

RAILWAY ENGINEERING (CENG 5242)

CHAPTER 3
RAILWAY TRACK STRUCTURES

The background image shows a railway track curving through a landscape with trees. A train is visible in the distance on an elevated section of the track. In the foreground, there are several sets of tracks with sleepers and rails. A black box with a white border contains the text for the presentation.

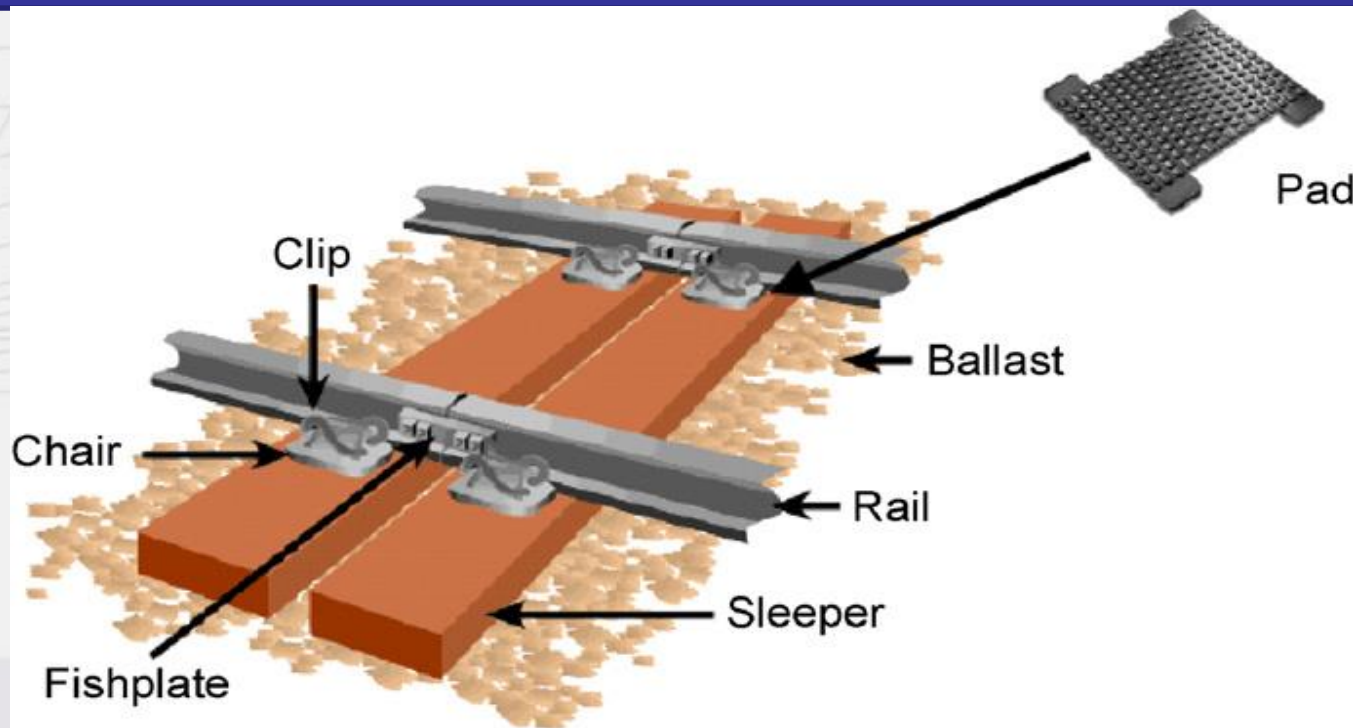
Contents

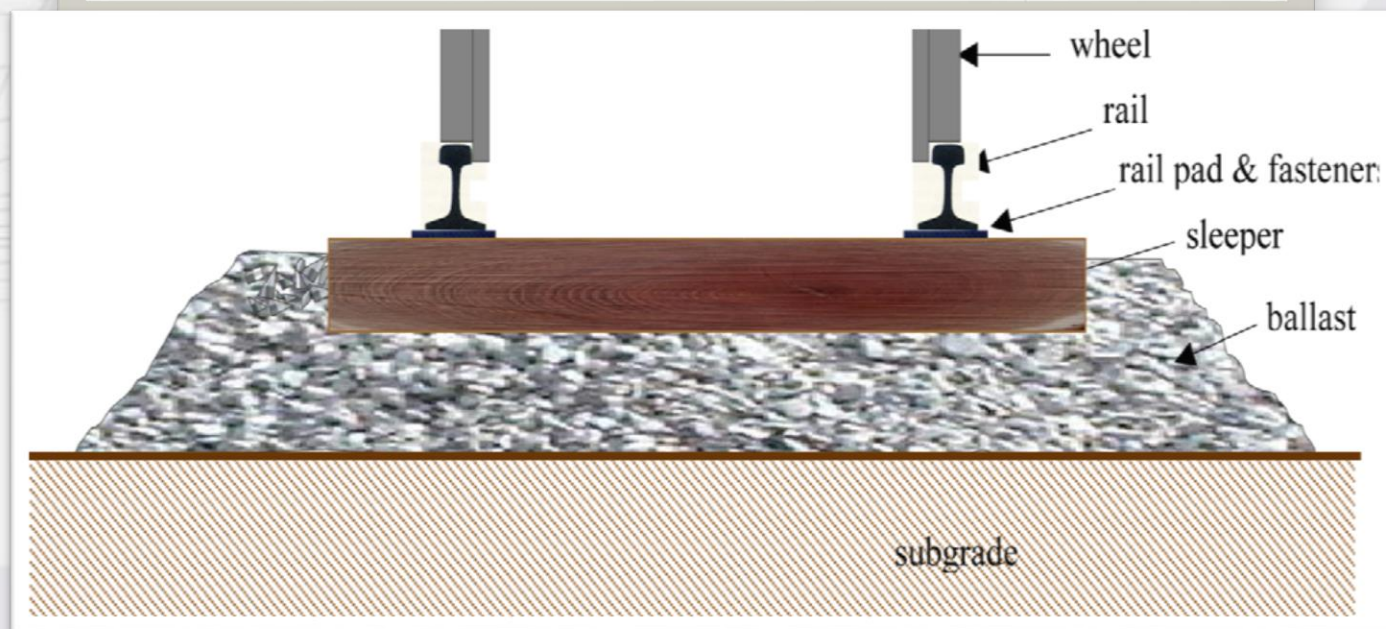
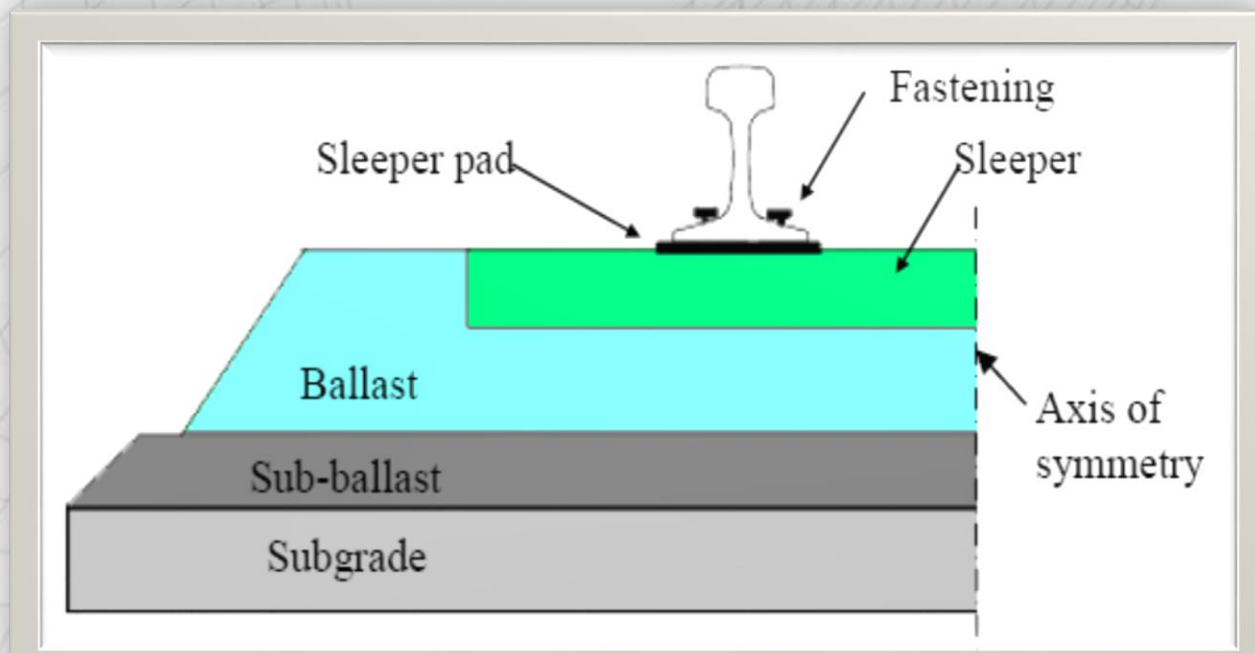
1. **Component and function of track structure**
2. **Rail support: sleepers/ties, ballast**
3. **Ballasted track**
4. **Slab track**
5. **Rail fastening system**

3.1 Component and function of track structure

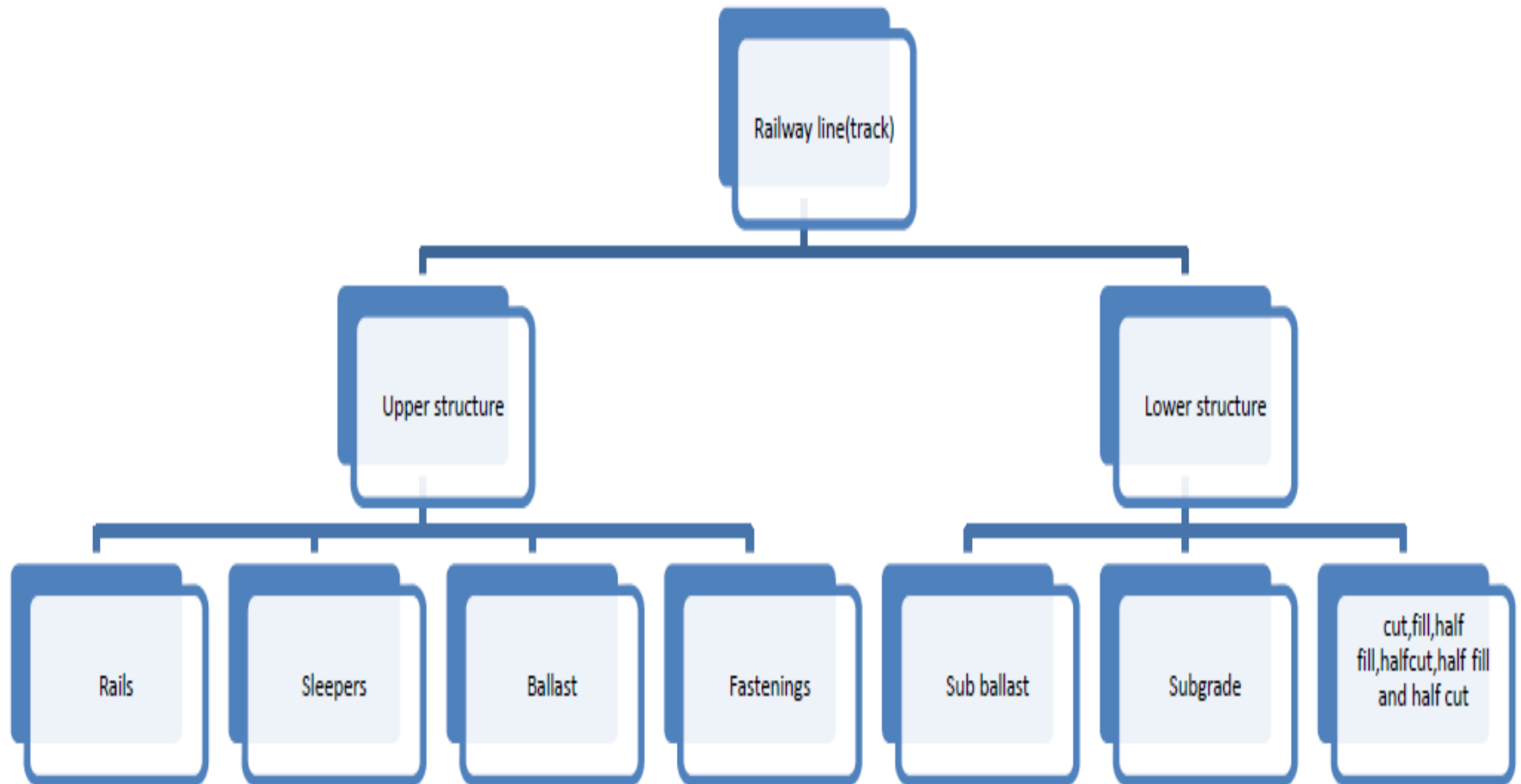
In contrast to road transport, where vehicles merely run on a prepared surface, rail vehicles are also directionally guided by the tracks they run on.

Track usually consists of steel rails installed on sleepers/ties and ballast, on which the rolling stock, usually fitted with metal wheels, moves.





Components of track structure



TRACK LOADS

The requirements for the **bearing strength and quality of the track** depend to a large extent on the load parameters:

- ✓ axle load: static vertical load per axle;
- ✓ tonnage borne: sum of the axle loads;
- ✓ running speed

The static axle load level, to which the dynamic increment is added, in principle determines the required strength of the track.

The accumulated tonnage is a measure that determines the deterioration of the track quality and as such provides an indication of when maintenance and renewal are necessary.

The dynamic load component which depends on **speed** and horizontal and vertical track geometry also plays an essential part here.

Structural design of track

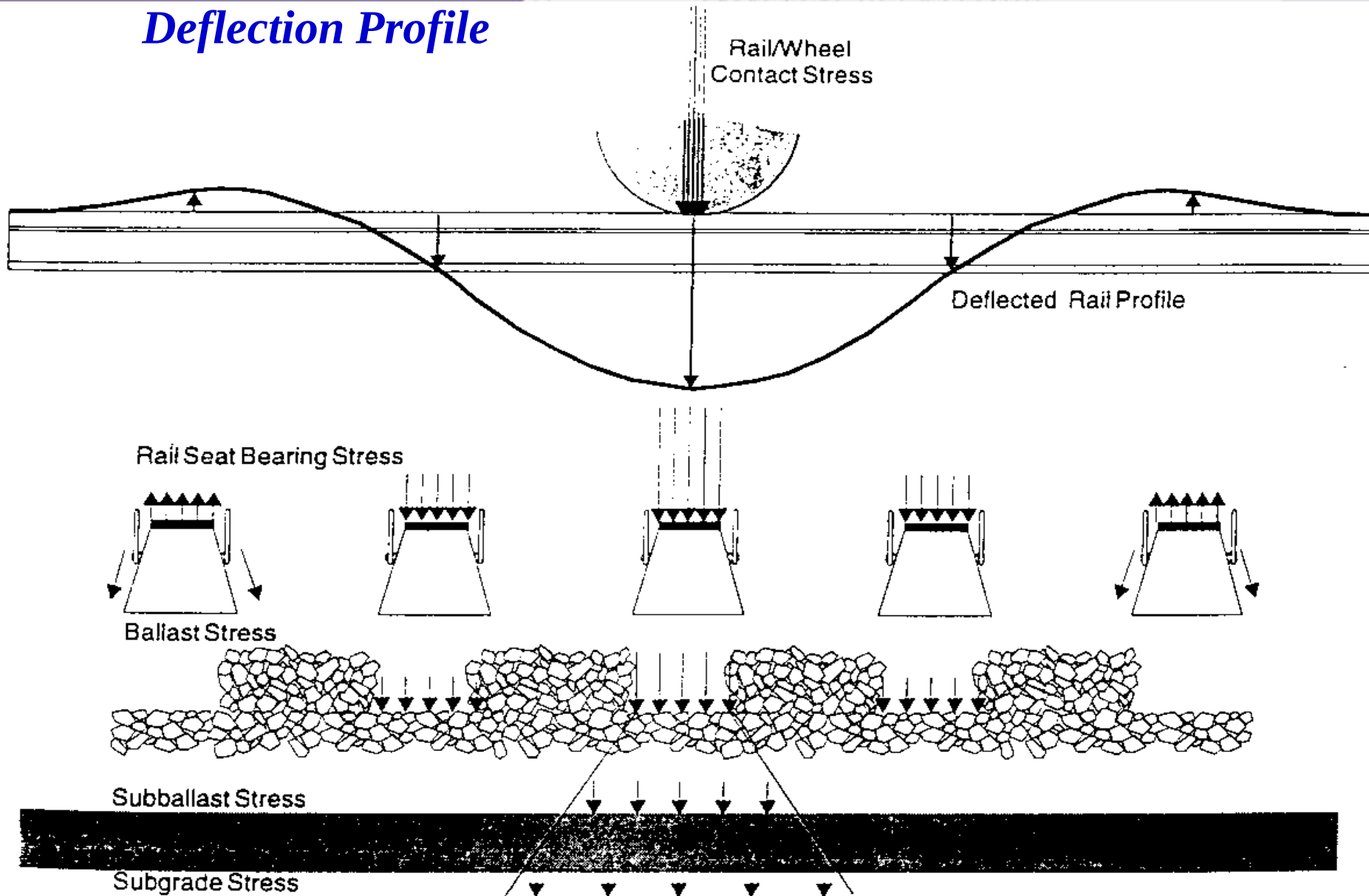
The Principle:-

- Components do not function independently!*
- Each component layer must protect the one below.*

Main design components

- 1. Rail*
- 2. Rail pad/plate*
- 3. Sleeper*
- 4. Ballast*

Deflection Profile



Source: Selig and Waters, *Track Geotechnology and Substructure Management*, 1994

Static vs. Dynamic Loads

- ❖ Dynamic loads higher
 - Acceleration from speed
 - Downward rotation of wheel
 - Smaller wheels, faster rotation, more acceleration

- ❖ Speed/wheel influence

- $P_v = P + \theta P$ (**AREMA**)

$$\theta = \frac{D_{33} \times V}{D_w \times 100}$$

Where, P_v = Vertical Dynamic Load (lbs)

D = Wheel diameter (in)

V = Speed (MPH)

P = Static Load (lbs)

– ***Larger wheels impose less influence***

- ❖ Additional dynamic loads from impacts such as caused by wheel flat spots, rail discontinuities (e.g. frog flange ways), track transitions (e.g. bridge approaches), track condition, etc.

Track Stiffness

- Rail is assumed to be a beam on an elastic foundation
- Modulus of Track Elasticity, u (or k) (Track Modulus)

$$u = P/\Delta$$

Where, u = Modulus of Track Elasticity (lbs/in/in)

P = Wheel load per unit length of rail (lbs/in)

Δ = Unit of Track Deflection (in), less “play” or track
“looseness”

or

$$u = P/S$$

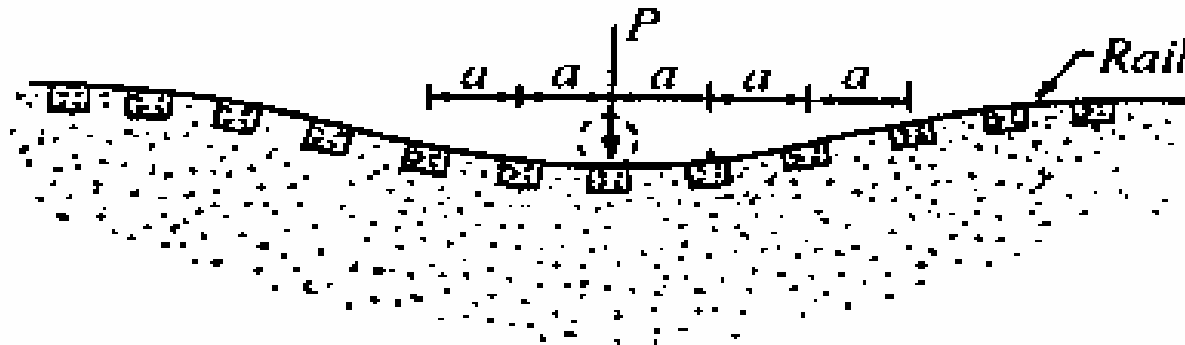
Where, u = Modulus of Track Elasticity (lb/in/in)

P = Wheel load (lbs) required to deflect the track 1 inch on
one tie

S = Tie spacing (in)

Classic Approach to Track Analysis and Design

Continuously supported beam

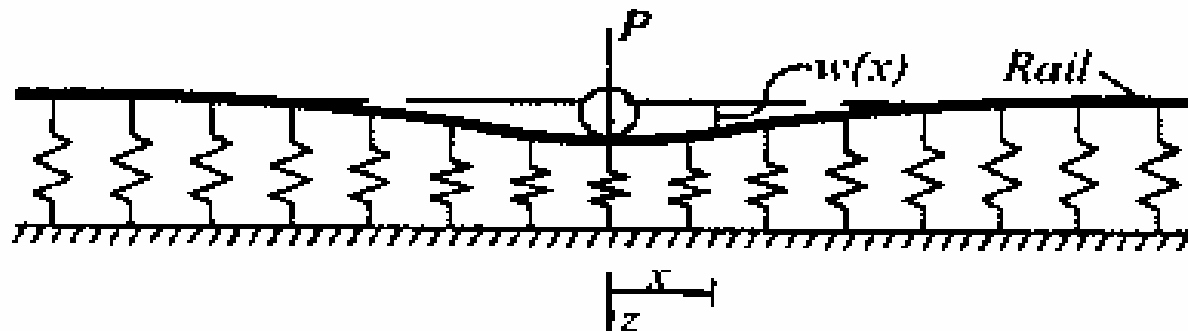


(a) Physical problem

Notes:

a = tie spacing “s”

$w(x)$ = deflection “y”



(b) Analytical model for rail analysis

Talbot equations

Rail Moment: $M_o = 0.318Px_1$

Deflection: $Y_o = 0.391P/ux_1$

Rail Seat Load: $Q_o = 0.391PS/x_1$

where: P = Wheel Load (lbs)

u = Track Modulus (lbs/in/in)

S = Tie spacing (in)

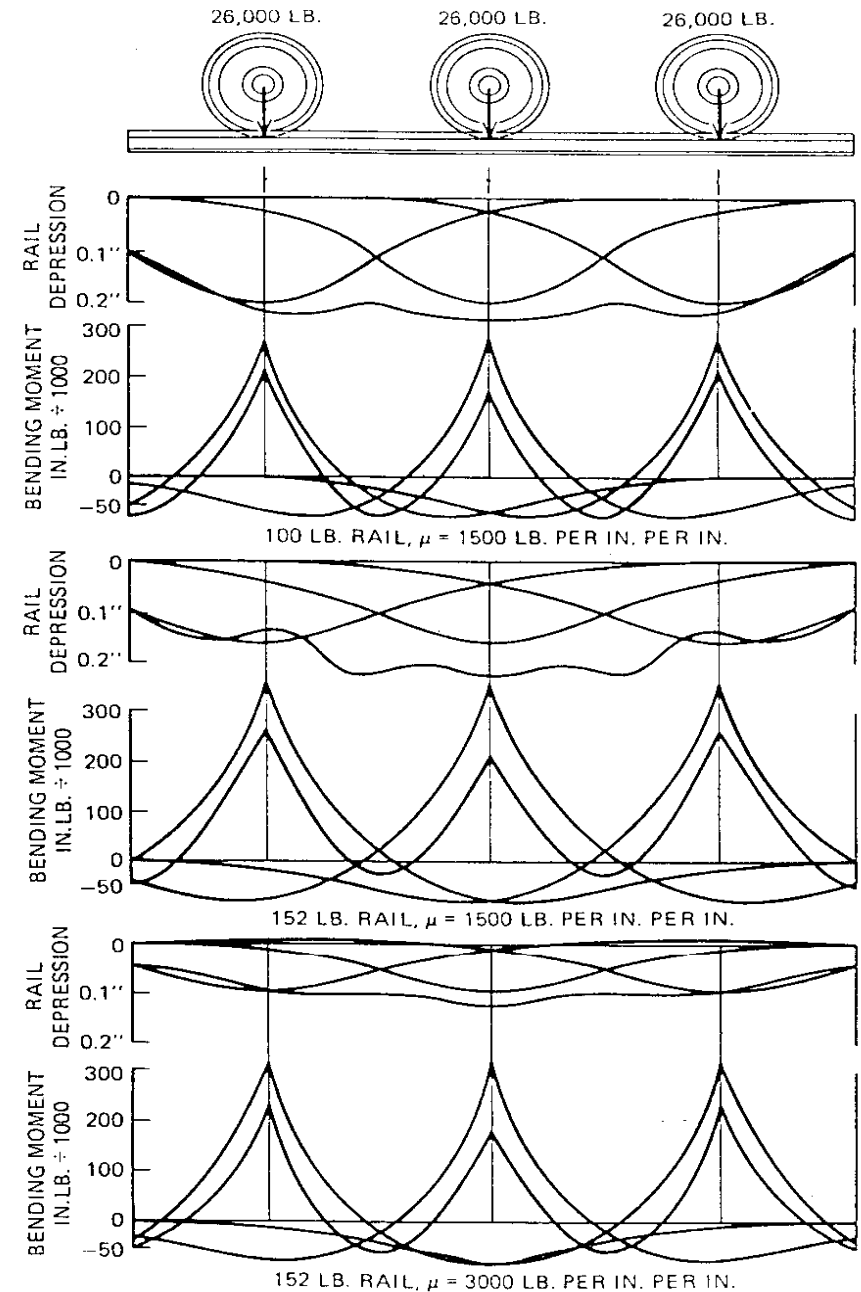
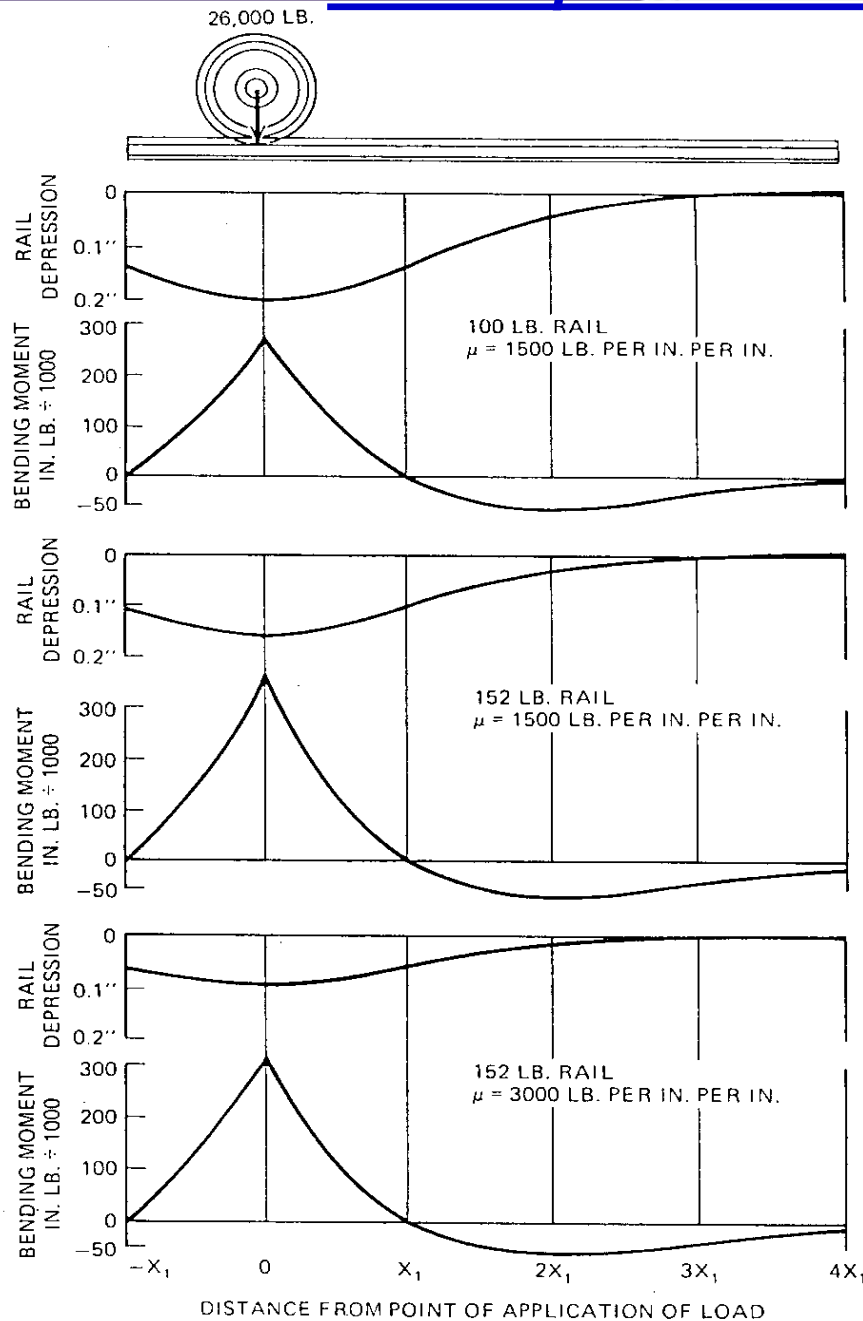
$x_1 = (\pi/4)(4EI/u)^{1/4}$ (in)

EI = Flexural rigidity of rail

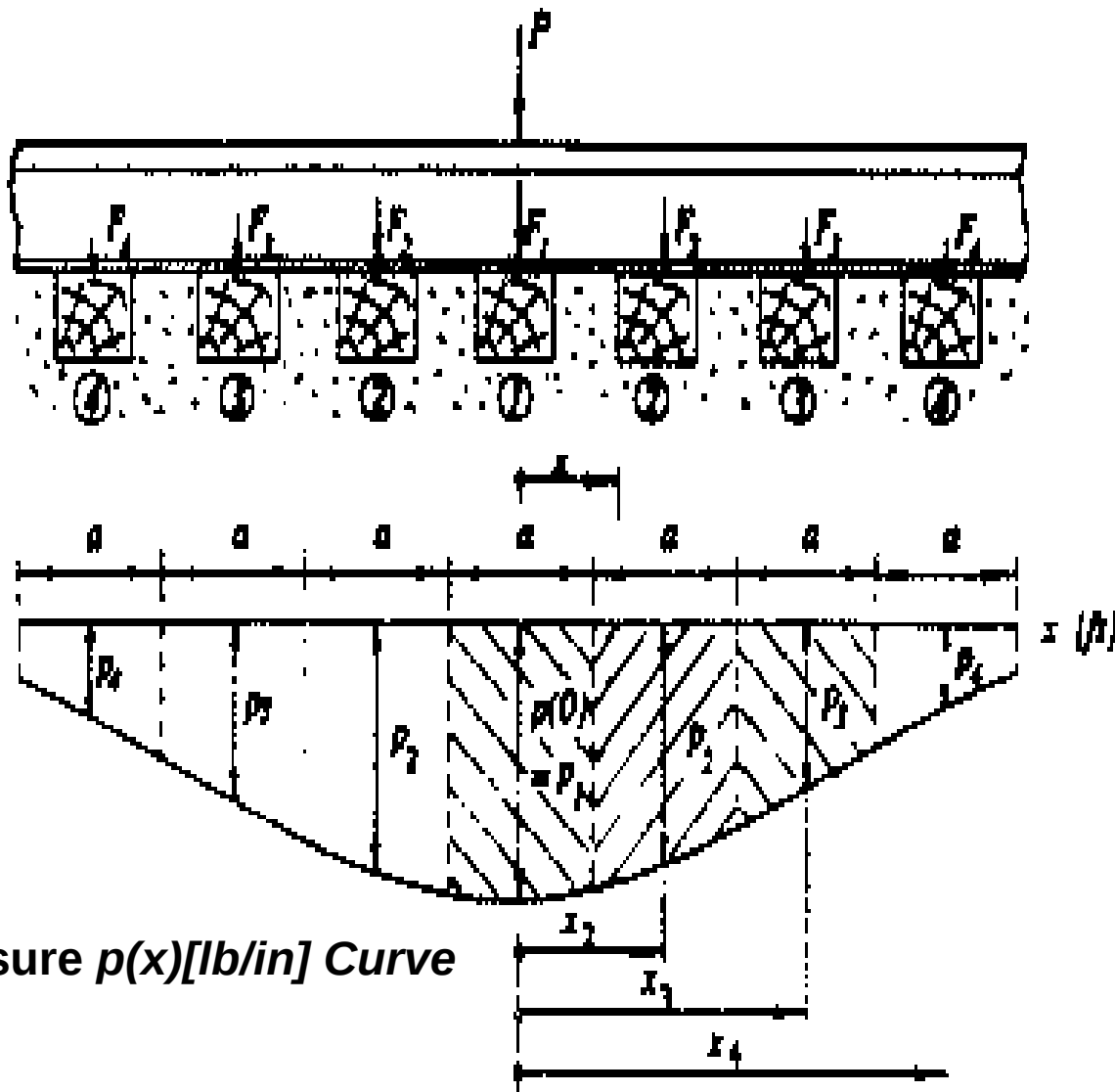
with: E = Modulus of Elasticity of Rail (30×10^6 psi)

I = Rail Moment of Inertia (in⁴)

Load Deflections and Bending Moments



Determination of Rail Seat Forces (Q or F)



Pressure $p(x)$ [lb/in] Curve

Design Steps (AREMA and Others) *(Generalized)*

1. Select design wheel load based on most common, heaviest car and desired track speed. Consider all wheels in a truck and proximity of adjacent cars.
2. Select a Track Modulus, u or k , based on desired design deflection
3. Select rail size and section
4. Determine moment and loading coefficients
5. Check rail bending stress
6. Choose trial tie spacing and calculate maximum rail seat load
7. Select tie size
8. Check tie bending stress

Design Steps (AREMA, U.S. DoD, and Others) (Generalized)...

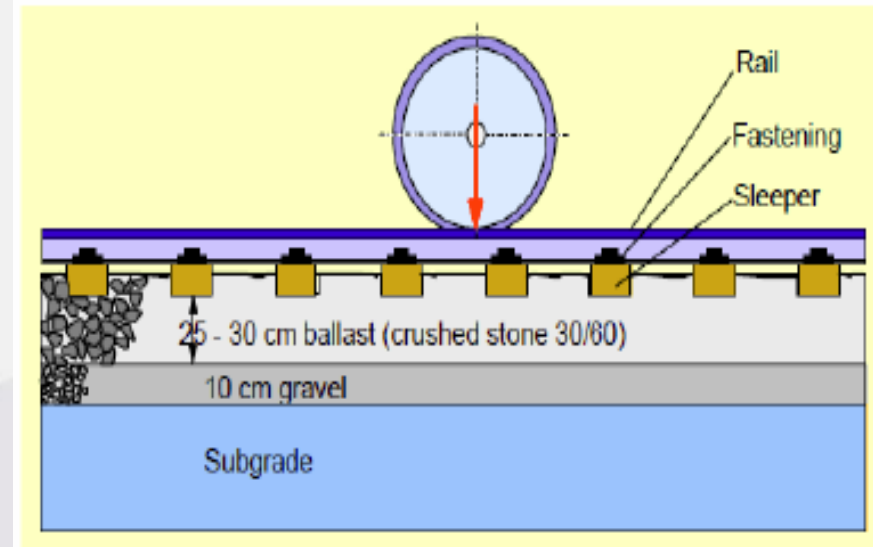
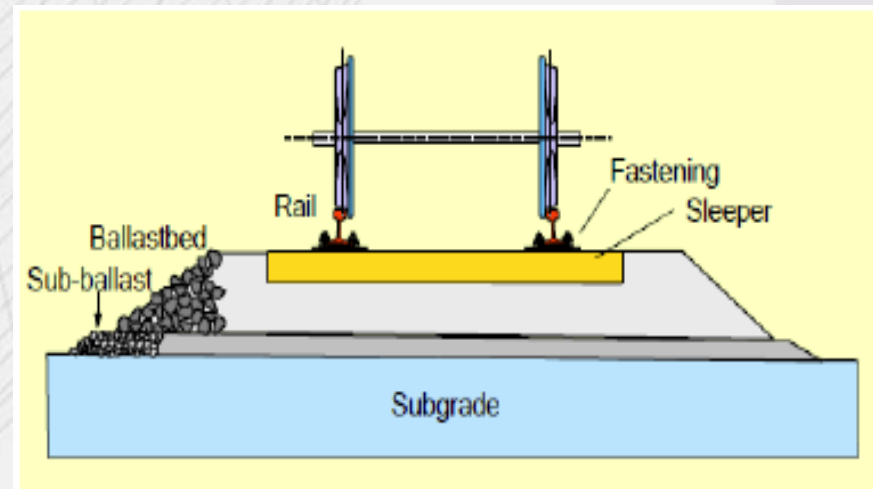
9. Determine and select plate size based on minimum area
10. Determine ballast surface stress
11. Determine ballast depth based on allowable subgrade stress
12. Calculate track deflection under load and check on acceptability
13. If deflection is unacceptable, re-do design

Always consider economics!

Upper structures

- Rail, fasteners, tie and ballast

- The upper part consists of two parallel steel rails, anchored perpendicular to members called ties (sleepers) of timber, concrete, steel, or plastic to maintain a consistent distance apart, or gauge.
- The track guides the conical, flanged wheels, keeping the vehicles on the track without active steering and therefore allowing trains to be much longer than road vehicles



1. Rail

Rail guides the conical, flanged wheels, keeping the vehicles on the track without active steering and therefore allowing trains to be much longer than road vehicles

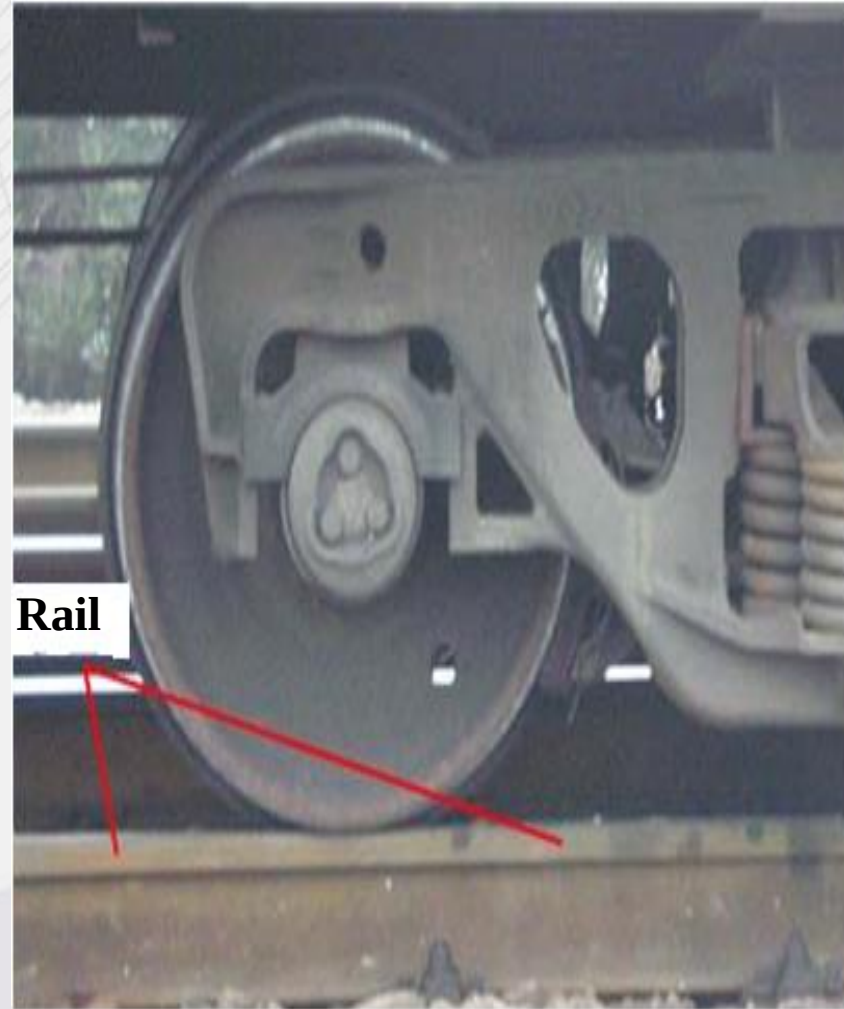
a) Characteristics

rigidity

tenacity

hardness

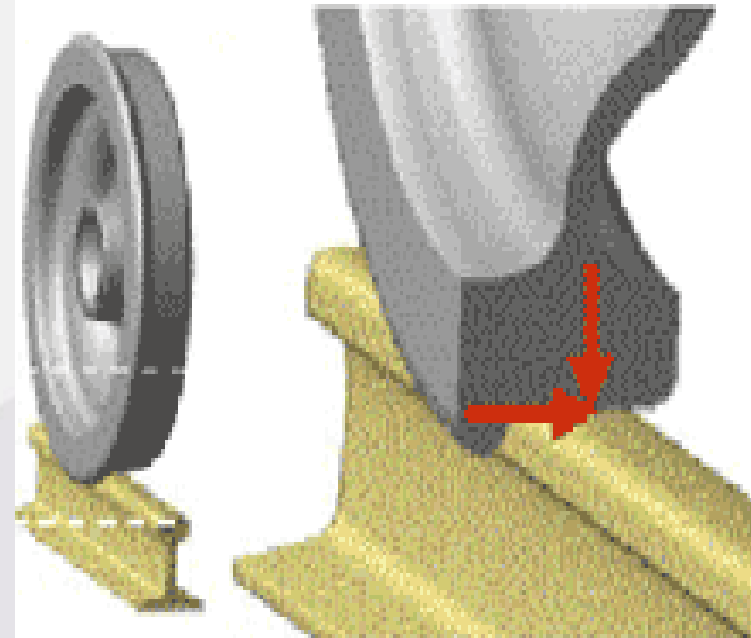
roughness of top surface



1. Rail...

b) Functions:

- Supports the loads of vehicles (cars) and locomotives and guides their movements
 - The excellence of the track determines the permissible wheel loads, speeds, safety and dependability of railroad operation
 - support and guide the wheels
 - provide a surface with smaller resistance
-
- No modern railroad can hope to survive in a competitive economy if its track is a hindrance to safe, dependable, on-time service
 - bear the force of the wheels and spread it to sleeper
 - used as track circuit in electrified railways and automatic block segments



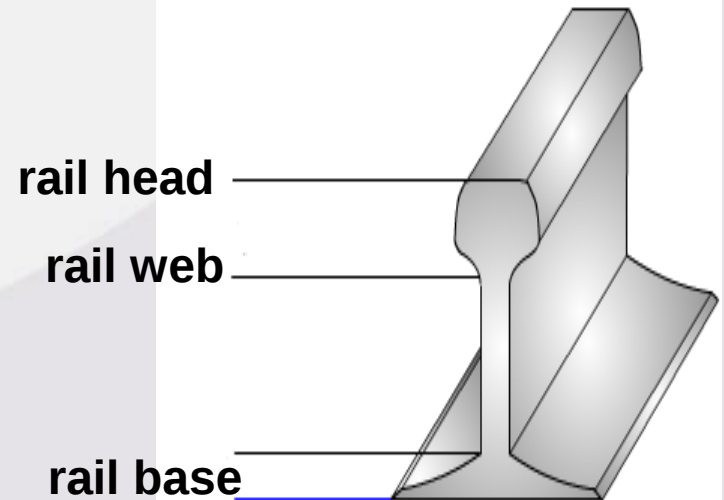
1. Rail...

C) Profile

The rail profile is the cross sectional shape of a railway rail, perpendicular to the length of the rail.

A rail is hot rolled steel of a specific cross sectional profile (an asymmetrical I-beam) designed for use as the fundamental component of railway track.

- Composed of **rail head**, **rail web** and **rail base**
- The rail head and base must be large and thick



[illegible]

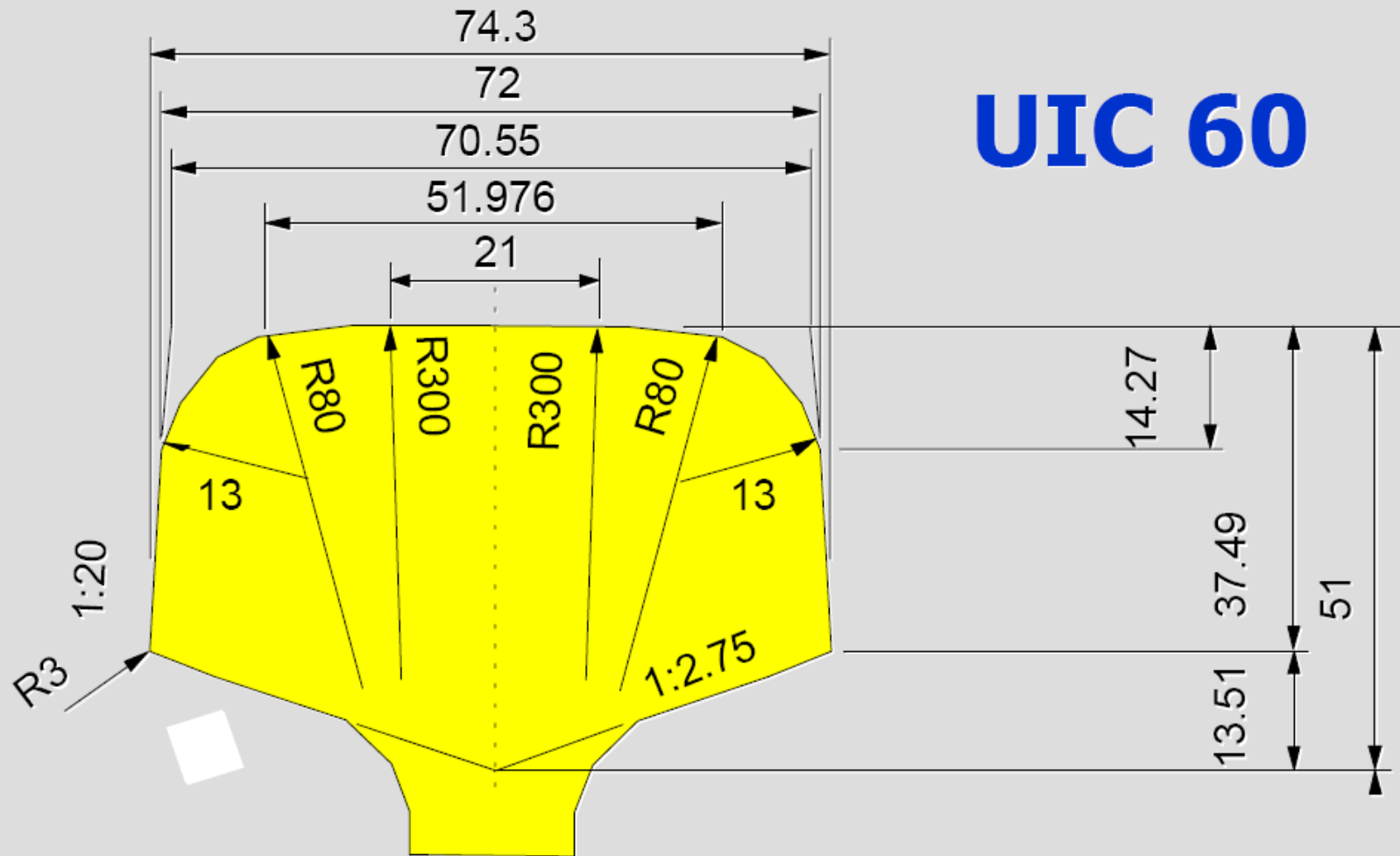
Technical drawing of a mechanical part, likely a bracket or flange, showing dimensions and geometric features. The drawing includes the following dimensions and labels:

- Overall Dimensions:**
 - Total width: 150
 - Total height: 176
- Horizontal Dimensions (from left edge):**
 - 29.25
 - 91.5
 - 29.25
- Vertical Dimensions (from top edge):**
 - 48.5
 - 48.5
 - 48.5
 - 81.23
 - 30.5
- Geometric Features and Labels:**
 - Top Section:**
 - Top width: 73
 - Top radius: $R300$
 - Top fillet: $R80$
 - Top fillet: $R13$
 - Top fillet: $R2$
 - Top fillet: $R25$
 - Top fillet: $R400$
 - Top fillet: $R400$
 - Top fillet: $R20$
 - Top fillet: $R40$
 - Top fillet: $R4$
 - Top fillet: $R2$
 - Internal Features:**
 - Internal radius: $R13$
 - Internal fillet: $R2$
 - Internal fillet: $R25$
 - Internal fillet: $R400$
 - Internal fillet: $R400$
 - Internal fillet: $R20$
 - Internal fillet: $R40$
 - Internal fillet: $R4$
 - Internal fillet: $R2$
 - Angles and Slopes:**
 - 1:20
 - 1:3
 - 1:3
 - 1:9
 - Other Labels:**
 - 中和轴 (Neutral Axis)
 - R400中心线 (Center Line of R400)
 - 螺栓中心线 (Bolt Center Line)

CN 60 kg/m rail (unit: mm)

1. Rail...

UIC 60



1. Rail...

d) Types and length

Determining factor for rails strength and hence axle loads and speeds is weight of a rail per length . So rail types are divided by its unit weight in China, such as 75, 60, 50, 43 kg/m.

- Weights are measured in kilograms-per-meter or pounds per yard; the pounds-per-yard figure is almost exactly double the kilograms-per-meter figure.
- types: 75 kg/m 、 60 kg/m 、 50 kg/m and so on.
- Standard rail length: 12.5m and 25m.

1. Rail...

The following rail forms are in use at present:

- *Vignoles* rail (standard railway rail with head, web and foot),
- double-head rails with head, web and foot (obsolete)
- grooved rails for tram ways,
- switch rails and
- crane rails etc

EMBEDDED RAIL



1. Rail...

e) Rail gap

To adapt to the needs of expanding with heat and contracting with cold, the rail gap can not too big or too small.

$$\delta = 0.0118L(t_2 - t_0) + \frac{1}{2}\delta_q$$

- δ — size of rail gap(mm)
- L —length of track(m)
- δ_q — structural joint gap, track of 38kg/m、43kg/m 50kg/m、60kg/m、75kg/m are 18mm
- t_0 — temperature of rail gap(°C)

$$t_2 = \frac{1}{2}(t_{\max} + t_{\min})$$



1. Rail...

e) Continuous welded track (CWR)

The 25 m rail are welded into 100-200m long rail in factory, and then be welded again into 1000-2000m long rail in the laid place



Advantages:

- smooth driving
- low maintenance cost
- long life

1. Rail...

f) Rail requirement

- The rail is running surface, carrier and guiding element at the same time.
- It is subject to equal static and dynamic stress. In heavy haul traffic, axle loads up to 35t are applied.
- Depending on the topography rails are laid with radii as low as 300m, therefore, they have to bear very high lateral forces exerted by the wheel flange striking against the gauge corner of the outer rail.

To be able to withstand manifold and high forces, the rails must meet the following requirements:

- high resistance to wear,
- high resistance to compression,
- high resistance to fatigue
- high yield strength, tensile strength and hardness
- high resistance to brittle fracture
- good weld ability,
- high degree of purity
- good surface quality
- evenness and observance of profile and
- low residual stress after manufacturing

1. Rail...

g) Composition

Unlike some other uses of iron and steel, railway rails are subject to very high stresses and have to be made of very **high quality steel**. It took many decades to improve the quality of the materials, including the change from iron to steel.

Minor flaws in the steel that pose no problems in reinforcing rods for buildings, can, however, lead to broken rails and dangerous derailments when used on railway tracks

1. Rail...

Rail Analysis and Design (weight and section selection)

- Bending stress

$$S = M_{oc}/I \text{ or } S = M_o/Z$$

Where, S = Bending stress, psi

M_o = Max bending moment, in-lbs

c = Distance to base from neutral axis, in

I = Moment of inertia of rail, in⁴

Z = Section modulus, I/c (properties of rail section)

Allowable bending stress, typically is:

–32,000 psi for jointed rail

–25,000 psi for continuously welded rail (CWR)

1. Rail...

Rail Analysis and Design(weight and section selection)

Maximum bending moment, M_o

$$M_o = P(EI/64u)^{1/4} \quad (M_o = 0.318Px_1)$$

Where, M_o = Max bending moment

P = Max wheel load, lbs (static or dynamic)

E = Modulus of elasticity = 30×10^6 psi

I = Moment of inertia, in^4

$$x_1 = (\pi/4)(4EI/u)^{1/4}(\text{in})$$

u = track modulus, lbs/in/in

Note: Must account for moments from adjacent wheels. Compute from Master Diagram, computer code, or EXCEL.

I and c are a function of design: –Greater weight -greater I

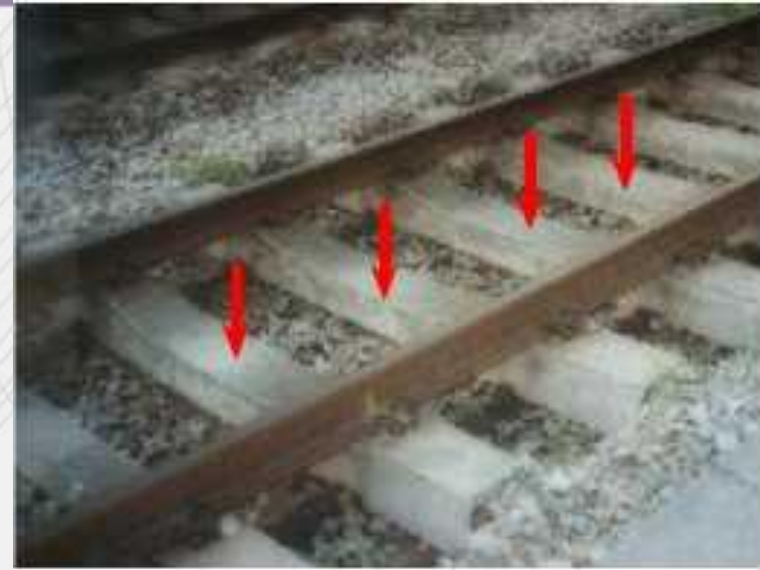
–Increase height -greater I (**limiting factor is web height - thickness ratio**)

maximum bending stress $\leq$ allowable bending stress!!!

2. Sleeper

(a) Function

- ✓ bear the force of track
- ✓ Act as elastic medium to absorb blows & vibrations
- ✓ Longitudinal & lateral stability
- ✓ spread the force to ballast bed and roadbed
- ✓ keep the direction, position and gauge of track
- ✓ Supporting wheels and/or jacks direct (in a derailment situation).
- ✓ *Acting as transverse beams when sitting on temporary 'way beams'.*

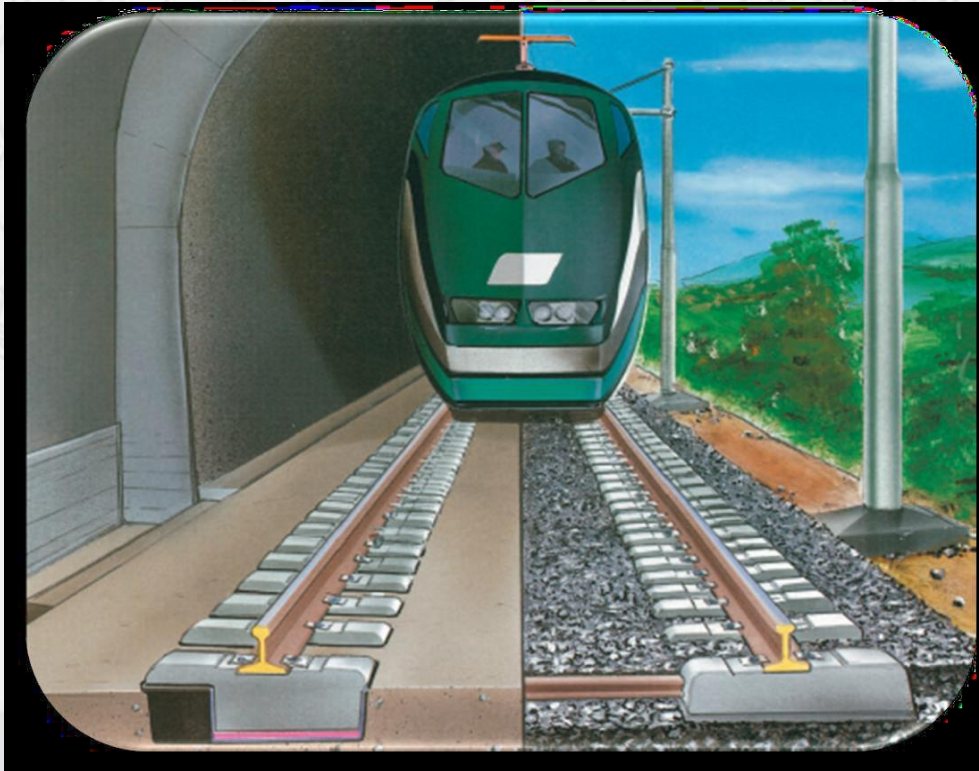


- ✓ *Supporting signal engineering and other safety related equipment such as trip cocks and point motors.*
- ✓ *Supporting conductor rails, electrical bonds and feeder cables.*
- ✓ *Reducing noise and vibration on non-ballasted bridge decks*

2. Sleeper...

(b) Characteristic

It is solid, flexible, reasonably cost, convenient for manufacturing and maintenance.



2. Sleeper...

c) Requirements

- *Moderate weight- easy to handle*
- *Fixing and removing of fastening should be easy*
- *Sufficient bearing area*
- *Easy maintenance and gauge adjustment*
- *Track circuiting must be possible*
- *Able to resist shocks and vibrations*
- *Minimum maintenance and initial cost*

2. Sleeper...

(c) types

- Traditionally, ties have been made of wood, but concrete is now widely used. Steel ties and plastic composite ties are currently used as well, although far less than wood or concrete ties
- **According to production material:** *reinforced concreted sleeper, wooden sleeper, steel sleeper*
- **According to their usage:** *regular sleeper, switch sleeper and bridge sleeper.*

2. Sleeper...

1. Wooden Sleeper

- Timber ties are usually of a variety of **hardwoods, oak** being a popular material.
- They have the advantage of accepting treatment more readily, they are more susceptible to wear. They are often heavily creosoted. **Creosote treating** can reduce insect infestation and rot. However, creosote is also carcinogenic and environmentally damaging.
- Less often, ties are treated with other **preservatives**, although some timbers are durable enough that they can be used untreated.

2. Sleeper...



2. Sleeper...

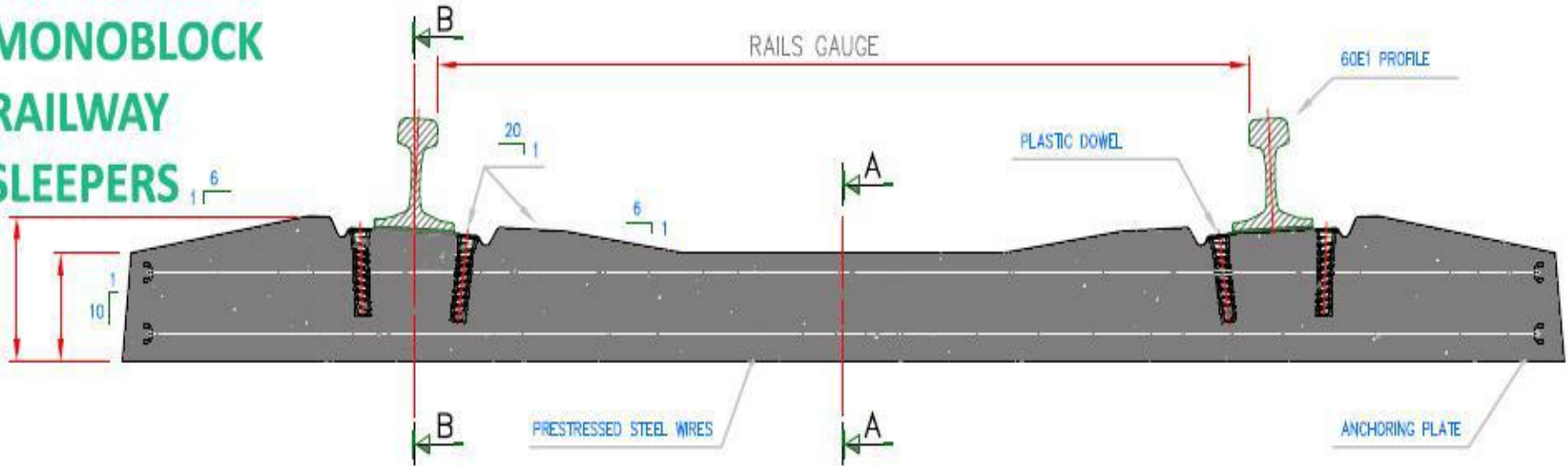
2. Concrete Sleeper

- Concrete ties have become more common mainly due to *greater economy and better support of the rails* under high speed and heavy traffic than wooden ties



2. Sleeper...

MONOBLOCK RAILWAY SLEEPERS



Wooden sleeper



concrete sleeper

2. Sleeper...

	Wood	Concrete
advantages	low weight good elasticity good insulation properties Repair on track possible quick replacement	resistance against animals and fungi long life span track remounting possible with polymer plugs
Disadvantages	prone to cracks low resistance against animals and fungi short life span waste disposal problem (due to biocides)	high weight for handling no repair on track removal after derailing of trains necessary

24.09.2008 Sheet number 22



2. Sleeper...

3. Steel sleeper

- In past times steel ties (sleepers) have suffered from poor design and increased traffic loads over their normal long service life. These aged and often obsolete designs limited load and speed capacity but can still, to this day, be found in many locations globally and performing adequately despite decades of service.
- The steel sleepers' cost benefits together with the ability to *hold rail gauge, lower long-term maintenance costs, increase the life of other track components, reduce derailments and meet ever growing and stricter environment* standards provide railroad companies with savings and capital to redirect to other areas of maintenance-of-way and business projects.

2. Sleeper...*steel sleepers*

Advantages:

- Long life
- Better lateral rigidity
- Free from decay and fire hazards
- Good scrap value
- Lesser damage during handling /transportation
- Less maintenance problems
- Easy to maintain gauge

Disadvantages:

- Liable to corrosion
- Unsuitable to track circuiting
- Becomes center bound due to sloping ends
- Rail specific

2. Sleeper...*steel sleepers*



鋼枕 Steel Sleeper

Other sleepers

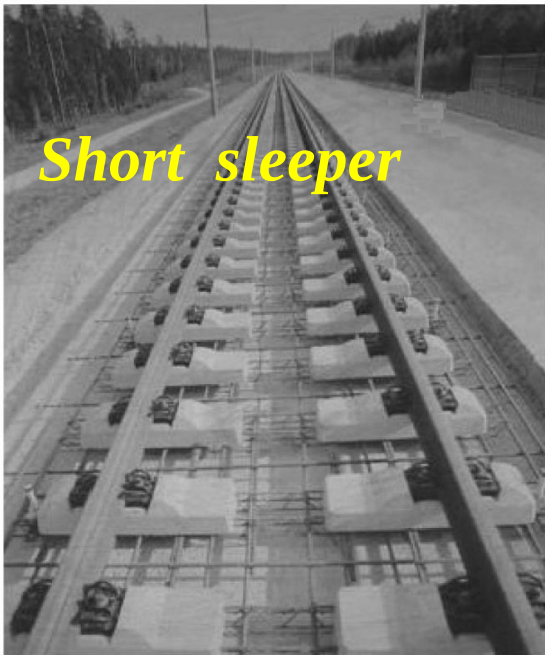
Switch sleeper



Bridge sleeper



Short sleeper



a)

long sleeper



b)

2. Sleeper...

Wide sleeper

- ❖ Concrete monoblock sleepers have also been produced in a wider form (e.g. 57 cm (22 in))
- ❖ there is no ballast between the sleepers;
- ❖ wide sleeper increase lateral resistance and
- ❖ reduces ballast pressure.



2. Sleeper...



2. Sleeper...

Y-shaped sleepers

- An unusual form of sleeper is the Y shaped sleeper.
- First developed in 1983
- Compared to conventional sleepers the *volume of ballast required is reduced* due to the load spreading characteristics of the Y-sleeper.
- Noise levels are high
- The resistance to track movement is very good.
- For *curves the three point contact of a Y steel sleeper* means that an exact geometric fit cannot be observed with a fixed attachment point.

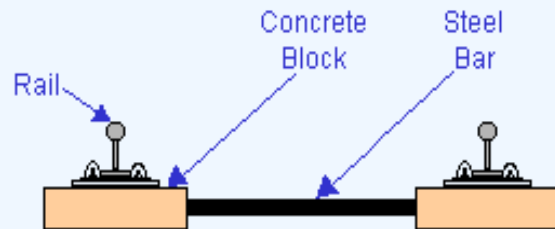


2. Sleeper...

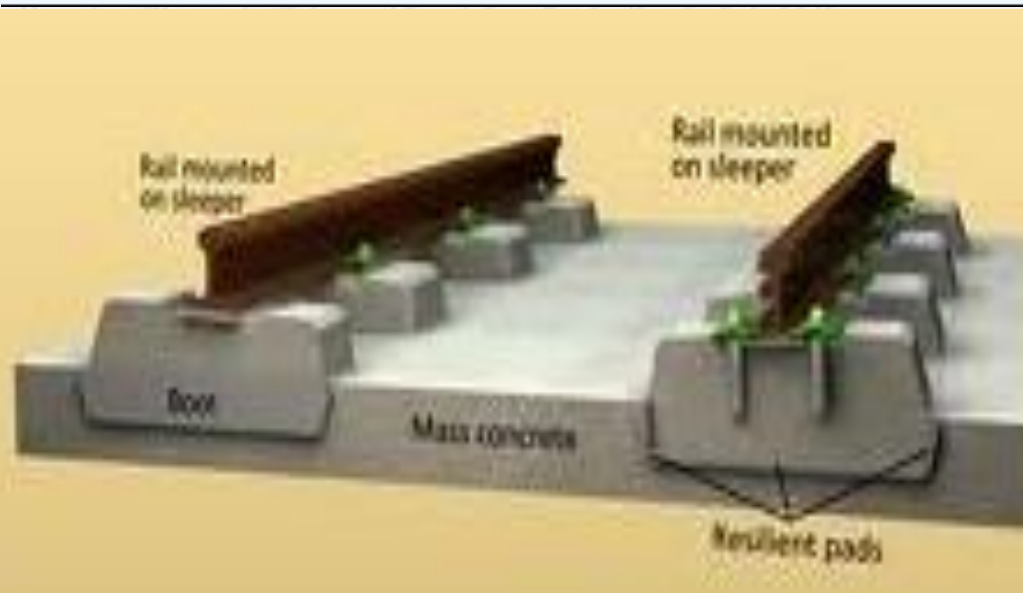
Bi-block sleepers

- Bi-block (or twinblock) sleepers consist of two concrete rail supports joined by steel
- Advantages include
 - ✓ increase lateral resistance
 - ✓ lower weight than monoblock concrete sleepers
 - ✓ eliminate damage from torsional forces on the sleeper centre due the more flexible steel connections
- Bi-block sleepers are also used in ballastless track systems

2. Sleeper...*Bi-block*



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 Sonnevile 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.



Wood 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.

2. Sleeper...

Mono-block vs. twin block sleepers

The advantages of the twin-block sleeper

- *Well-defined bearing surfaces in the ballast bed;*
- *high lateral resistance in the ballast bed*

The advantages of the mono-block sleeper

- *low price*
- *less susceptibility to cracking*
- *can be pre-stressed*



2. Sleeper...

d) Arrangement

- Configuration number at each kilometer is decided by volume, speed and line level

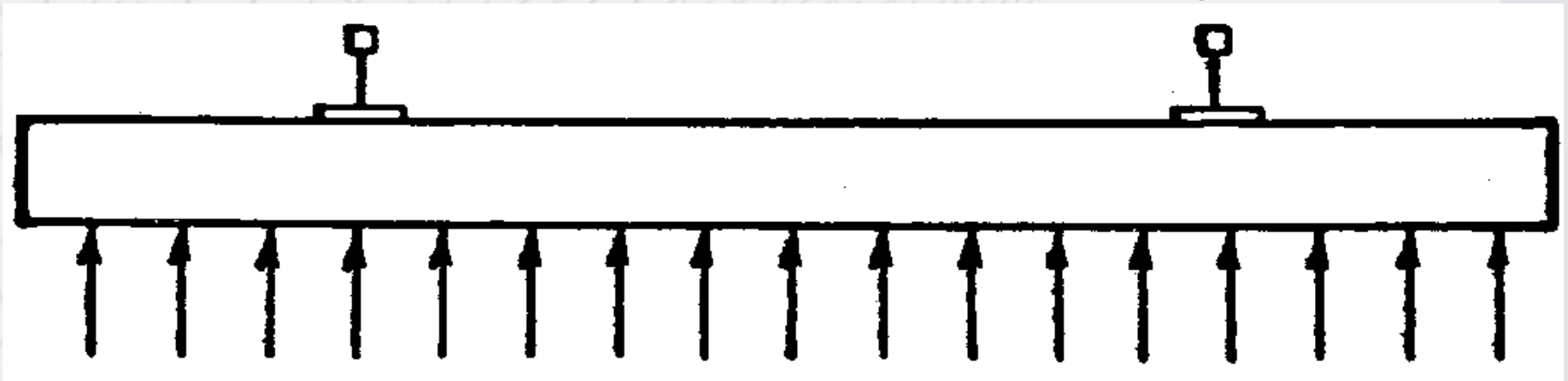
The rule:

- **wooden sleepers** must **no more than 1920 per 1km and no less than 1440**
- ***Reinforced concreted sleepers*** must ***no more than 1840 per 1km and no less than 1440***

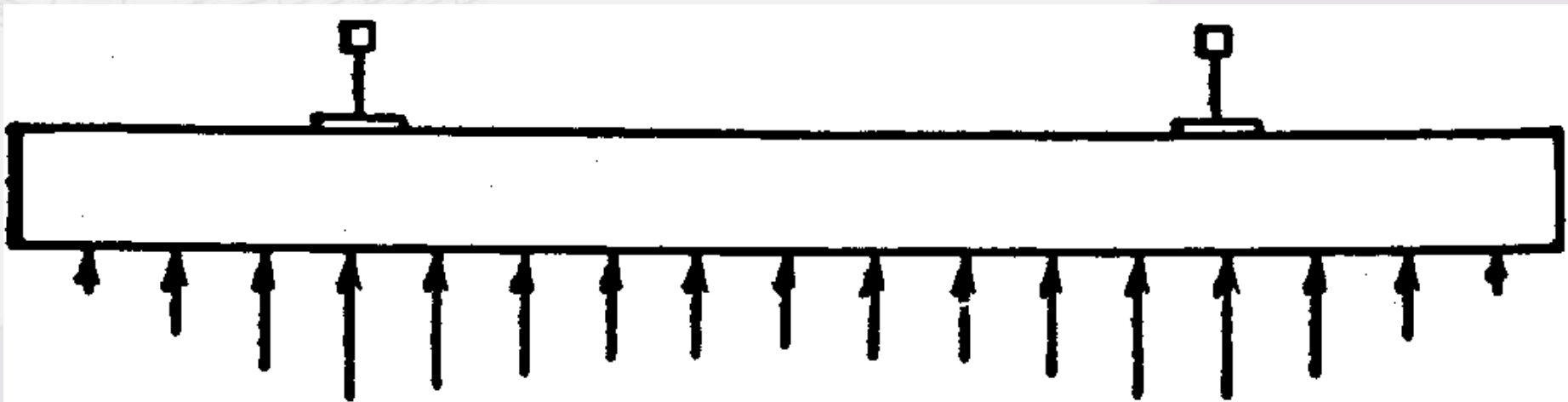
2. Sleeper...

Tie Analysis and Design(size and spacing)

- Action under load
 - *Earlier tie reaction was considered as uniform*



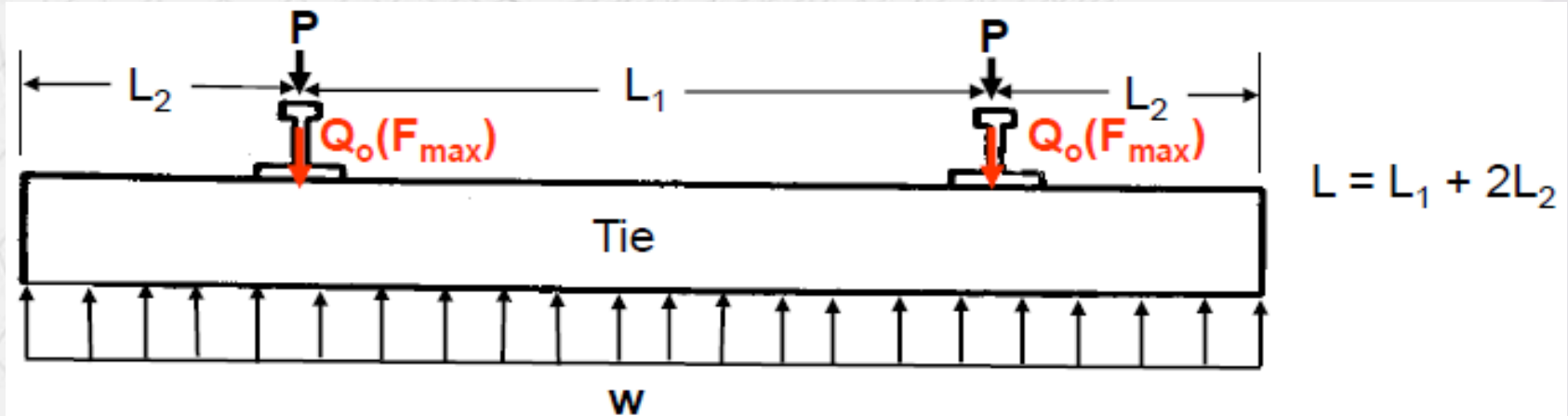
- *Talbot found that stress concentrated under rail seat*



2. Sleeper...

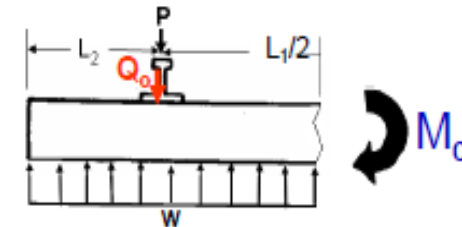
Theoretical Design

- Force diagram (close to center-bound condition)

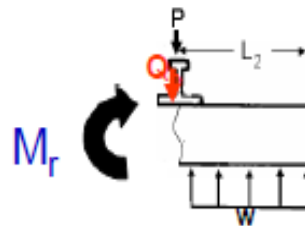


- Look at bending moments under center and rail seat

– $M_c = (Q_o/4)(L_1 - 2L_2)$



– $M_r = -Q_o L_2^2 / L$



Q_o must account for adjacent wheels. Recall, pressure distribution and principle of superposition.

2. Sleeper...

Maximum allowable bending moment (e.g. wooden sleeper)

–Simple beam moment

$$S = Mc/I \quad \text{or} \quad M = SI/c$$

Where, M = bending moment, inch-lbs

I = moment of inertia = $bh^3/12$, in⁴

c = dist from base to neutral axis = $h/2$, inches

S = allowable wood fiber bending stress, lb/in²

h = tie height, inches

b = tie width, inches

Then, $M = (bh^3S/12)/(h/2) = bh^2S/6$

–S varies by wood specie (e.g., 1000 psi for shortleaf yellow pine, 1200 psi for longleaf yellow pine, 900 psi for Douglas fir, and *1400 psi for oak*)

2. Sleeper...

Practical Design

- Load distribution

—Bearing area is $\frac{2}{3}$ of tie length (tamping zone), so

$$A'_b = \frac{2}{3}Lb$$

and unit load on ballast will be

$$p_a = 2Q_o/A'_b$$

Thus, $p_a = 3Q_o/Lb$

Where, $p_a =$ unit tie pressure on ballast

(<65 psi wood, <85 psi concrete)

$A'_b =$ total tie bearing area, in²

$L =$ tie length, inches

$b =$ tie width, inches

$Q_o =$ Rail seat load, lbs (static or dynamic), based on trial tie spacing

2. Sleeper...

Plate Analysis and Design(size selection)

Two basic types

- Single shoulder
- Double shoulder

Size

- Width sized to fit tie
- Length to keep stress on wood tie <200 psi
- Stress = $Q_o / \text{Plate Area}$
- Limited set of fixed sizes (generally choose smallest size possible for economics)
- Distance between shoulders (double shouldered plates) spaced to match rail base width



3. Ballast and sub ballast

1. **Ballast-** it is a layer of broken stones, gravel, moorum or any other gritty material placed and packed below and around sleepers.
 - for distributing the load from the sleepers to the formation and
 - for providing drainage
 - as well as giving longitudinal and lateral stability to the track.

A layer of loose, coarse grained material which, as a result of internal friction between the grains, can absorb considerable compressive stresses, but not tensile stresses.



3. Ballast and sub ballast

a) Functions

The six most important functions of ballast:

- *To resist vertical & longitudinal forces and hold the track in position*
- *To provide energy absorption for the track*
- *To provide voids for storage and movement of fouling material in the ballast*
- *To facilitate the adjustment of track geometry*
- *To provide immediate drainage of water falling on to the track*
- *To reduce pressures on underlying materials by distributing loads*

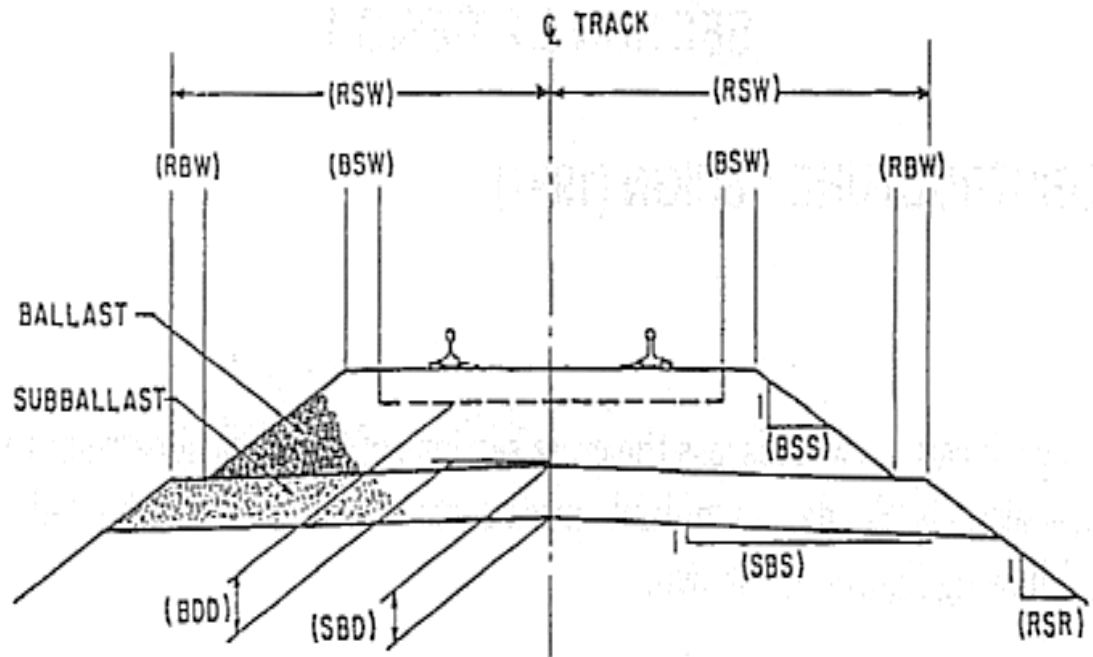
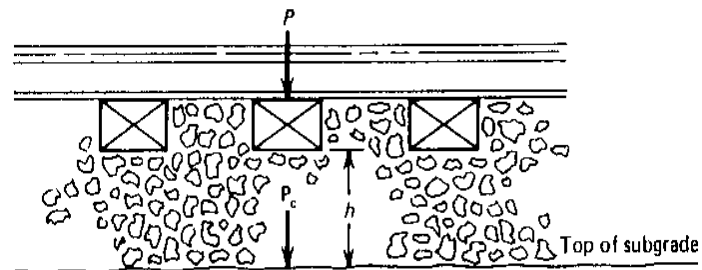
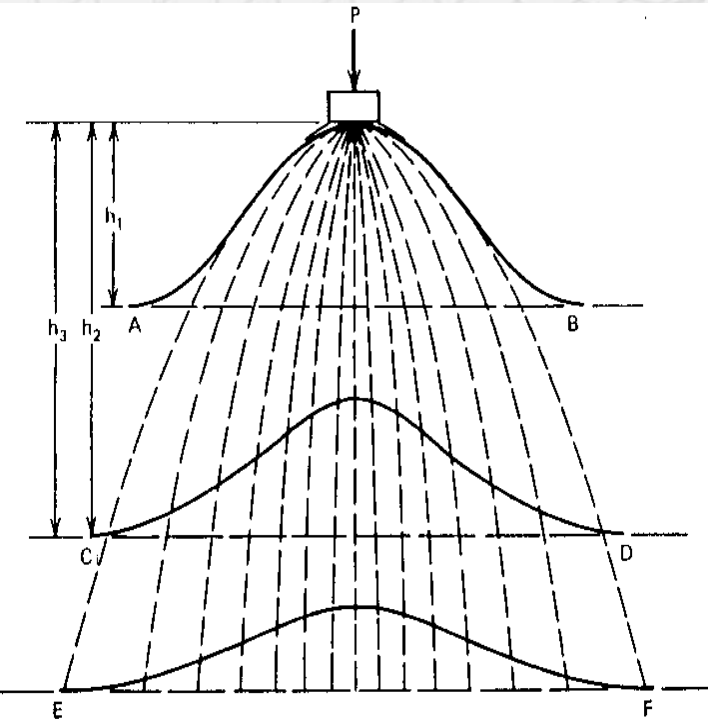
3. Ballast and sub ballast

(b) Requirements

- *Tough and resist wear*
- *Hard enough*
- *Cubical with sharp edge*
- *Non porous, non-water absorbent*
- *Resist attrition*
- *Durable*
- *Good drainage*
- *Cheap and economical*

3. Ballast and sub ballast

Ballast Analysis and Design(depth determination)



Ballast:

BDD = Depth of Ballast

BSW = Ballast Shoulder Width

BSS = Ballast Side Slope Run

Subballast:

SBD = Subballast Depth

SBS = Subballast Side Slope Run

Roadbed:

RSW = Roadbed Shoulder Width

RSR = Roadbed Side Slope Run

RBW = Roadbed Berm Width

Source:-AREMA

3. Ballast and sub ballast

Ballast depth determination

(ballast and subballast combined) = $f(\text{applied stress, tie reaction, and allowable subgrade stress})$

– **Talbot Equation,** $h = (16.8p_a/p_c)^{4/5}$

Where, h = Support ballast depth

p_a = Stress at bottom of tie (top of ballast)

p_c = Allowable subgrade stress

Note: Stress distribution independent of material

– **Japanese National Railways Equation**

$$p_c = 50p_a / (10 + h^{1.25})$$

– **Boussinesq Equation**

$$p_c = 6P / 2h^2 \text{ where } P = \text{wheel load (lbs)}$$

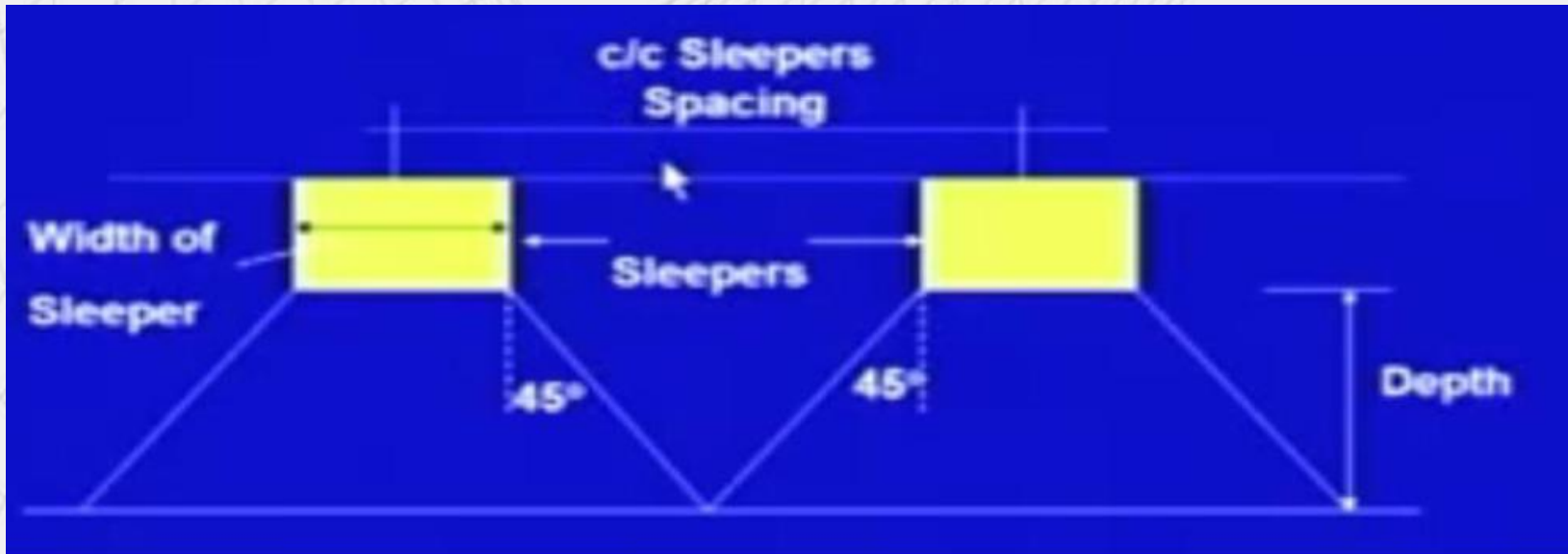
– **Love's Formula**

$$p_c = p_a \{1 - [1 / (1 + r^2 / h^2)]^{3/2}\}$$

where r = Radius of a loaded circle whose area equals the effective tie bearing area under one rail

3. Ballast and sub ballast

Minimum depth of ballast



Stress distribution is assumed as 45°

- Consider stress overlap area
- Provide adequate depth of ballast
- Thickness of ballast is a function of sleeper spacing, sleeper size etc

3. Ballast and sub ballast

2. Sub ballast

-Is a layer of material between the top ballast and sub grade with a gradation finer than the top ballast and coarser than the sub grade

a) Function

- Used to reduce total ballast cost
- Provide a filter layer between the top ballast and a fine grained sub grade

b) Application

A sub ballast layer is recommended for most new construction. In addition to providing filter to keep sub grade particle from working up in to and fouling the ballast, it provides a good mat to distribute loads from the ballast and prevents ballast particles from being pushed in to the sub grade

3. Ballast and sub ballast

A sub ballast layer is required whenever:

- i. The sub grade contains 85% or more (by weight) of silt and clay sized particles or,
- ii. The sub grade material has a liquid limit greater 50 and a plasticity index greater than 20

c) Material

Sub ballast should be hard, angular, non cementing material, primarily of sand sized particles

3. Ballast and sub ballast

d) Gradation

To function as a filter layer, the sub ballast particles should range in size from the smallest ballast particles to the largest sub grade particles

e) Depth

- i. *During structural analysis, the sub ballast layer is considered as part of the total ballast depth*
- ii. A sub ballast layer may comprise up to 40% of the total ballast thickness on main running tracks and up to 50% on auxiliary and terminal tracks

4. Rail fastening system/ Union piece

- A Rail fastening system is a means of fixing rails to railroad sleepers.
- The terms rail anchors, tie plates, chairs and track fasteners are used to refer to parts or all of a rail fastening system. Various types of fastening have been used over the years.
- Union pieces are divided into rail joint fastenings and middle joint fastenings.

a) **Function:**

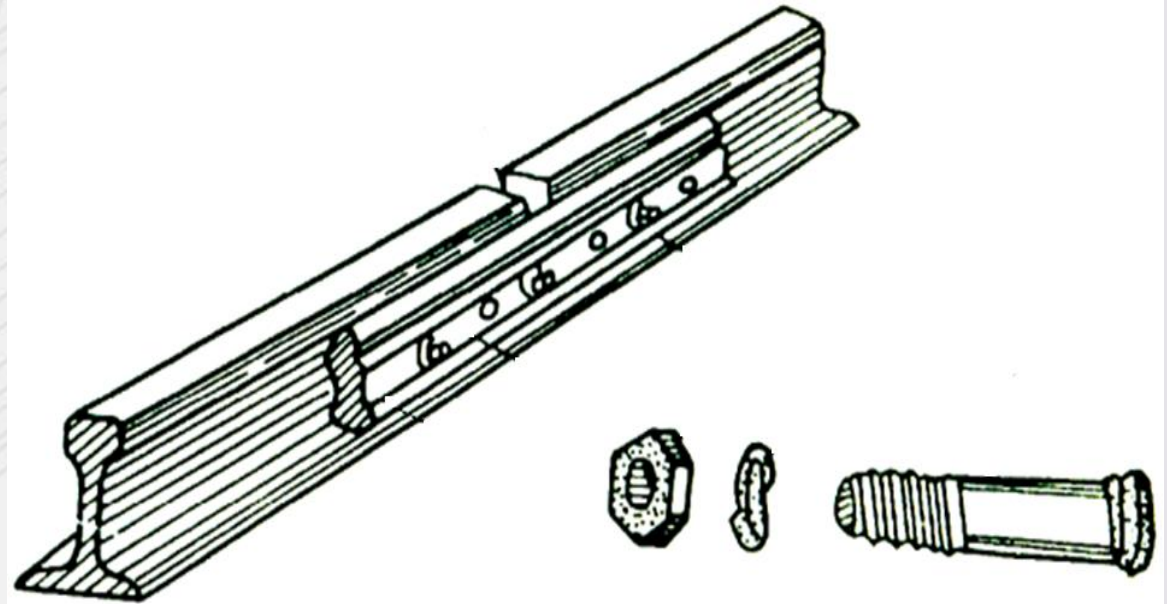
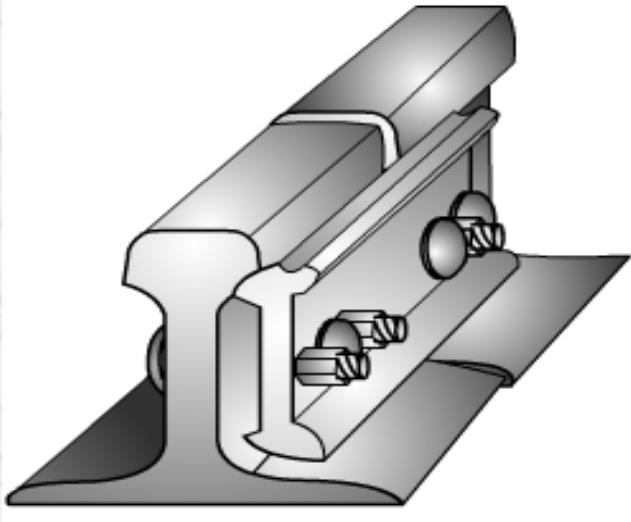
The purpose of the rail fastenings:

- To maintain the track gauge
- Offer sufficient resistance in a vertical direction, each pair of rail fastening elements has to be able to take over the weight of the concrete sleeper and the respective rail section without excess deformation.
- To transmit forces acting on and in the rails to the sleepers (cross, longitudinal, concrete plates etc.)
- Electrically insulate the sleeper against the remaining track grid, to minimize the loss of signals of the direct-current circuits

b) Types

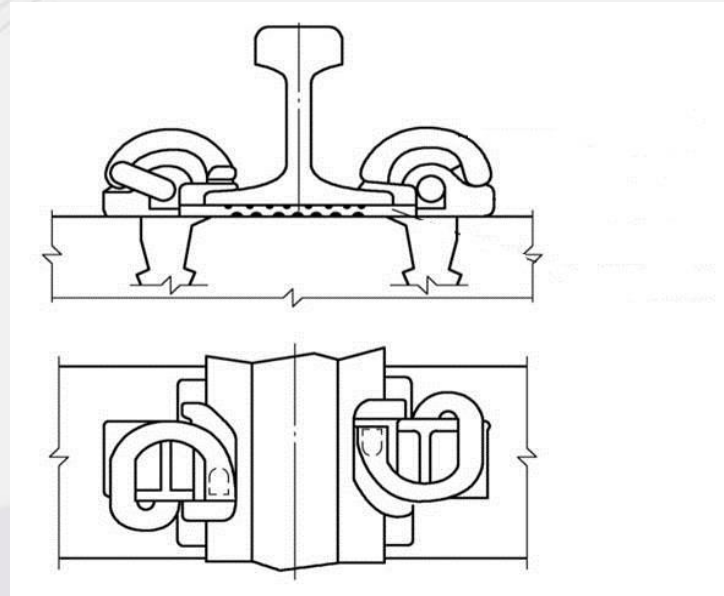
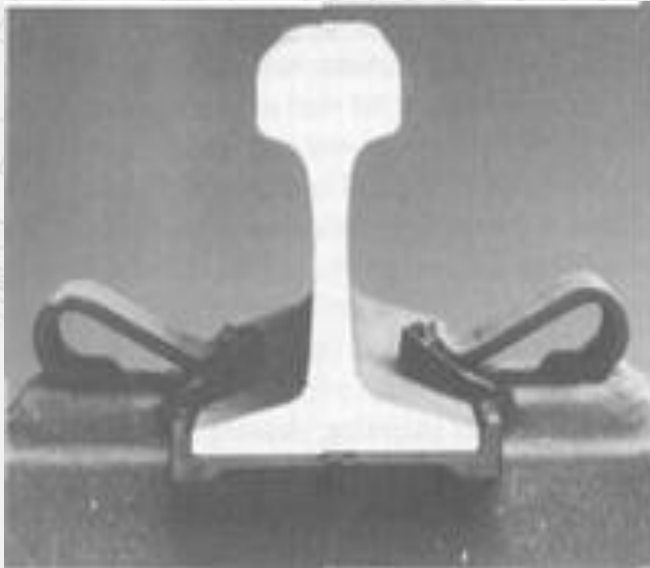
(1) rail joint fastenings

Rail joint fastenings are used at the end of the two tracks.

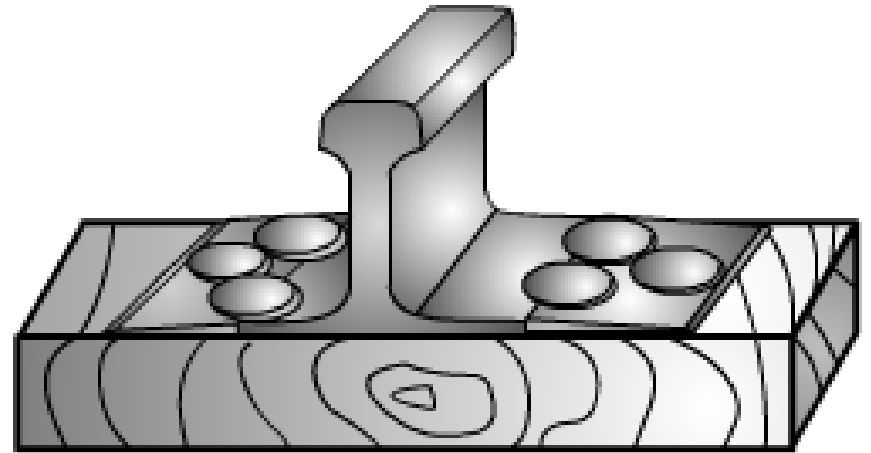


(2) Middle joint fastenings

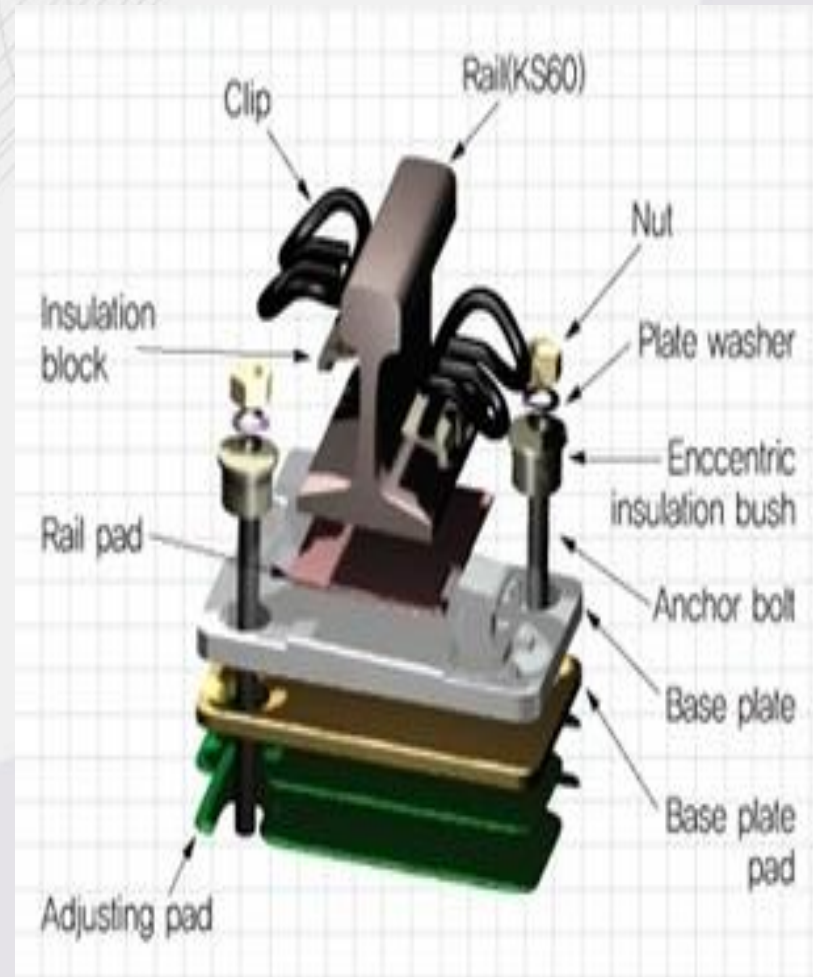
- They are used to connect the track with the sleeper
- According to the character of sleeper, middle joint fastenings can be divided into reinforced concrete joint fastenings and wooden joint fastenings .



wooden joint fastenings



Reinforced concreted joint fastenings



Reinforced concreted joint fastenings



5. Ballasted and slab track

a) Ballasted track

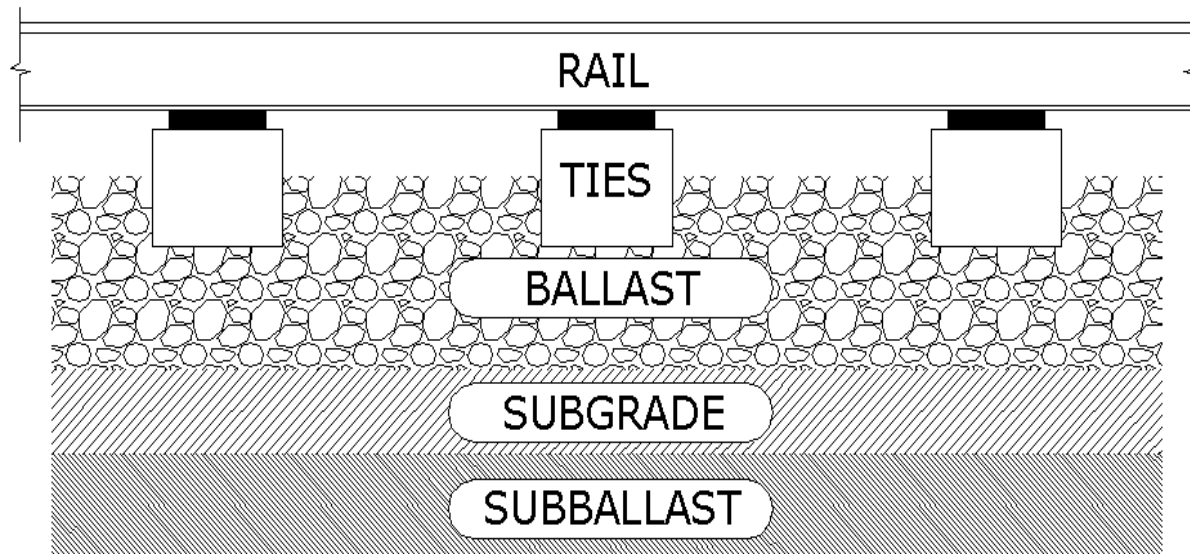
Advantages:

Lower cost, small noise emission scope, short construction period, easy repair when failure occurs, high efficiency of maintenance work due to its mechanization, easy to adjust its geometrical unevenness



Ballasted track...

- Experience from Japan and France shows:
 - Ballast has tendency of **deterioration**, **wear** due to traffic loading, railway lines thus need to be repaired time after time
- *On high-speed railways*, the time for repairing lines is limited due to fast speed and short interval between trains, it is **unpractical to do high-frequency maintenance work**.



Ballasted track...

Disadvantages

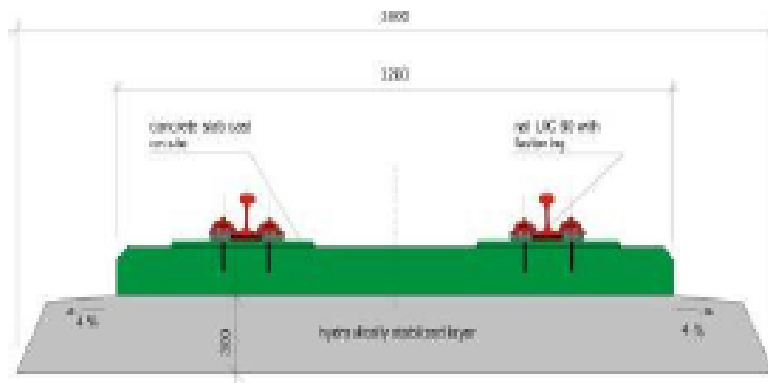
In comparison to slab track:

- The tendency of the track to “float” in both longitudinal and lateral direction after a period of time
- Limited non-compensated lateral acceleration in curves caused by the limited lateral resistance provided by ballast
- **Pulverization** of the ballast grains in the ballast bed resulting in particles damaging the rail and wheels
- Problems with ballast churning with high speed
- Reduced permeability due to contamination, the wear of the ballast, and intrusion of fine particles from the sub grade
- Limited non-compensated lateral acceleration in curves caused by the limited lateral resistance provided by ballast
- Pulverization of the ballast grains in the ballast bed resulting in particles damaging the rail and wheels

b) Slab track

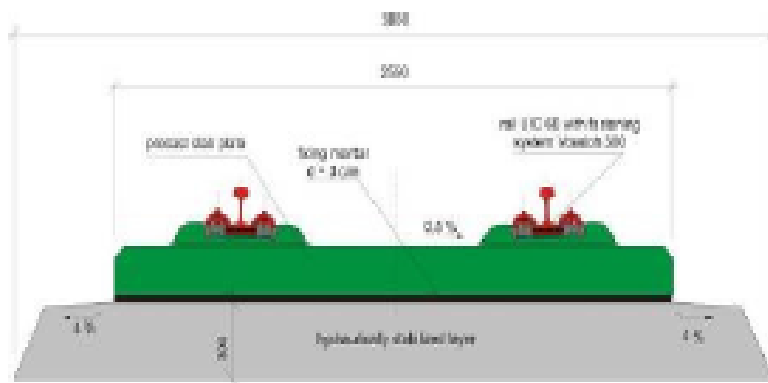
- In slab track, ballast as the load distributing element is replaced by another material which has a stable position, such as **concrete or asphalt**.
- The necessary elasticity has to be provided by inserting elastic elements below the rail or the sleeper, as the concrete or asphalt layer is very stiff.
- In comparison to ballasted track, the advantages of slab track are ***in general reduction of maintenance and a higher stability of the track***

Slab track design



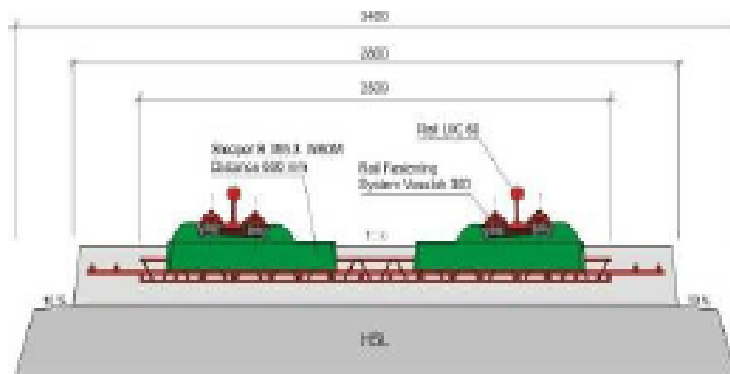
In situ concrete without ties

- In situ concrete at fastening fixation
- Concrete cracking at sensitive areas
- No adjustment help available



Precast concrete slab

- Exact rail positioning
- Very high quality of entire slab; still in-situ concrete required
- Handling of large elements required



In-situ concrete with ties (Rheda)

- Exact rail positioning due to pre-fabricated tie elements
- Smooth, exact and high quality concrete in important areas (rail seats)
- High quality, crack-free factory produced rail supporting points
- Adjustment of every tie necessary

Slab track



Advantages:

- Less or free maintenance, costs 20%~30%
- better line evenness
- Increased service life, and possibility of almost full replacement at the end of the service life
- Increased lateral resistance and stability
- Reduced structure height and weight
- The excess of super elevation and cant deficiency of the track with mixed used of freight- and passenger trains does not cause altering of the track position
- Track accessibility to road vehicles
- Preventing the release of dust from the ballast bed into the environment

Disadvantages:

- Higher construction costs and
- Higher airborne noise reflection
- Adaptability to larger sink age in the embankment is relatively small
- In case of derailment, repair works will take much more time and effort
- Transitions between ballasted track and slab track require attention
- Large attentions in track position and super elevation can only be made possible by substantial amounts of work
- The application of slab track may require extensive measures concerning the preparation of the foundation.
- The sub layers must be homogenous and capable of bearing the imposed loads without significant settlements.

Types

Main types of non-ballasted track:

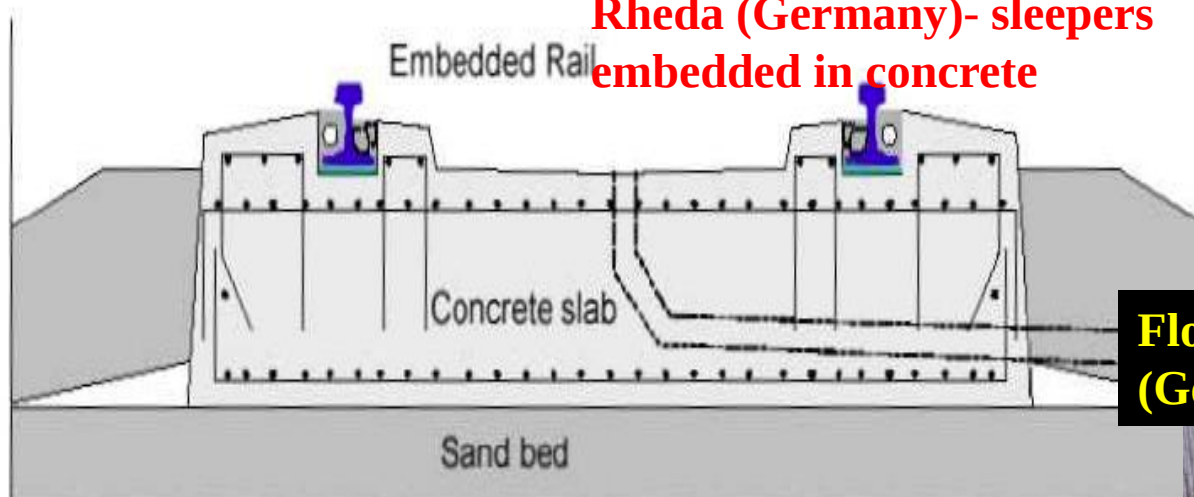
- Embedded in concrete
- Prefabricated slabs
- Monolithic slab
- AC(asphalt concrete)-road bed
- Embedded rail



LVT (Sonneville Company)



**Rheda (Germany)- sleepers
embedded in concrete**



**Floating Slab Track on springs
(Gerb Company)**



Slab track (Japan)- prefabricated

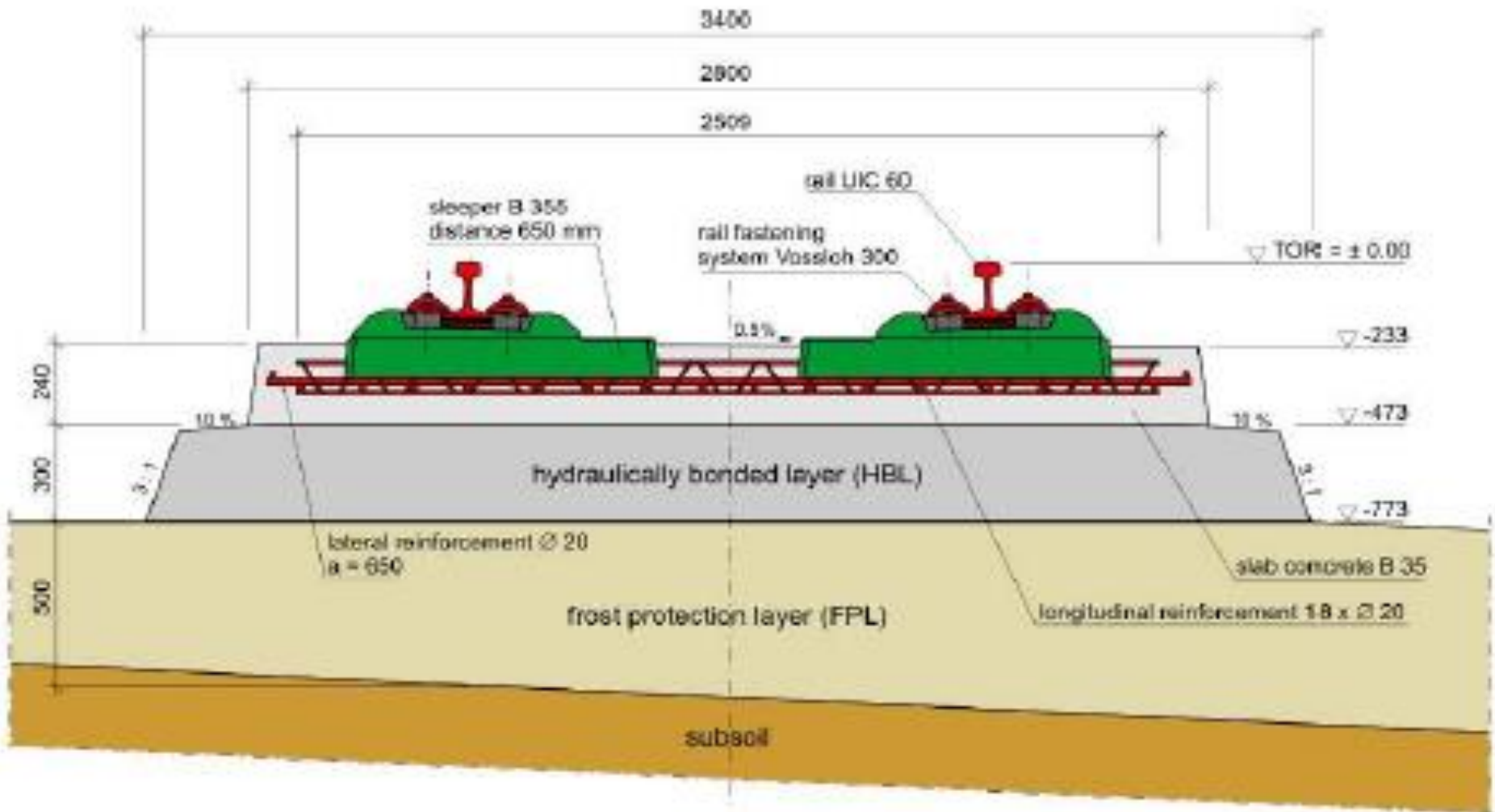


Practical uses of slab track

- Metro, urban rail transit
- Bridge
- Repair inconvenience, small space, traffic density
- Tunnels, subways, elevated crossing, stations & terminals
- High speed railway



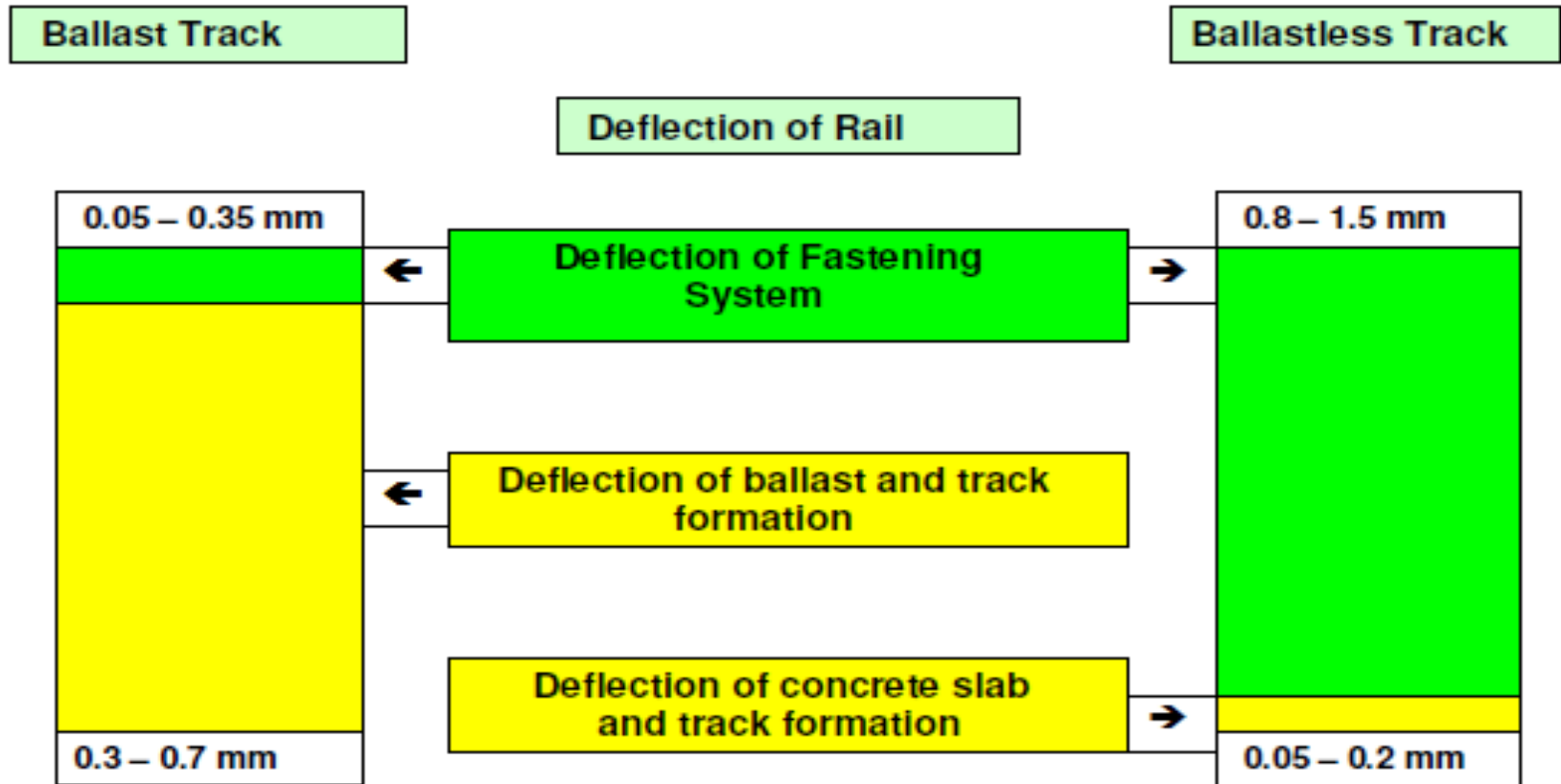
Rheda 2000

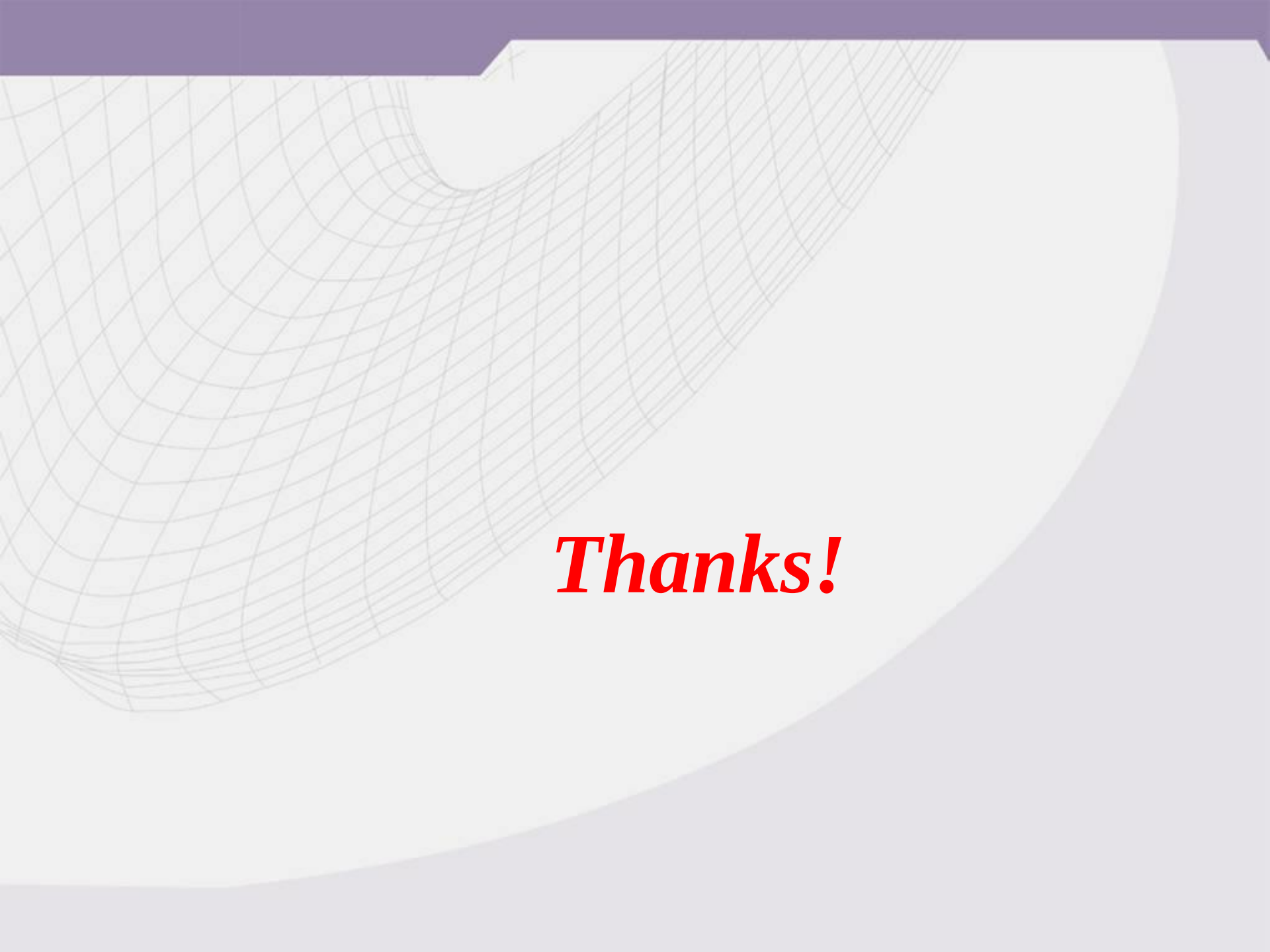


Comparison of ballasted and slab track

Rail Deflection

Ballasted Track - Slab Track





Thanks!