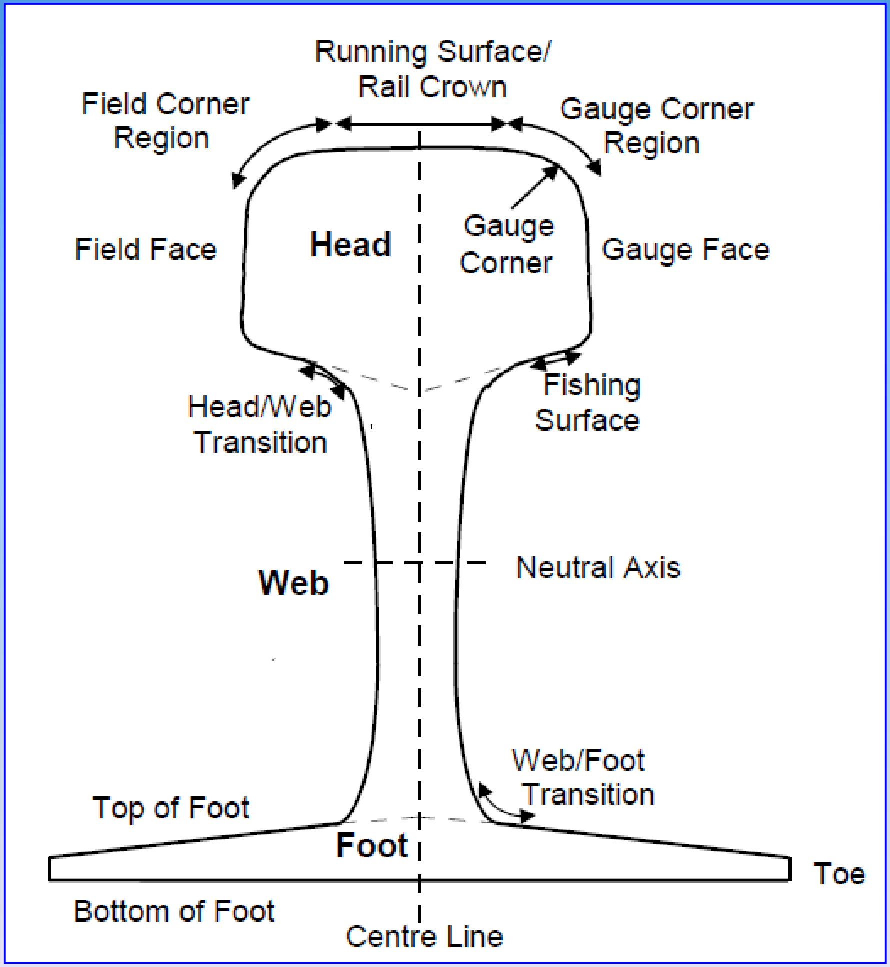
- Tamping lowers the RLD by around 40%, ballast bed cleaning lowers it by about 50%.
- Ballast consolidation raises the resistance to lateral displacement by approximately 4-7%.
- The Dynamic Track Stabilizer is most effective. It increases the resistance to lateral displacement by 30-40%.
- Stone blowing as an alternative mechanised technique, reduces the RLD by 50-65%.

Poor Ballast

Rails

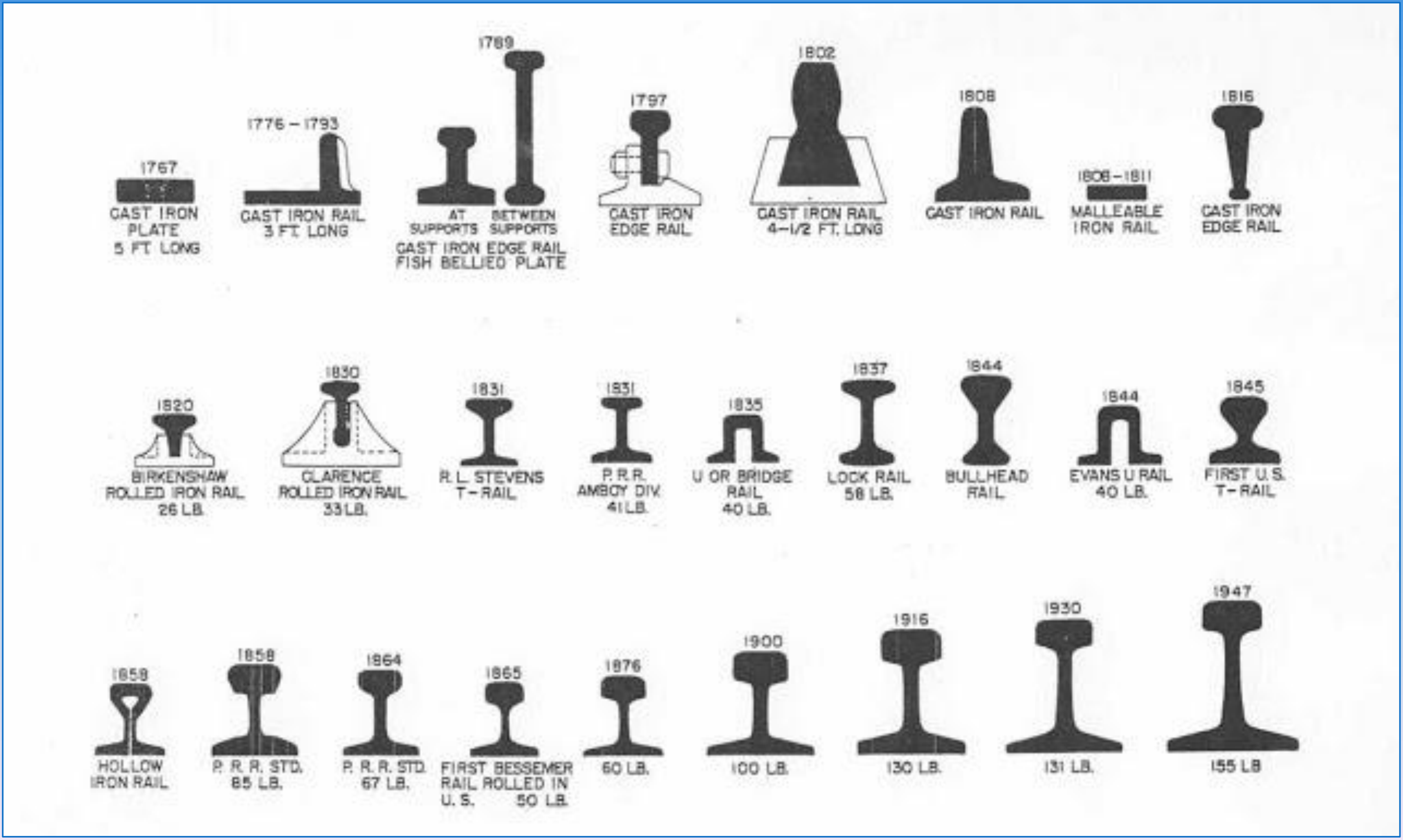

Double Headed Rail
Bull Headed Rail
Flat Bottom Rail


68 kg/m Rail
31 kg/m Rail

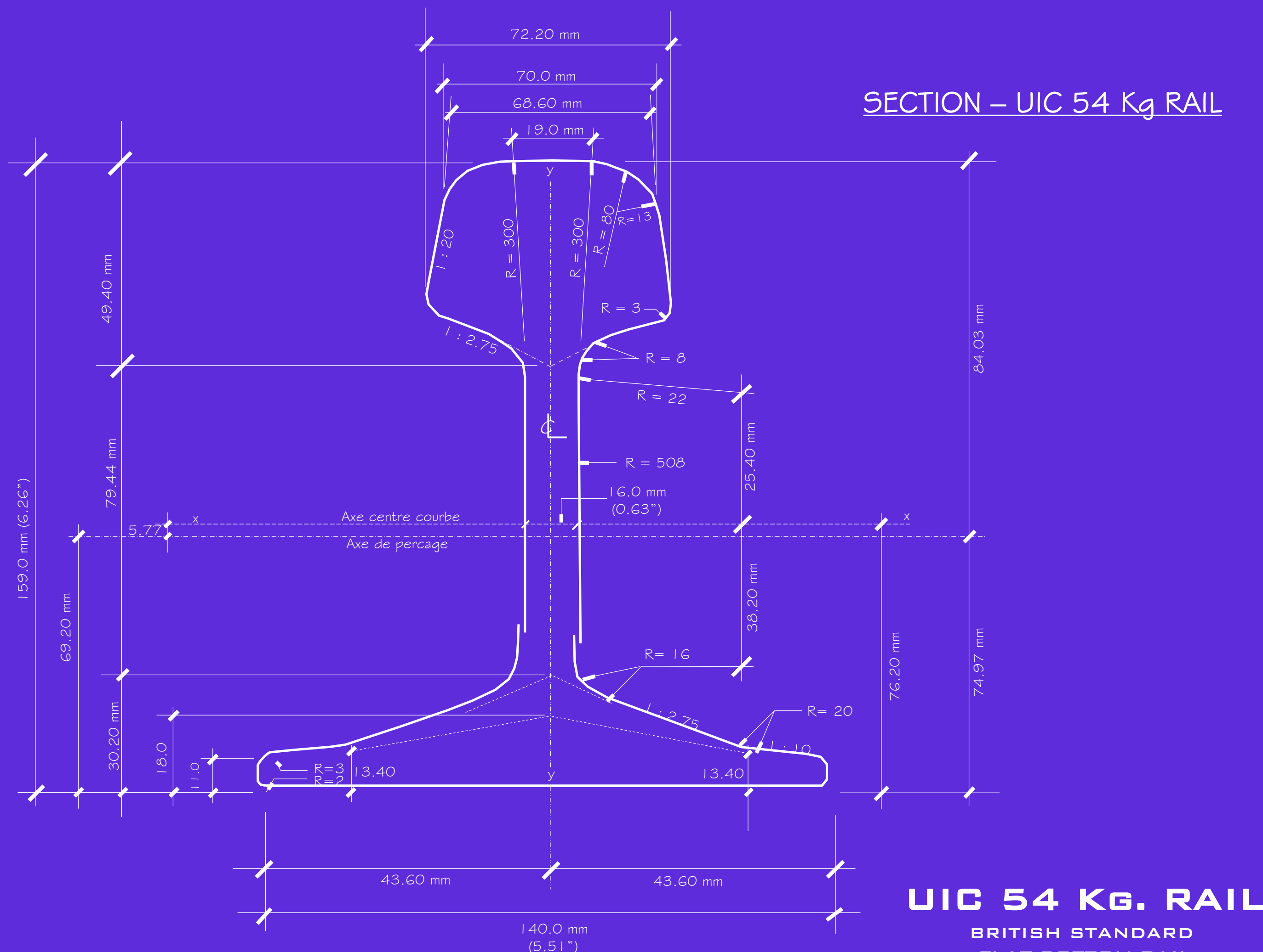

Running Surface/ Rail Crown
Field Corner Region
Gauge Corner Region
Field Face
Head
Gauge Corner
Gauge Face
Head/Web Transition
Fishing Surface
Web
Neutral Axis
Web/Foot Transition
Top of Foot
Foot
Toe
Bottom of Foot
Centre Line

Rail Section Profile

Historical development



Rail Profile UIC 54 KG

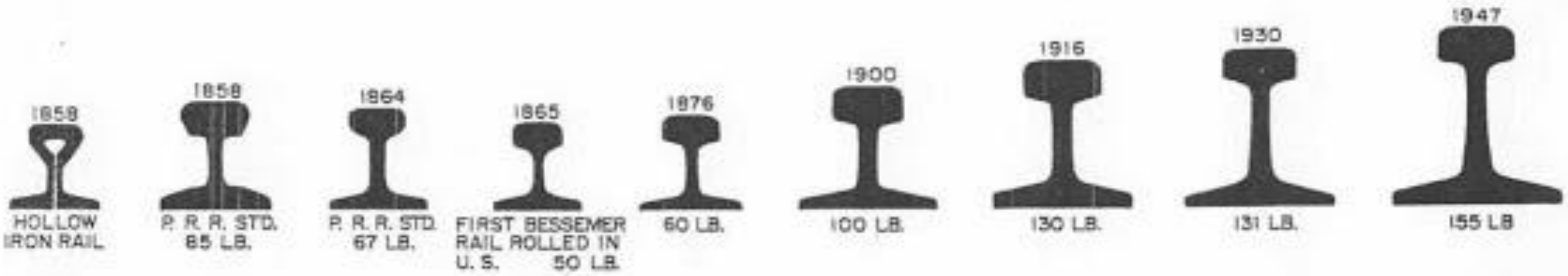


Rails

The first British Standard for rail steel manufacture was BS11 issued in 1903 which required a minimum tensile strength of 618 N /mm^2

Heavy axle loads of North America and "Premium" rails of around 1300/1400 N/mm^2 tensile strength are used.

They are finding increasing use in European railways in tight curve/high wear situations.



Rails

Alloying elements such as chromium and nickel can be added to some rail steels to improve properties

Alternatively, the rail can be cooled quickly

The rail can also be heat treated

Rails not only wear, they also break. (*Hatfield accident)

A railway's choice of rail grade is made in terms of traffic and track conditions and excellent service life can be achieved, particularly if modern rail head lubrication and grinding practices are used.

Rail Specification

- ✓ Weight
- ✓ Dimensions
- ✓ Squareness
- ✓ Straightness
- ✓ Chemical content
- ✓ Tensile strength
- ✓ Fracture toughness
- ✓ Fatigue Strength

Types of rails in used in KTMB

Rail Weight / Type	Specification	Grade	Minimum UTS (N/mm^2)
80A 80RBS 80BS	BS-11-1978 BS-11-1959 BS-11-1959	A Normal Normal	880 -1030 710 710
54 kg	UIC 860-O	900A	880-1030
54 kg	UIC 860-O	1100	1100
60 kg	UIC 860-0	Grade A Grade B Grade 1100	880-1030 880-1030 ≥1080

Typical Chemical Composition

Grade of Steel	Chemical composition, elements in % of mass						Tensile strength, N/mm^2	Elongation A Min. %
	C	Mn	Si	Cr	P_{max}	S_{max}		
R0700	0.4~0.6	0.8~1.25	0.05~0.35	-	0.05	0.05	680 ~ 830	14
R0900A	0.6~0.8	0.8~1.3	0.1~0.5	-	0.04	0.04	880 ~ 1030	10
R900B	0.55~0.75	1.3~1.7	0.1~0.5	-	0.04	0.04	880 ~ 1030	10
R1100*	0.6~0.82	0.8~1.3	0.3~0.9	0.8~1.3	(0.025)	0.03	≥ 1080	9

* Other alloy elements such as V or Mo can be applied according to agreement between manufacturer and employer.

Current Rail Standard

- European CEN guideline for procurement of rails shall be based on the latest European Standard EN 13674-1:2011 (Railway applications: Track — Rail Part 1: Vignole railway rails 46 kg/m and above).
- In this standard, the quality of rails is based on measured values of hardness.

Extract of EN 13674

Grade of Steel EN 13674-1	Tensile Strength N/mm2	Hardness HBW
R200	≥680	200 - 240
R220	≥770	220 - 260
R260	≥880	260 - 300
260 Mn	≥880	260 - 300
R320 CR	≥1080	320 - 360
R350 HT	≥1175	350 - 390
R350 LHT	≥1175	350 - 390

Sleepers (Ties)

- **The base for the rail to support and hold the track gauge**
- **Function to transfer the loads from rails to the ballast and subgrade,**

Steel Sleepers

Wooden Sleepers

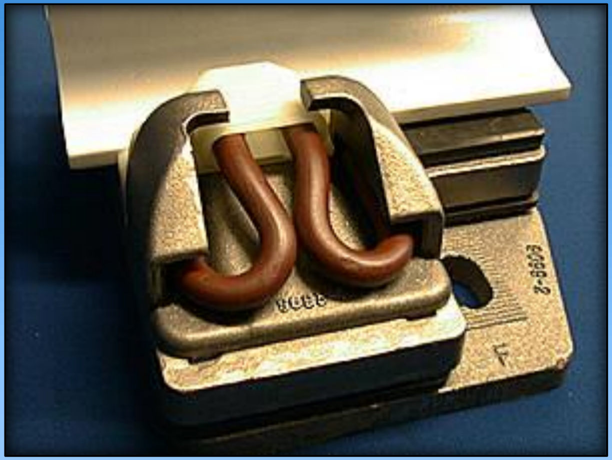
Concrete Sleepers

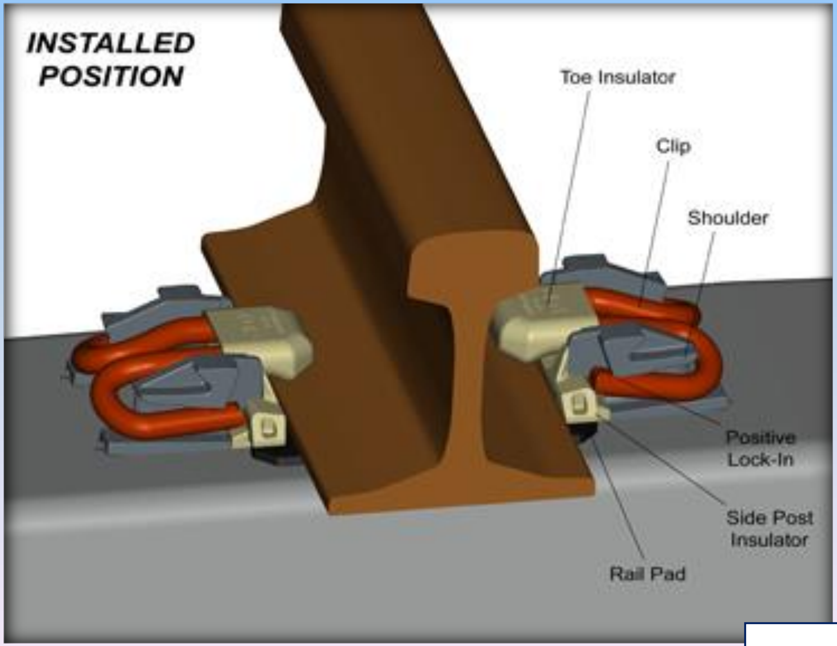
Other materials

i. Plastic sleepers
ii. Composite sleepers

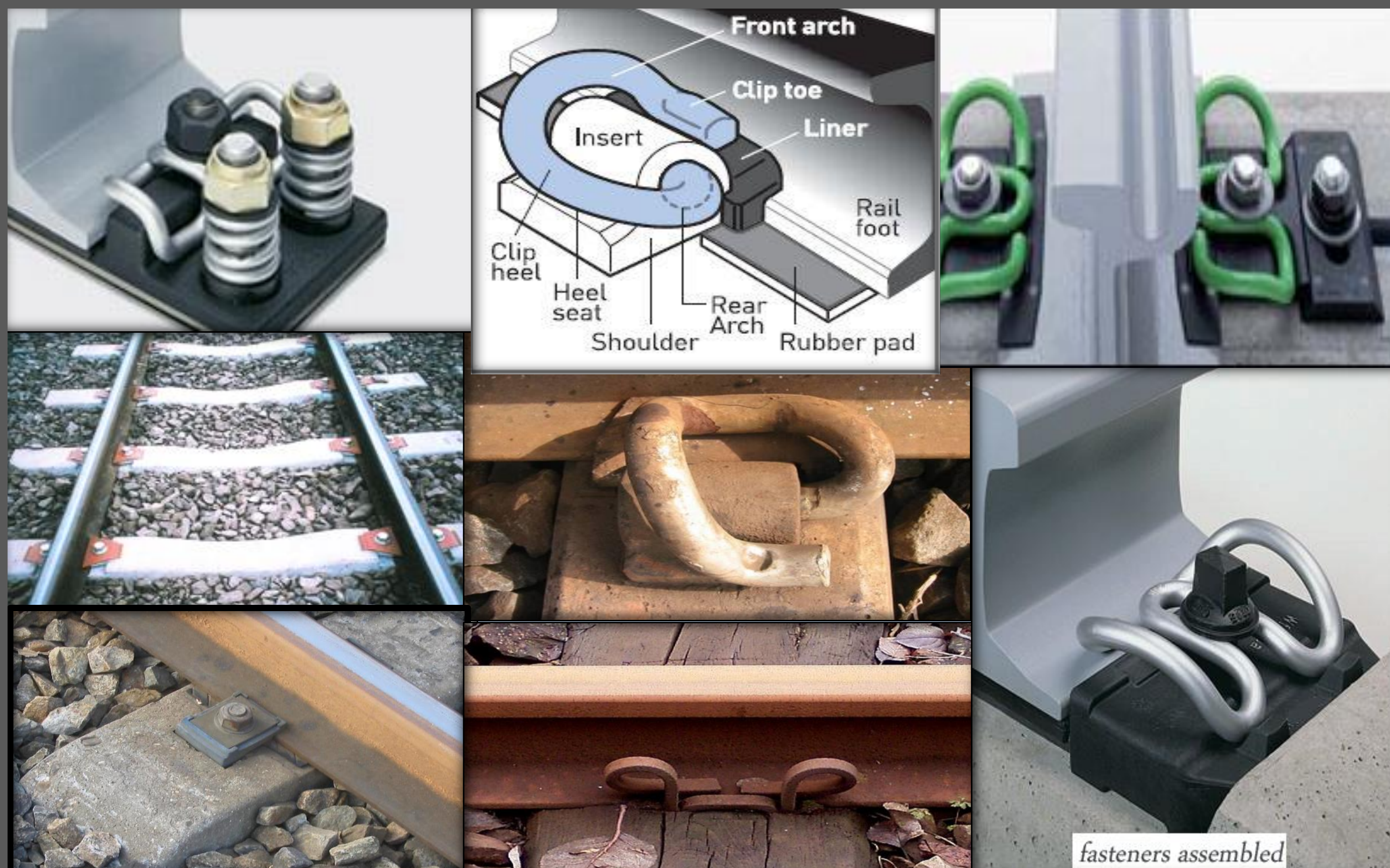
Poor conditions of timber sleepers

Rail Fastenings

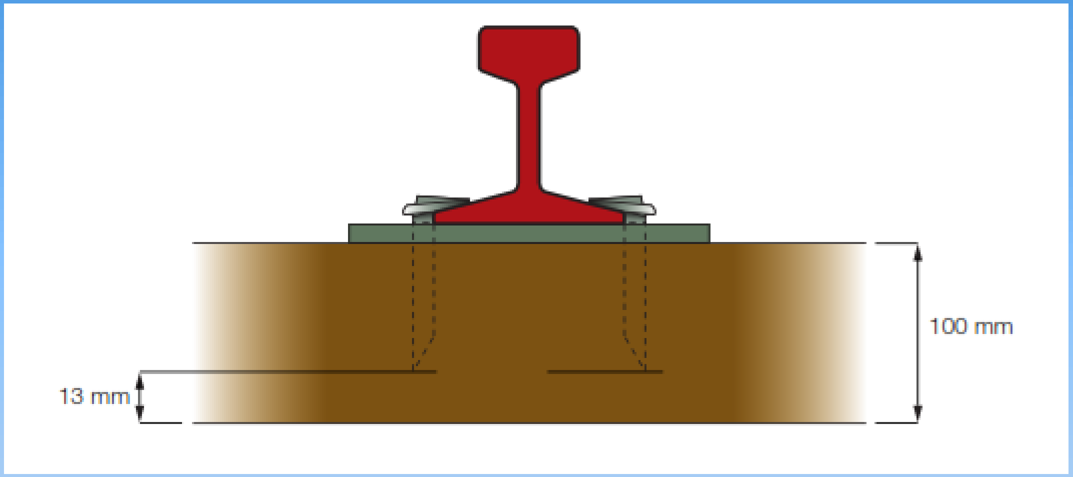


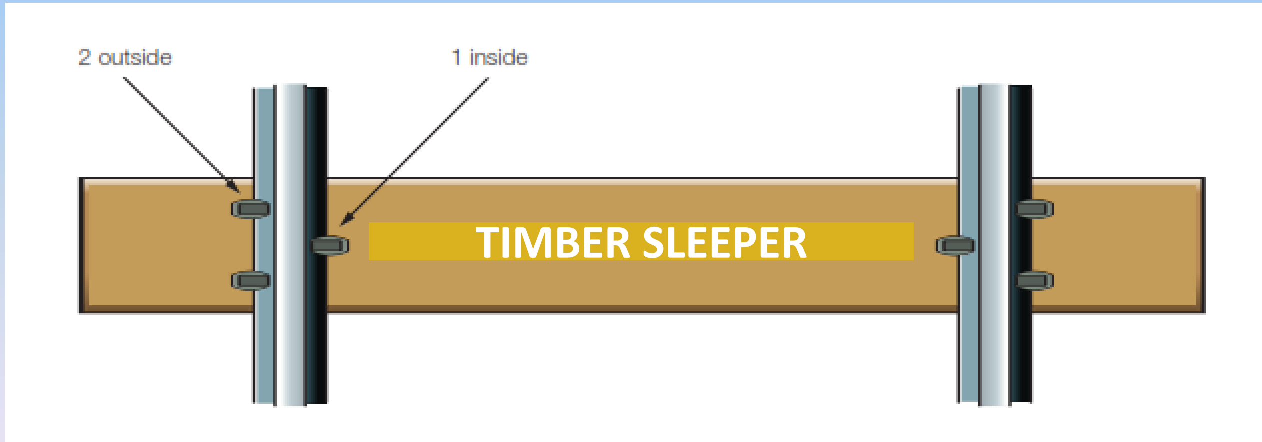


Rail Fastenings

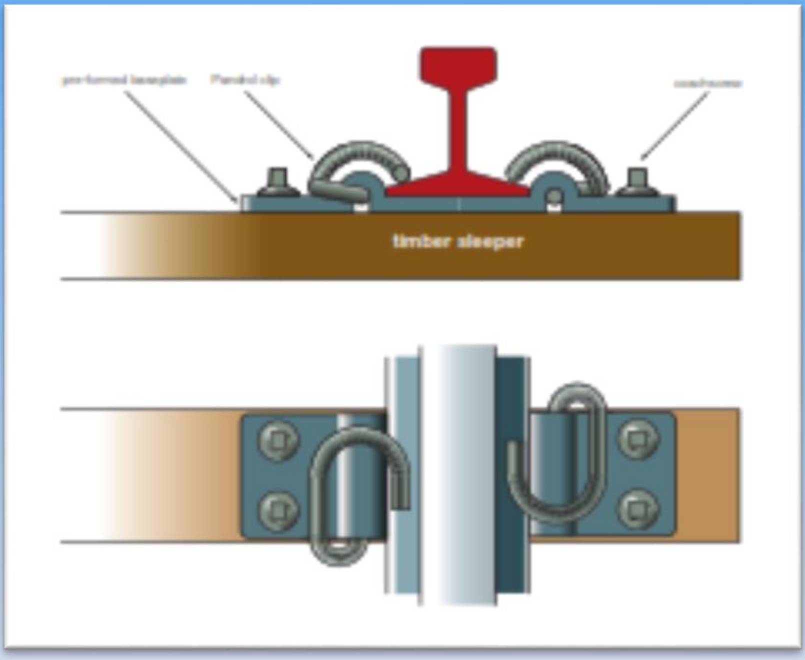


DIRECT INELASTIC FASTENINGS

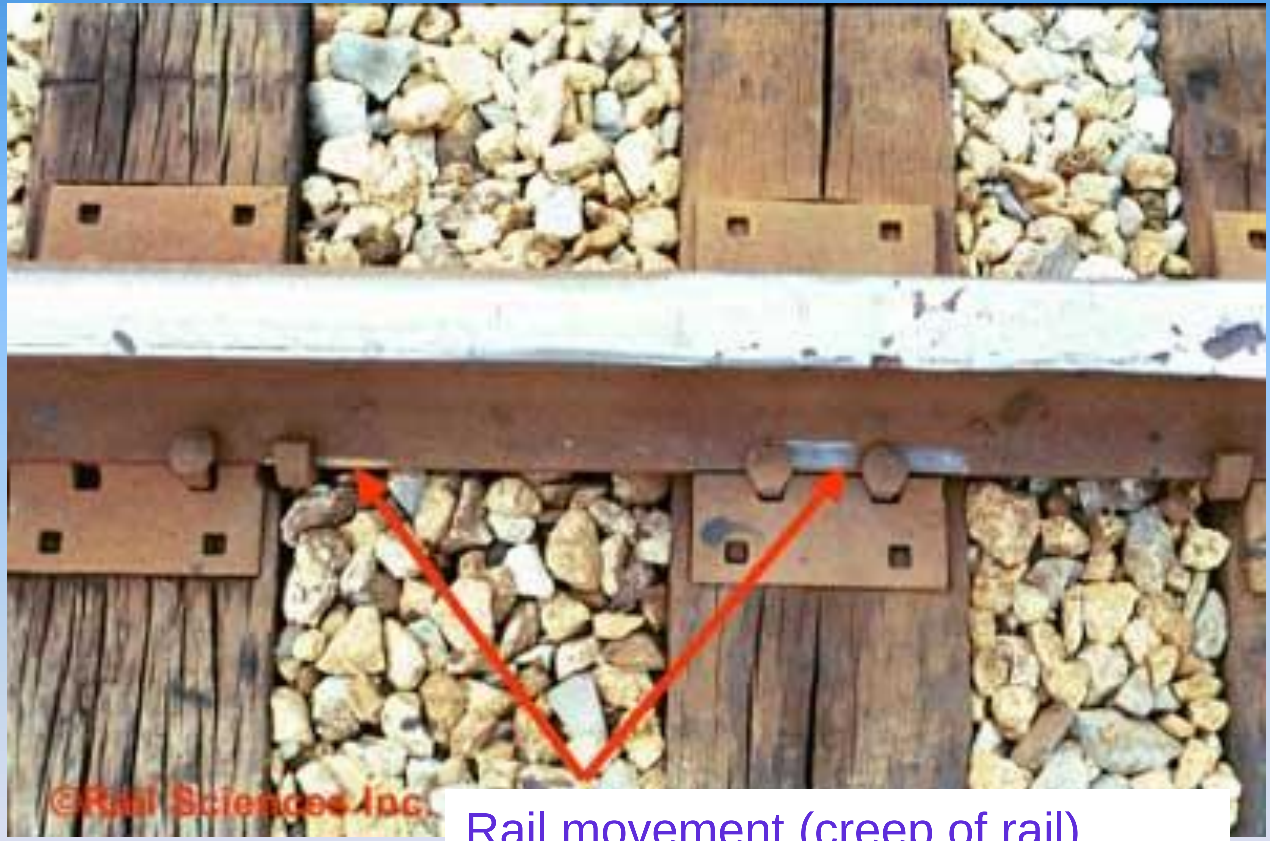




ELASTIC INDIRECT FASTENINGS



Poor Fastenings



Rail movement (creep of rail)
(Anchor and fastenings ineffective)

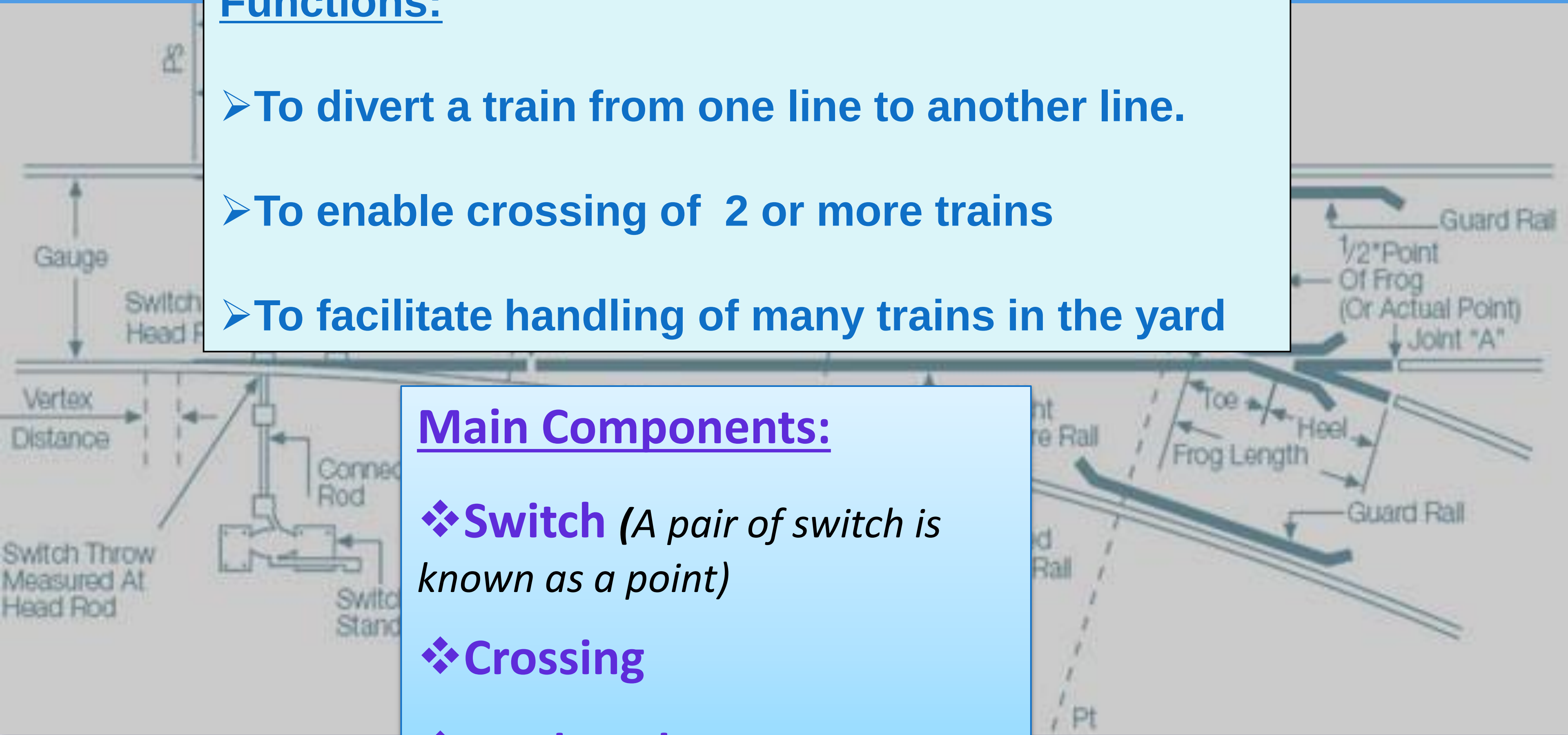
Points & Crossings (Turnouts)

Functions:

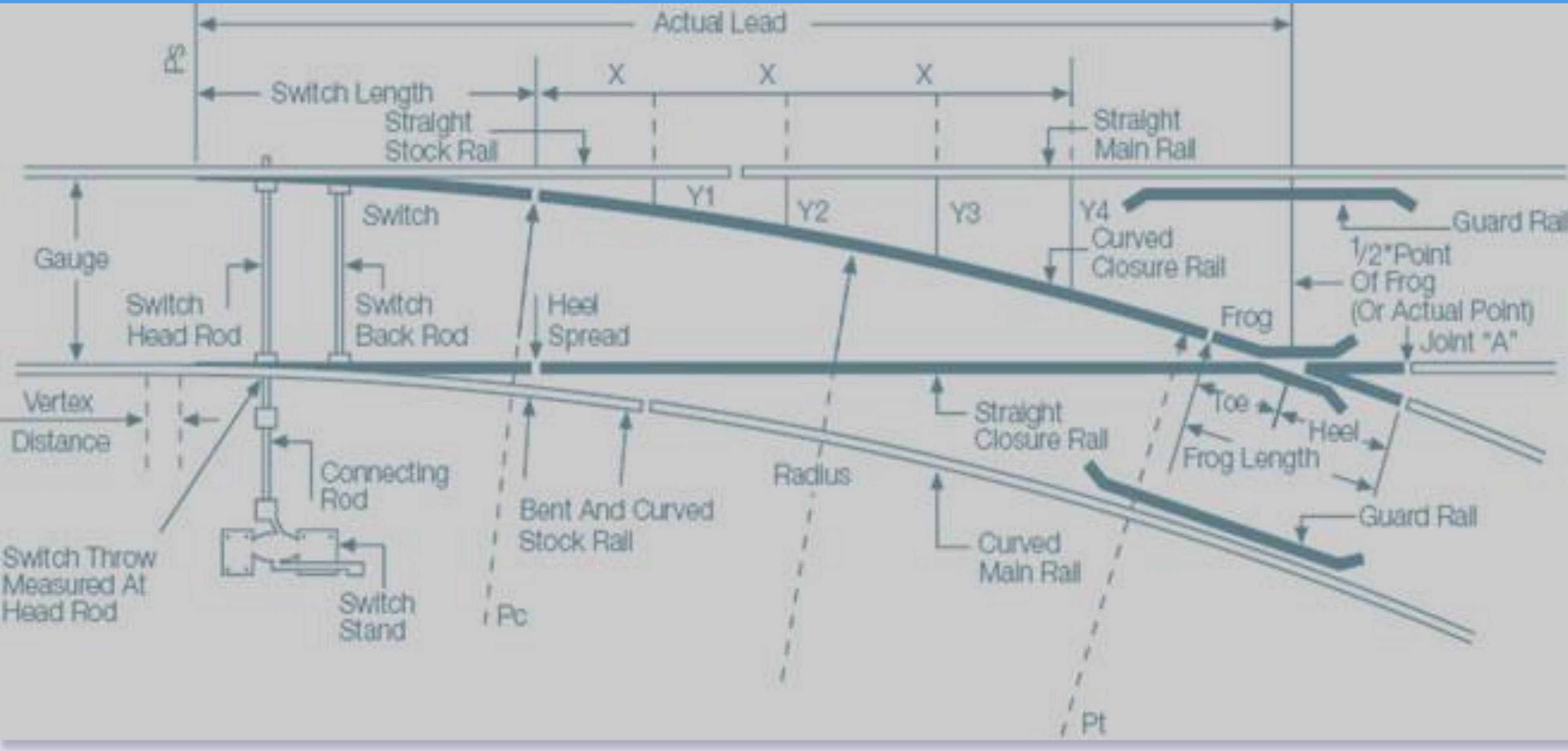
- ➢To divert a train from one line to another line.
- ➢To enable crossing of 2 or more trains
- ➢To facilitate handling of many trains in the yard

Main Components:

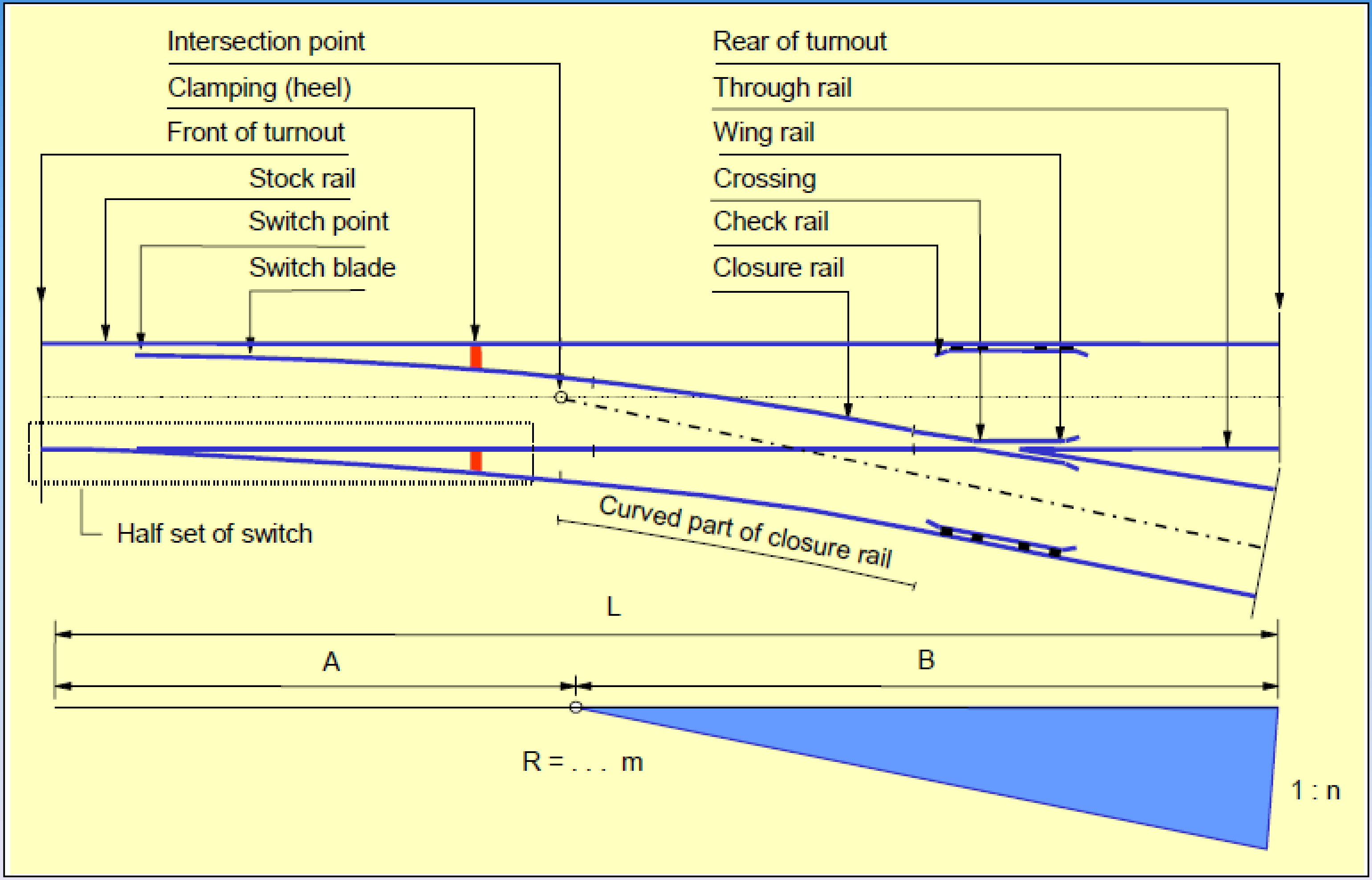
- ❖**Switch** ***(****A pair of switch is known as a point)*
- ❖**Crossing**
- ❖**Lead or closure**



Points & Crossings (Turnouts)

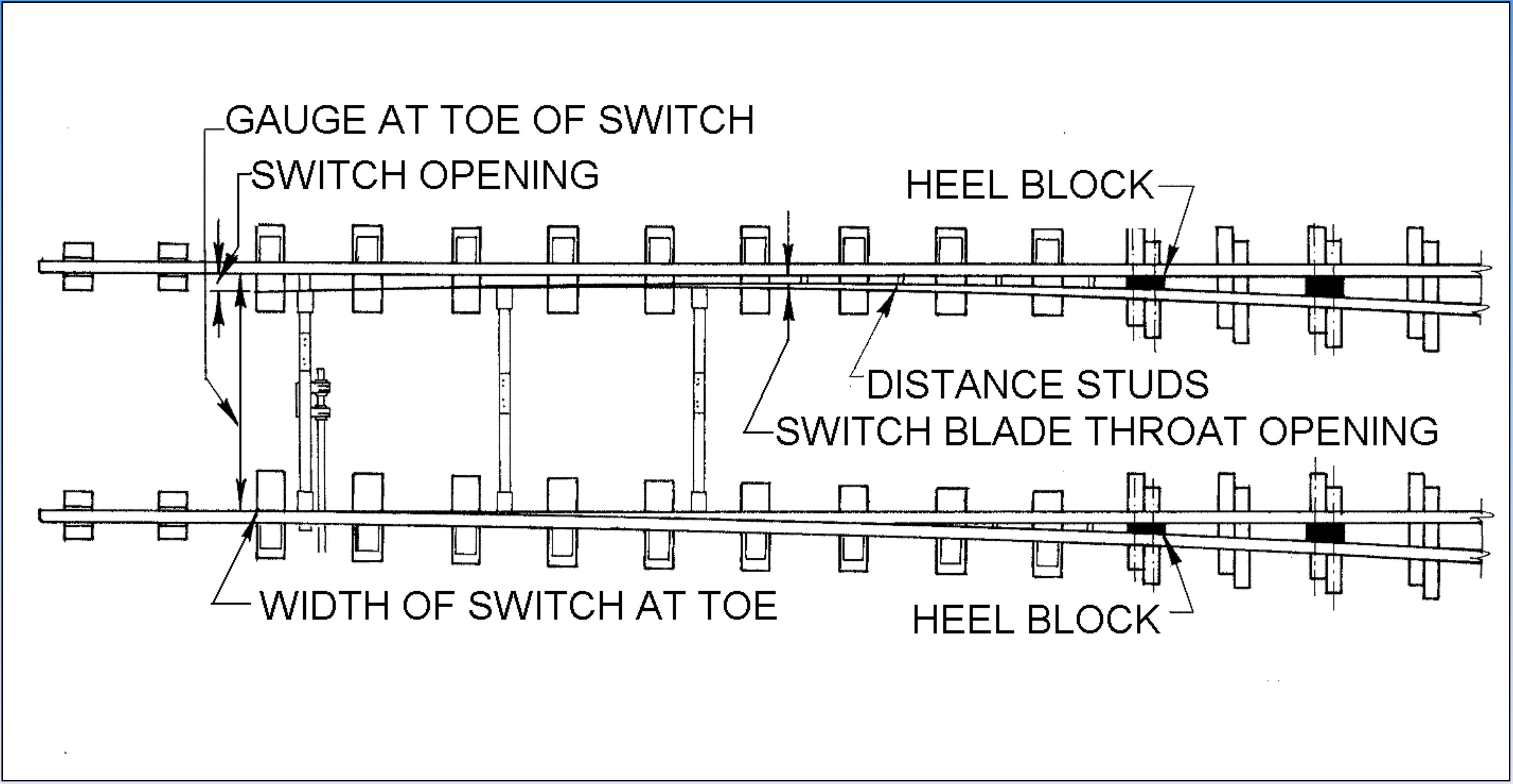


Points & Crossings (Turnouts)

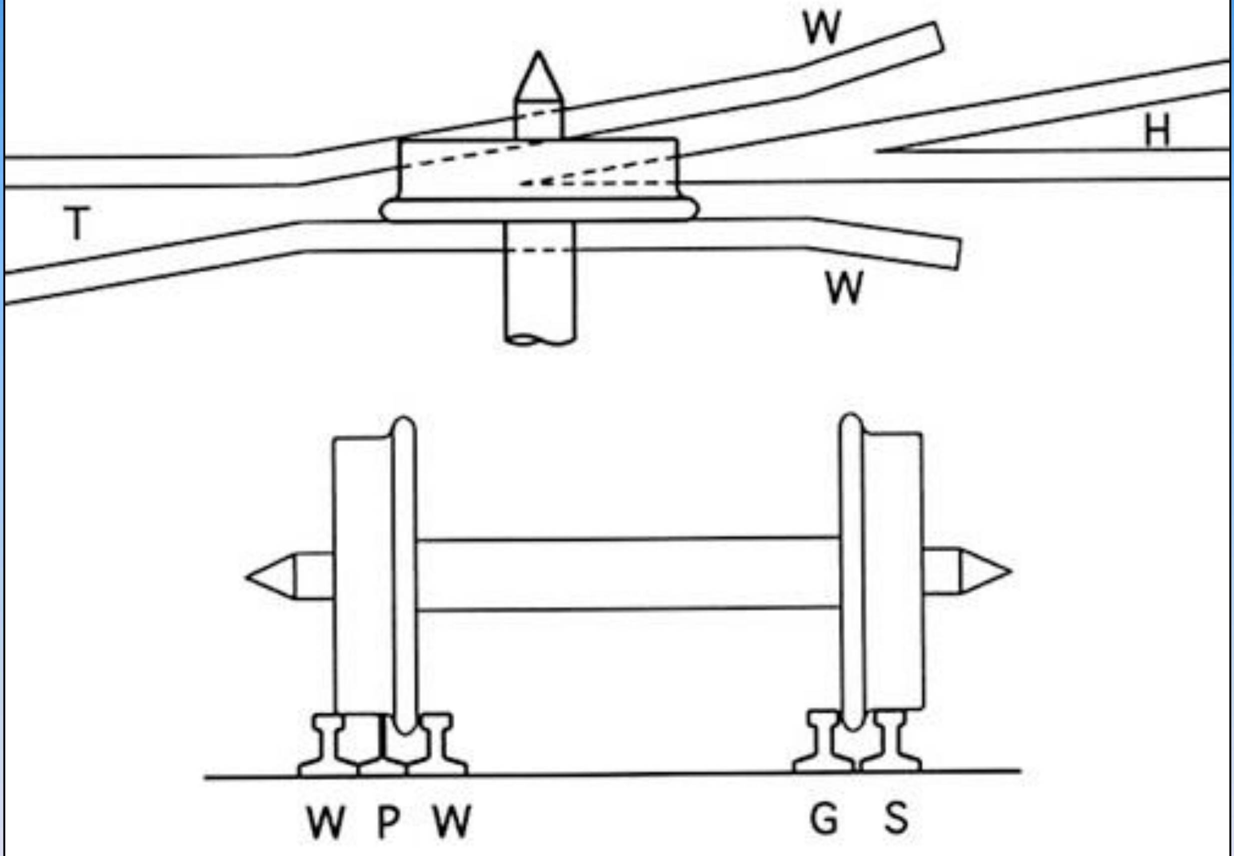


TMY Dec 2015

Points (Switch) Assembly

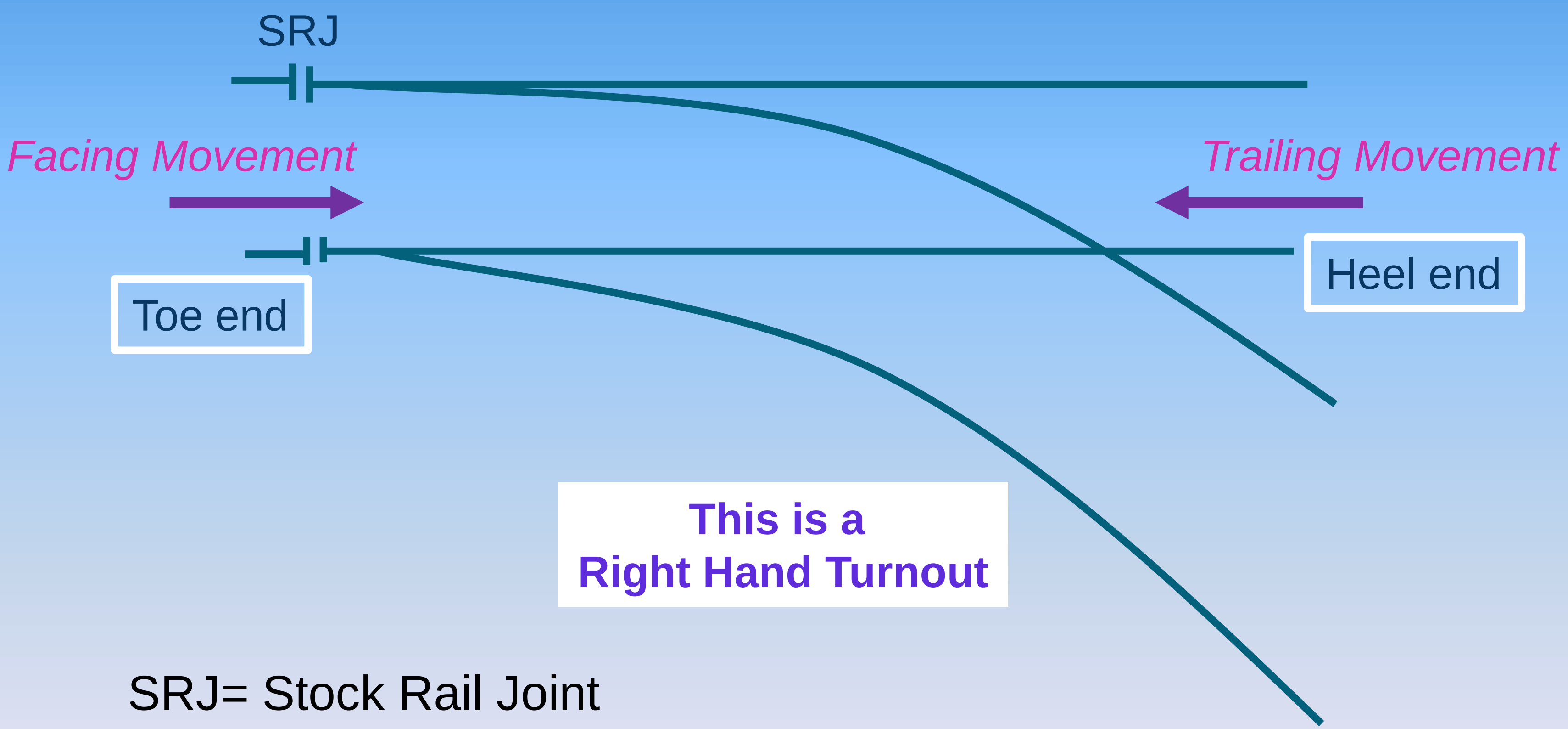


Wheel moving through a Crossing (Frog)



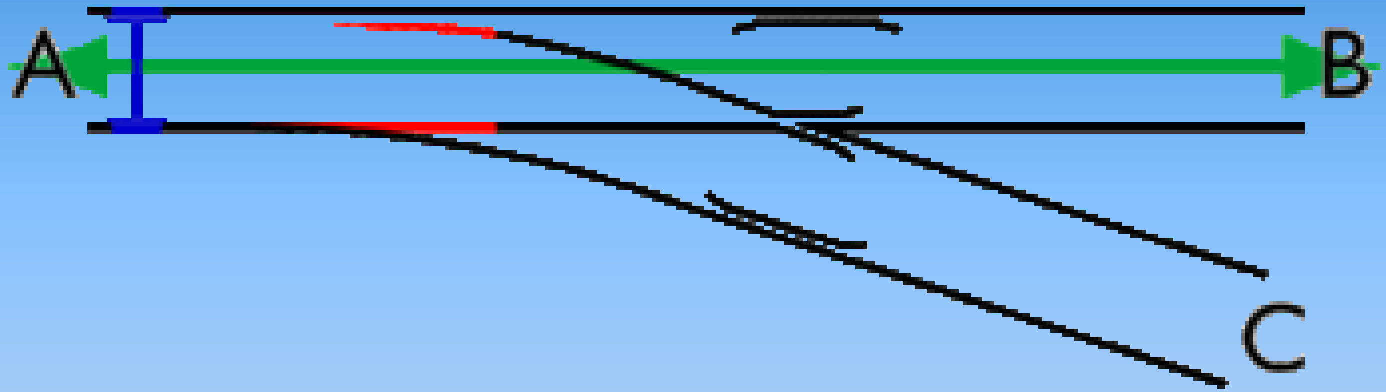
P = point of frog W = wing rail S = stock raill
G = guard rail T = toe H = heel

Terminology for movement over a turnout



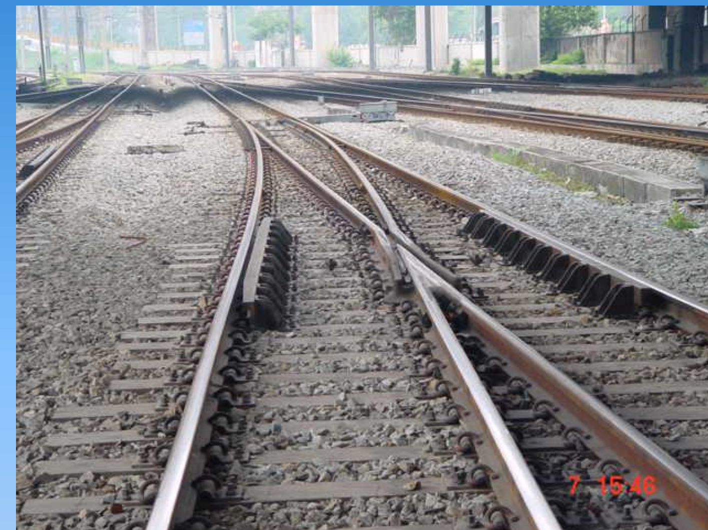
This is a Right Hand Turnout

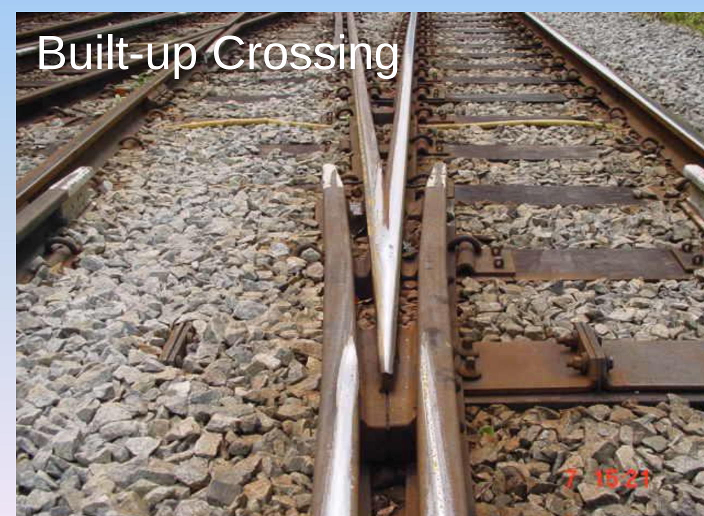
SRJ= Stock Rail Joint


A
B
C

Switches & Crossings (Turnouts)

The Crossing (Frog)





Close view of diamond crossing

RAILVIDEO

Courtesy from YouTube

RAIL WELDING

VIDEO

1

Track Quality

- ✓ Maintain track to a safe standard
- ✓ The existing track geometry compared to its design indicates the quality of the track
- ✓ Ensure good riding quality (freight & passengers trains)
- ✓ Comfort to passengers

Track Quality

The track parameters chosen are:

- **Gauge Variations**
- **Uneveness**
- **Cross Levels**
- **Twist**
- **Alignment**
- **Superelevation**

Track Gauge

The gauge is the distance between the two inner edges of the rail.

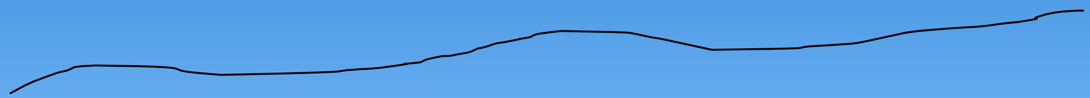
This distance is <u>1435mm</u> for <u>standard</u> gauge.

When we mention gauge in terms of a parameter we mean its variation.

For example if the distance measured is 1440 mm then the gauge is said to read +5 mm.

Track Gauge

Left and right rail surface (Unevenness)



This measures the difference in level along the longitudinal surface of the rail over a fixed distance.

The base chord is usually 10 metres so that measurements can be taken at every 5 metres interval

Cross Levels

This is the **difference** in level of two rail surfaces at same point on the track.

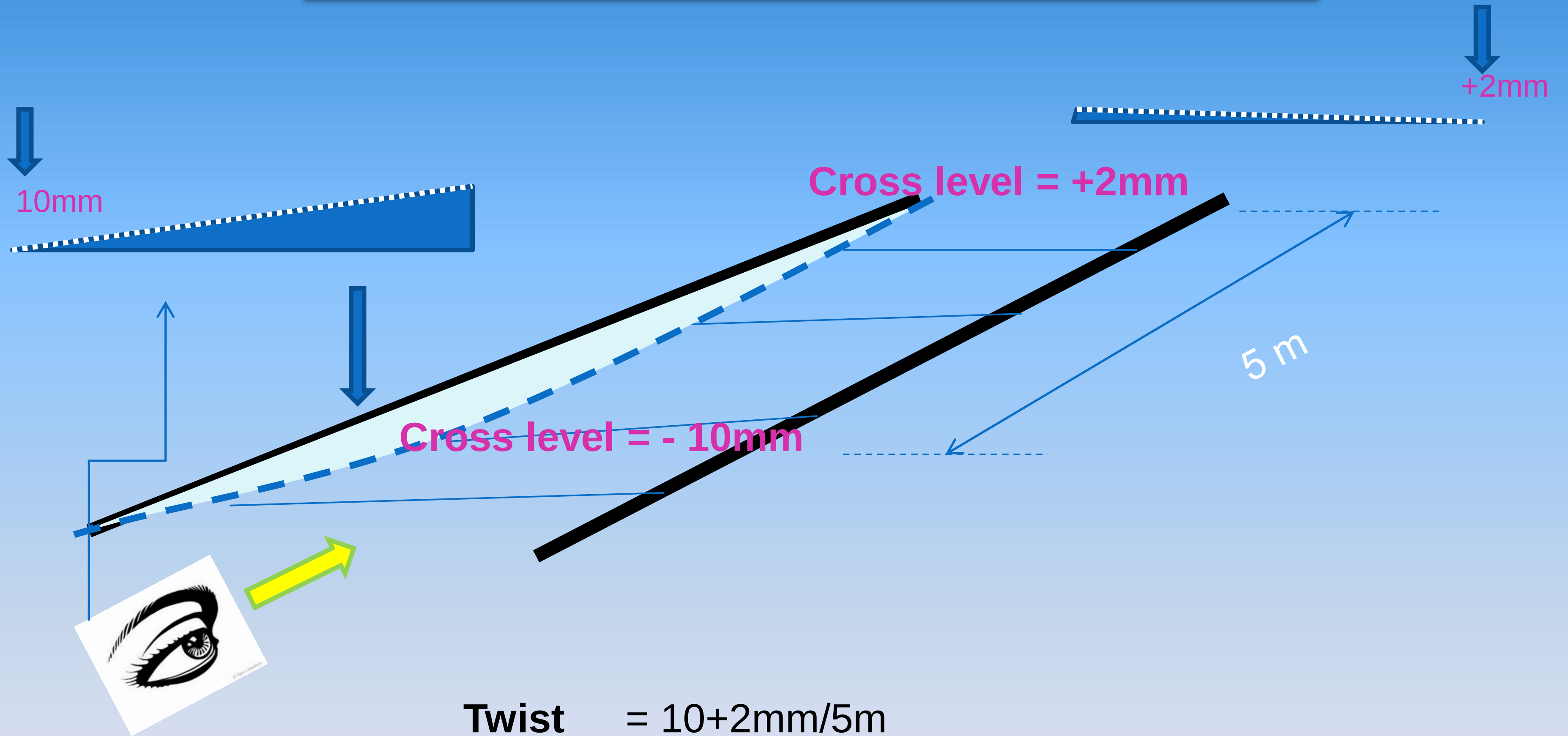
Track Twist

This measures the change in cross levels between tow locations of the track in the longitudinal direction.

This distance is the base and is usually 5 metres.

The difference in cross levels divided by the base is the measure of **twist in mm per metre**.

Track Twist



Twist = 10+2mm/5m
= 12/5mm/m
= 1.4mm/m

Alignment

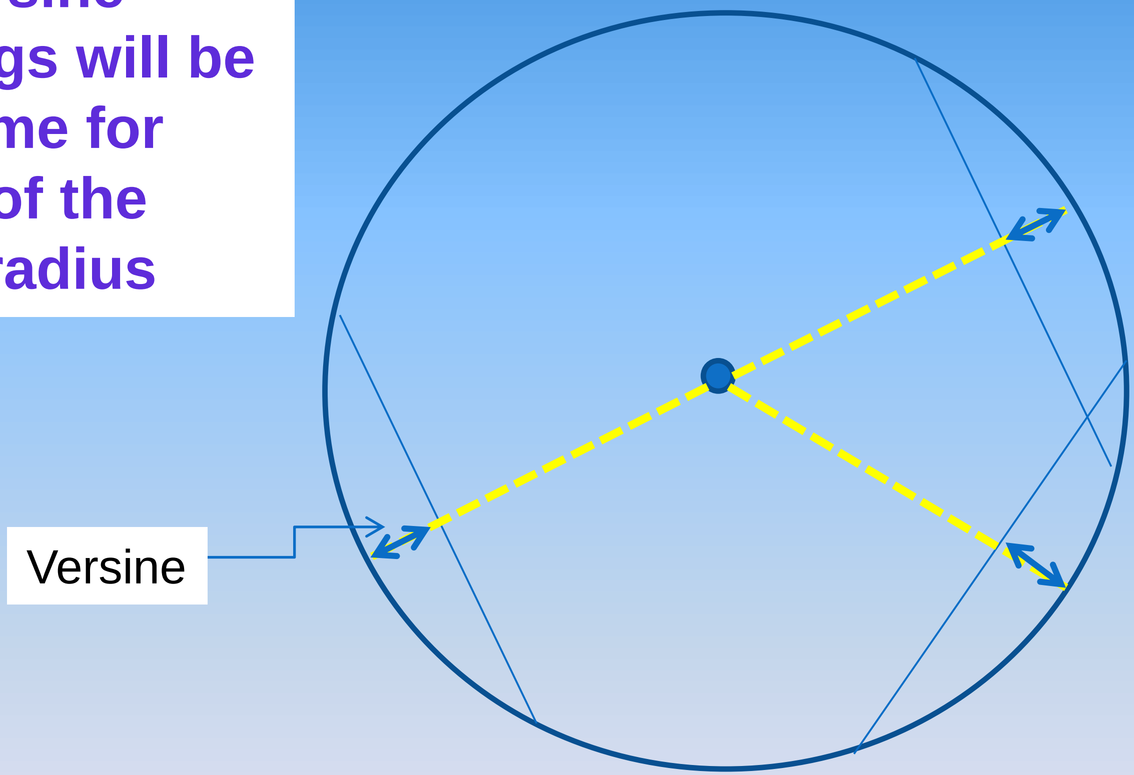
This measures the versines over successive chords of fixed lengths.

The chord length is 10 metres.

The versines are measured at every 5 metre interval along the track.

Versines

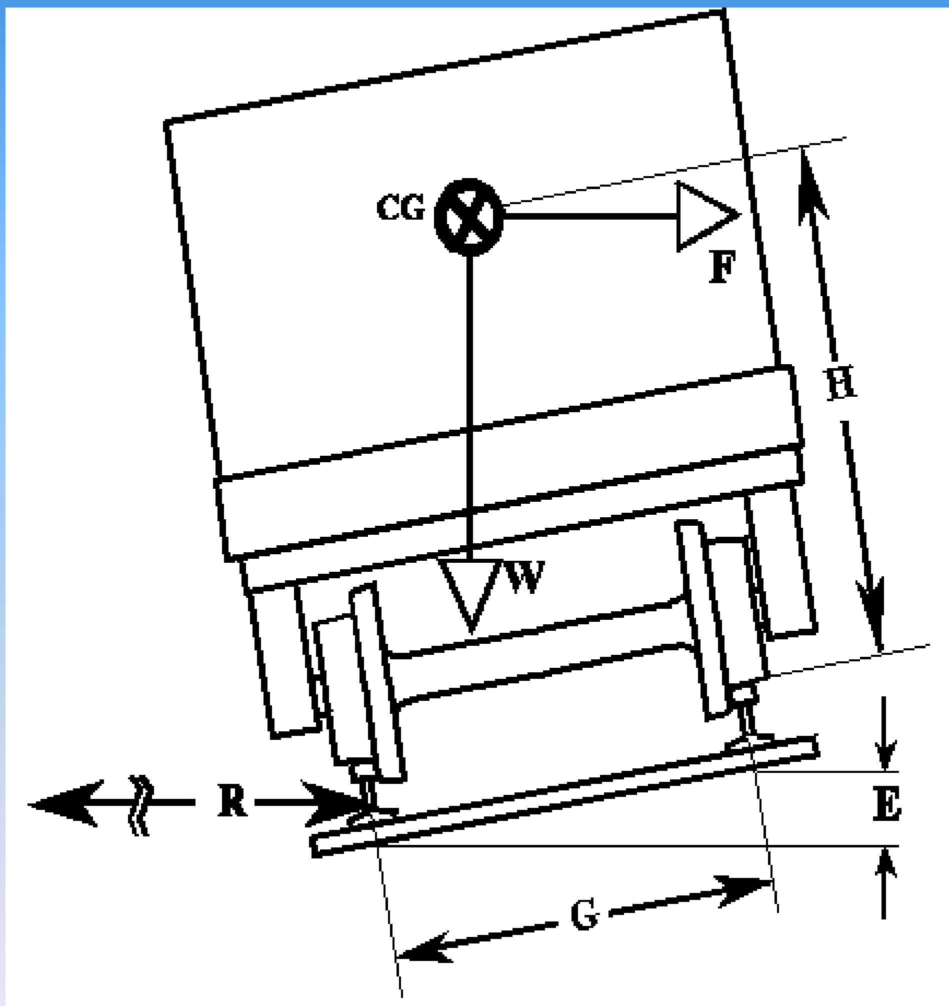
For the same chord length, the versine readings will be the same for curve of the same radius



Superelevation (Cant)

On a curve if we measure the height difference between the outer and inner rail, then this height is the superelevation (cant for the track curve).

Superelevation (Cant)



CLICK IMAGE TO ENLARGE

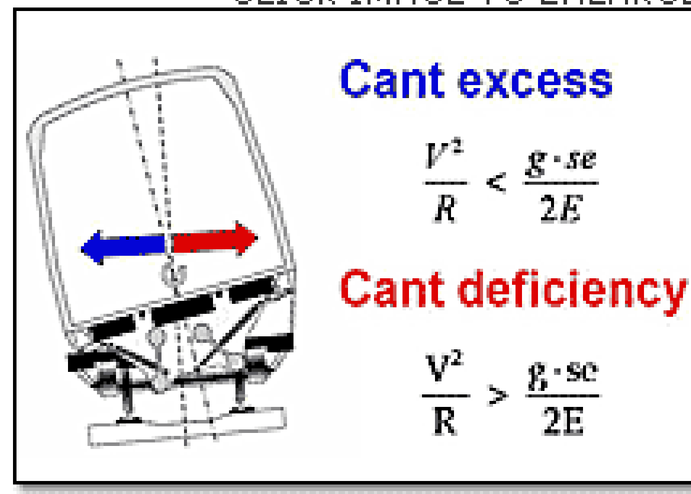


Figure 1. Cant deficiency. The left-hand term in each expression is the lateral acceleration. This is given by the square of the velocity "V" divided by the curve radius "R". The compensating effect of superelevation is the right-hand term. This is the acceleration of gravity "g" (roughly 32.2 ft/sec²) times the superelevation "se" divided by the distance between rail centers 2E (roughly 60 inches for standard gauge track).

Track Quality Measurement

Track Quality can be measured manually using permanent measuring tools.

In most railways measurements of track geometry are being carried out using Track Recording Cars.

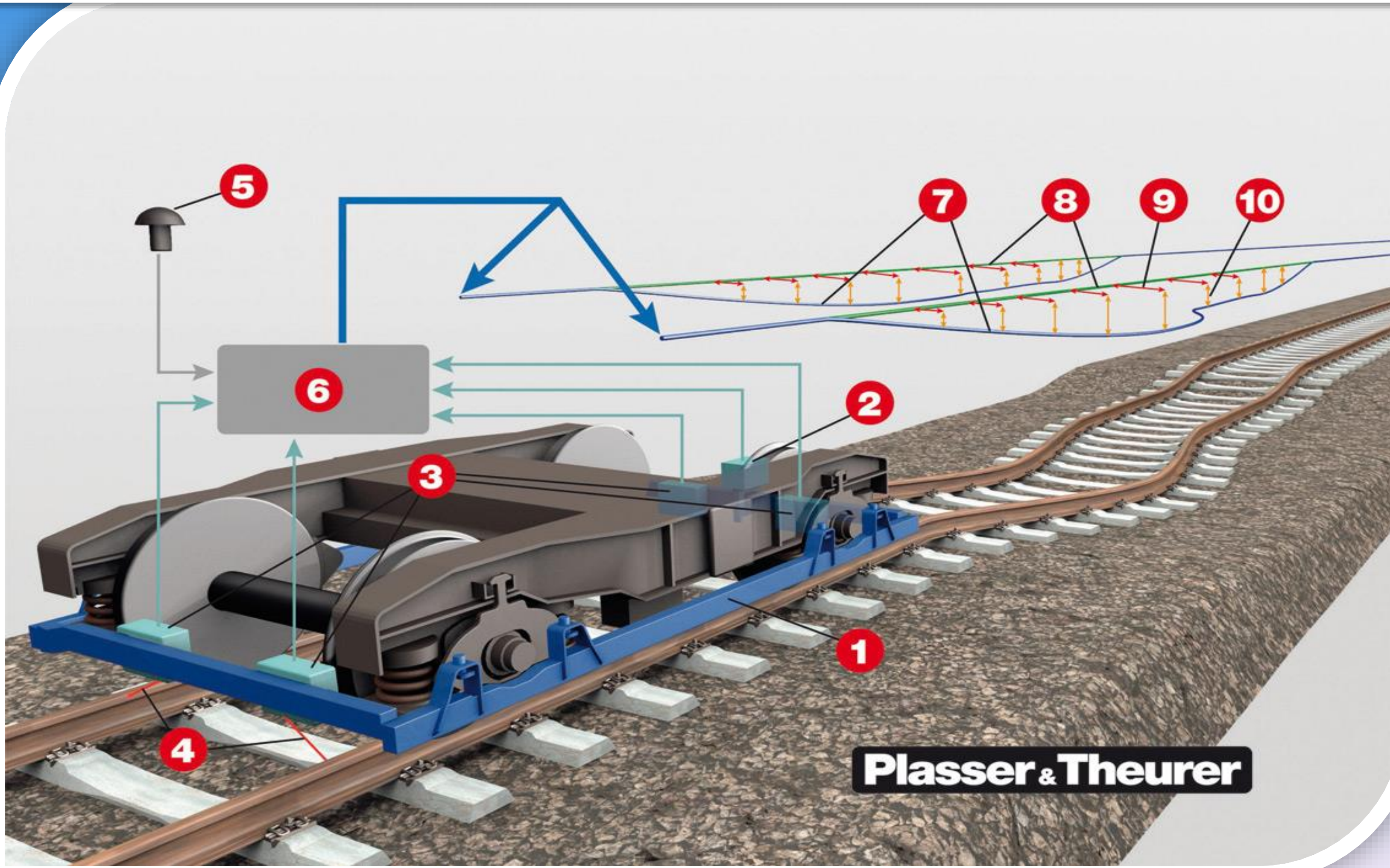
Track Quality Measurement

Manual Inspection Car

Measuring Trolley

EM120 Track Recording Car

Track Quality Measurement



Track Quality Measurement

The measurement is done electronically through an arrangement of transducers.

The data sampling rate is high so that track geometry can be measured and recorded at a high speed.

KTMB has a Track Recording Car that can measure and record track parameters at 120 km/hr.

Track Quality Measurement

The data from measurement are processed in the Track Recording Car by onboard computers.

The Track Recording Car plots track geometry measurements on paper.

It can also generate summary reports of track faults.

Track Recording Video

Track Quality Measurement

Track quality may be assessed by working out the **average** value of all the track parameter readings taken over a stretch of track say 1 km.

Averaging all the parameters is not a good way to quantify track condition.

Deviation of the readings from the average helps give a better assessment perspective.

The parameter used is the **Standard Deviation**

Standard Deviation

Deviation from the average is quantified by a parameter called Standard Deviation σ given by:

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

$x - \bar{x}$ value of reading - average

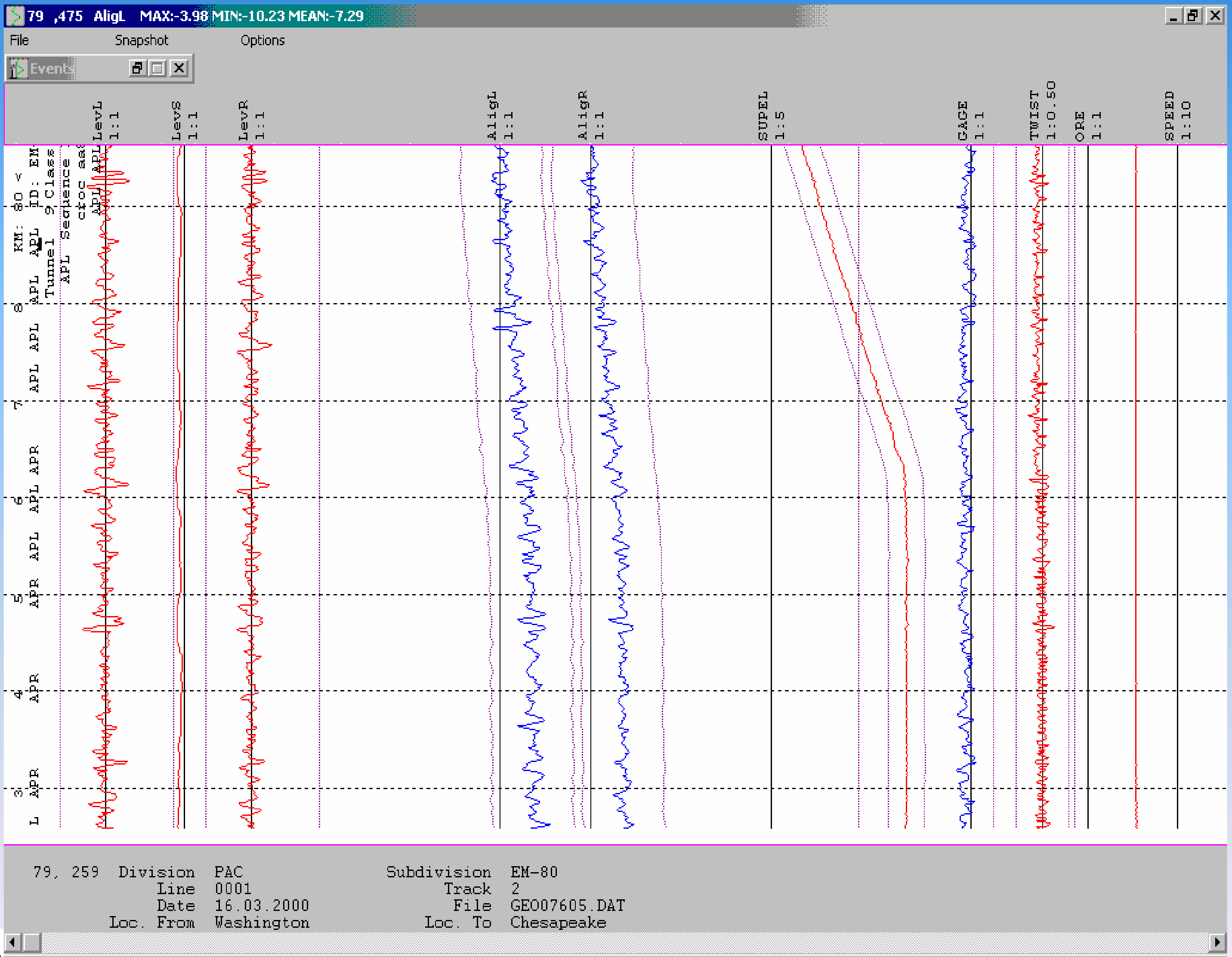
Track Quality Index

A Track Quality Index is defined based on this Standard Deviation principle.

Since track parameters have relative importance, weights are assigned to each parameter.

Track Quality Index is thus a weighted average of the index for each parameter.

Sample EM 120 chart



KTMB EM120 Track Quality Index

For Class 1 line (Max Operating Speed 140km/h)	
TQI	**MAINTENANCE STANDARD**
<24	Excellent
25 – 32	Very Good
33 – 45	Good
46 – 60	Fair
>61	Poor

For Class 2 and 3 lines (Max operating Speed 120kph)	
TQI	**MAINTENANCE STANDARD**
<30	Excellent
31 – 50	Very Good
51 – 70	Good
71 – 110	Fair
>111	Poor

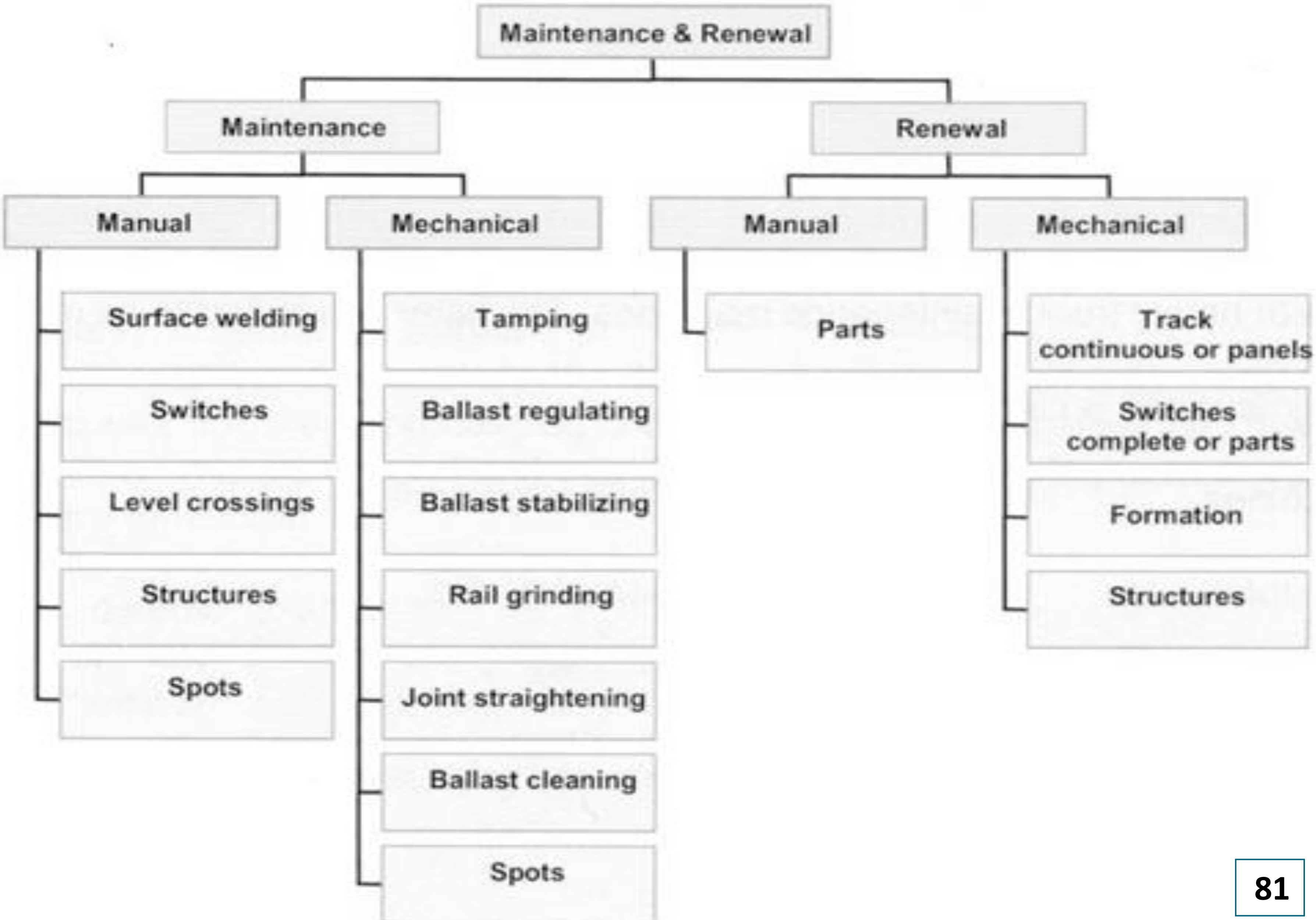
TMY Dec 2015

Track maintenance



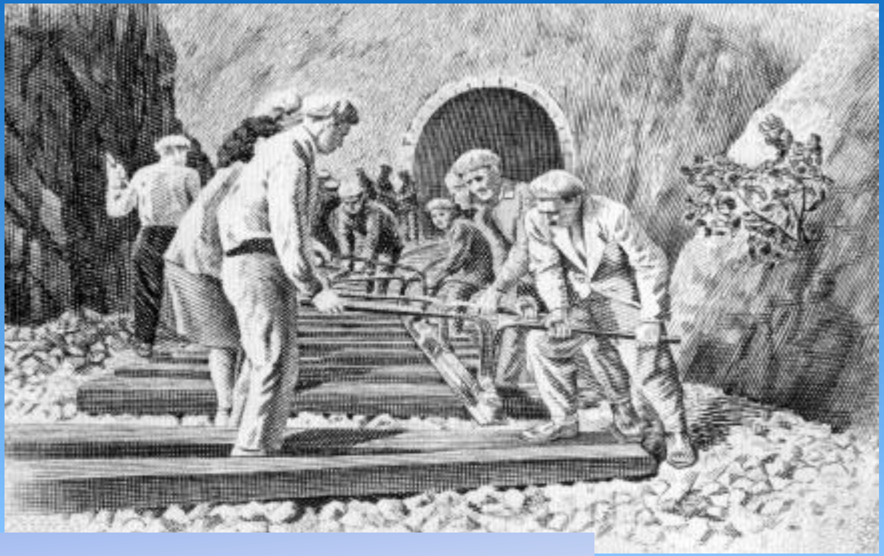


Track Maintenance Activities



Track maintenance

Maintenance Strategy	Maintenance Action	Maintenance Trigger
Preventive Maintenance	Rail grinding	Time
	Tamping	Condition
	Rail lubrication	Time
	Ballast cleaning	Condition
	Track inspection	Time
Renewal (Preventive Maintenance)	Rail renewal	Condition
	Ballast renewal	Condition
	Sleeper renewal	Condition
	Fasteners renewal	Condition
Corrective Maintenance	Rail replacement	Failure



We have progressed from this..

To this….

Mechanised Track Maintenance

Computerised Track Recording

Tamping works

Track fastening installation

Ballasting

TRACK MACHINES VIDEO

Tamping Machines

Stabiliser

Regulator 2

Regulator

Courtesy from KTMB

SUMMARY
Requirements of the Permanent Way

- **Uniform gauge**
- **Gentle and uniform gradient**
- **Uniform vertical and horizontal alignment**
- **Straight alignment as far as possible**
- **Resilient track with elastic and resilient components**

Requirements of the Permanent Way

- **Component Materials - adequate strength**
- **Optimised investment cost**
- **Easy to maintain, to replace etc**
- **Water to be drain out as soon as possible**

SUMMARY

- What is Permanent Way?
- Its role in the railway system?
- Main components features
- Track Quality
- Elements of track maintenance

Some Useful References

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- ***And of course: wikipedia***



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