TRACK COMPONENT DESIGN AND SPECIFICATIONS

22-24 APRIL 2019

Part 2

RAIL JOINTS AND WELDING OF RAILS

2

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WEAKNESS OF A TRACK

- Any moving parts of a track is a weak point
- Weak points require more maintenance
- Weak points
  - Free rail joints
  - Joints in fabricated (built-up) turnouts
  - Road-Rail Level crossing
- Rail joints and turnouts are locations where they deteriorates faster than the surrounding track

PURPOSE OF A JOINT

1. To join two pieces of rail where continuous rail is not possible or electrical separation is required

2. Structural objective - to distribute the bending moment and shear force developed from the train loads to the fishplate across the joint to the adjacent rail and subsequently to the track infrastructure.

TYPES OF JOINTS

- Free mechanical joints (fishplated joints)
- Insulated joints
  - Free
  - Glued
  - Plated
- Junction rail joints
- Closure rail joint
- Switch rail joints

MOVEMENT OF WHEEL OVER A JOINT

- Video….

FREE (MECHANICAL) JOINTS

- 2 fishplates are used with fish bolts, spring washers and nuts to mechanically join the rails together.
- The joint is usually between two sleepers but may also be supported directly over two sleepers placed closed together.

FREE (MECHANICAL) JOINTS

- Used in jointed track to join track sections when no insulation is required.
- Consists of the rail, the steel fishplates and 4 or 6 bolts.
- The two pieces of rail can be fastened with a gap typically at 6-10 mm

CLOSURE RAIL JOINT

INSULATED JOINTS

- Insulated Joints are used in track circuited areas where the rails form part of the Signalling System. The joints are placed in the track to prevent the flow of electricity between sections of rail. They divide and isolate the electrical circuit that is used to control the operation of signals.
- There are three types:
  - **Mechanical Insulated Joints**
  - **Bonded or Glued Insulated Joints**
  - **Insulated Plate joints**

MECHANICAL INSULATED JOINT

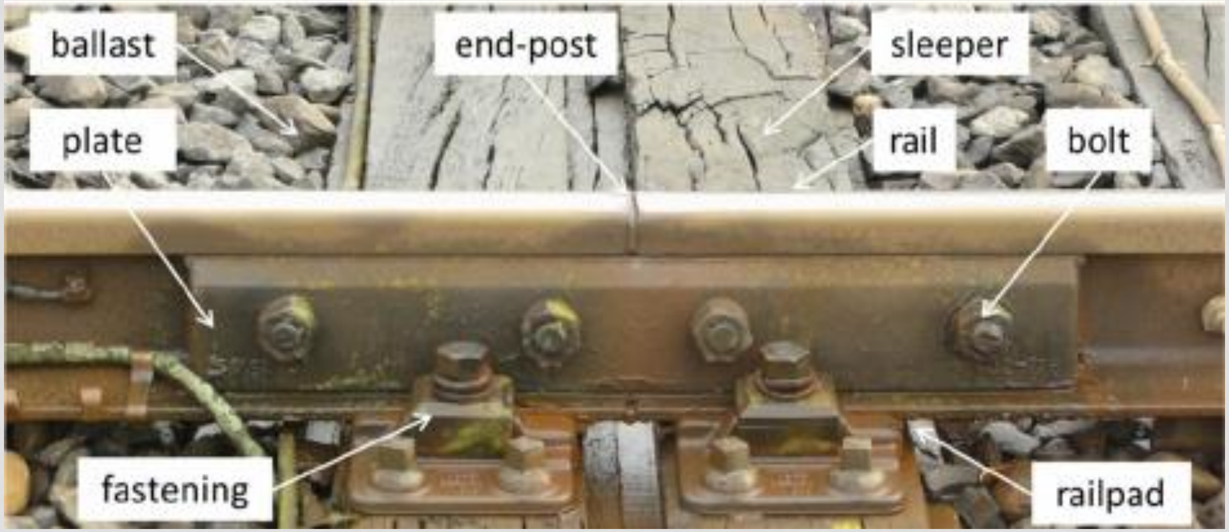
An insulating (non-conducting) material or "fibre" between the rail ends and between the rails, fishplates and fishbolts prevents them from touching or making contact.

Consist of:

- A fibre end post in the rail gap to isolate the two rail ends.
- Shaped liners to isolate the fishplates from the fishing surfaces of the rail.
- Ferrules, or fibre tubes, around the fishbolts to isolate them from the fishplates and the rails.

Photos from RailCorp, Australia

MECHANICAL INSULATED JOINT

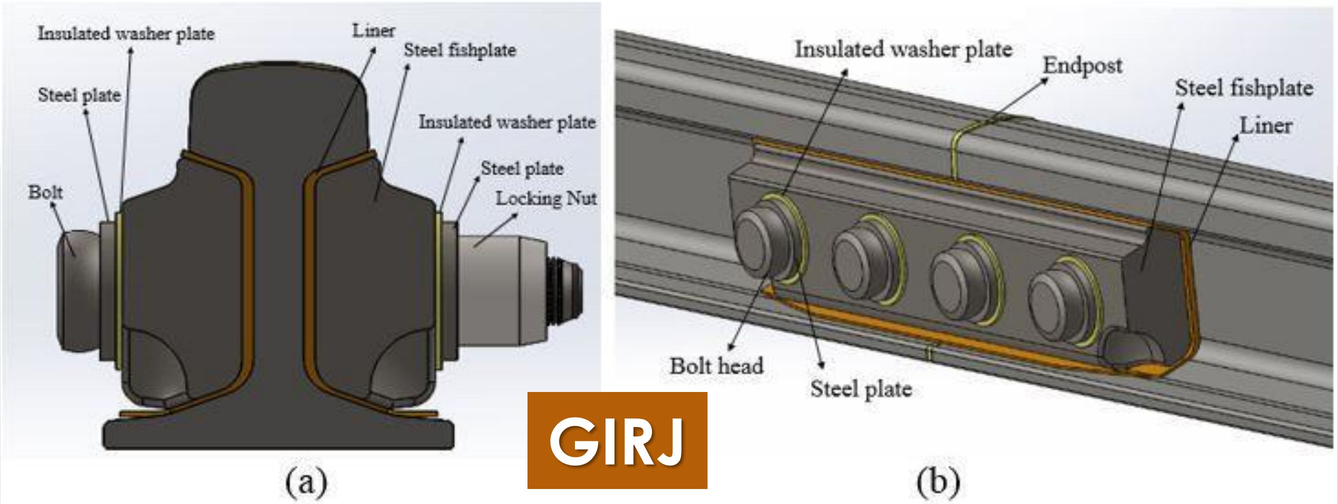


- The insulating endpost is used to insulate the rail ends from each other.
- Commonly manufactured from nylon, epoxy fibre-glass laminated sheet or polyurethane

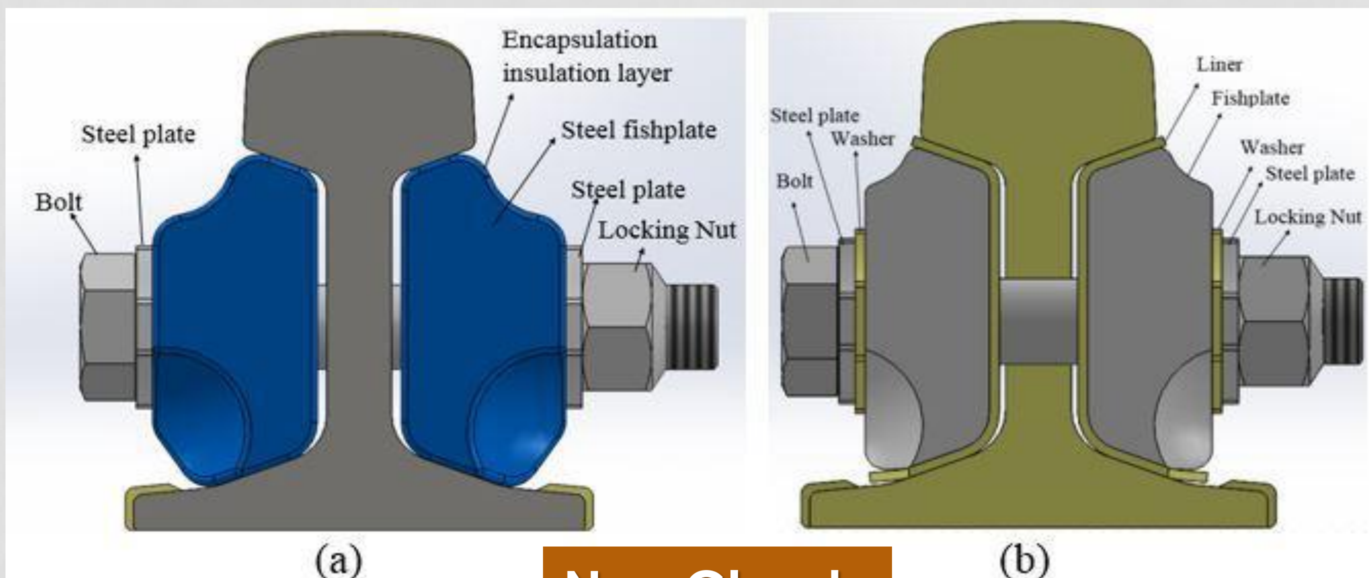
GLUED INSULATED JOINTS (GIJ)

- Specially manufactured and welded into place
- Glued insulated joints have several advantages over mechanical insulated joints.
  - The joint is stronger.
  - Being a rigid joint there is less chance of damage to the insulation through opening and closing of the joint.
  - The joint can withstand more compression and tension.

Photos from RailCorp, Australia



GIRJ



Non Glued IRJ

Source of picure:
GALLOU, M. ...et al., 2018
Assessing the deflection behaviour of mechanical and insulated rail joints through finite element analysis : Loughborough University UK

GLUED INSULATED JOINTS (GIJ)

Salient features of factory made GIJ are:

- The rails are sent to the factory and the joints are fabricated in lengths of 4 to 6.5 meters each. These are then transported to the site and inserted into the track by welding on both ends.
- Insulating resistance in dry condition - over 70 mega ohms.
- No flash over 4000 volts.
- Pull out strength of the Glued Joints with is about 200 tons.

PLATE-JOINT

- The fishplate is completely enclosed in insulation and the joint is fastened together with huck bolts.

JUNCTION FISHPLATE

Photos from RailCorp, Australia

SWITCH RAIL EXPANSION JOINT

SWITCH RAIL EXPANSION JOINT

Picture posted by: Col André Kritzinger

FAILURE MODES OF JOINTS

- Beside vertical forces, the jointed rail is also subjected to longitudinal and lateral forces
- Fishplate “sagging” and “hogging” deformation
- Predominantly fishbolts, fishplate and insulation failures.
- Fishplate failures
  - cracked or broken fishplates,
  - bent fishplates,
  - fishplates with a visible nib at the expansion gap;
- Wheel flanges striking fishplates can also be the reason for damage.

FAILURE MODES OF JOINTS

- Defects arising from use includes rail lipping, contamination (failed insulation) and rail defects (inherent and due to wear and tear)
- Broken rails may occur due to poor rail joints.
- Fatigue cracking due to changes in shear stresses which occur as the wheel passes across the joint.
- Fatigue is particularly severe in bolted joints due to the stress concentration effect on the bolt holes and the dynamic enhancement of the static wheel load due to the structural discontinuity (lower bending stiffness at the joint)

RAIL WELDING

- Standard rails are welded in a depot by the "Flash butt" welding process, or at site by mobile butt welding plant or using the "Thermit" process to form panels of welded rails
- In Flash butt welding two rail ends are brought together and supplied with an electrical current. This melts the rail ends, which are then squeezed together under hydraulic pressure, joining the two rails.
- The resulting excess material around the edge of the weld is sheared off and ground to produce the finished weld.

RAIL WELDING

- Rails are welded in the flash butt Welding Plant into panels, 146m long, which generally function as Long Welded Rail (LWR)
- LWR are welded at site using mobile butt welding plant into Continuous Welded Rail (CWR)

Photos from RailCorp, Australia

THERMIT WELDING (ALUMINO-THERMIC (AT) WELDING)

- In this process, the highly exothermic reaction between aluminium and iron oxides results in the production of molten steel which is poured into a mould around the gap to be welded.
- The superheated molten metal causes the rails to melt at the edges of the gap to be welded, and it is also the filler metal, so that the material from the rails coalesces with and joins the added molten steel as it solidifies to form a weld.
- Thermit is the trade name for one of the granular mixtures of aluminium metal and powdered ferric oxide that is used (also known generically as thermite).
- Ignition of the Thermit is usually carried out by lighting a magnesium ribbon or sparkler.

THERMIT WELDING

Photos from RailCorp, Australia

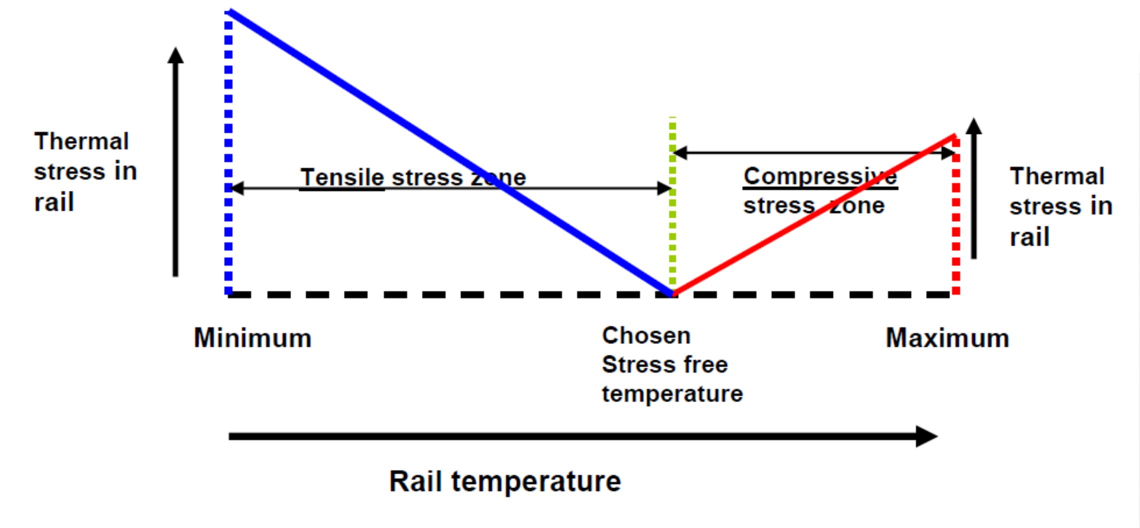
CONTINUOUS WELDED RAIL (CWR)

- Experiments had shown only the end (approx. 90m) that moves with temperature changes
- Called 'Breathing Length'
- Middle portion restrained, induce stress in the rail
- This induced stress = as if rail allowed to expand and compressed back to its original length
- = compressive stress = rail in compression

STRESS IN CWR

- Similarly under falling temperature
- Stress in the middle portion = as if rail allowed to contract and then pulled to its original length
- = tensile stress = rail in tension

THERMAL STRESS



At Neutral Temperature, thermal stress in the rail is Zero

It is not the mean of the Maximum and Minimum temperatures but nearer to the Maximum temperature to minimise compressive stress in the rail to mitigate occurrence of track buckling .

In KTMB 45^0 Celsius has been fixed as the Stress Free Temperature or Destressing temperature

NEUTRAL TEMPERATURE

- Temperature at which the axial forces in a rail are zero. Usually it is the rail temperature at which the stress free rail is anchored to the sleepers
- Direct relationship to the following formula (next slide), that uses Hooke's law where *Stress = Steel modulus of Elasticity* x *Strain*

Ref: Fundamental of Railway Engineering by Dr Arnold Kerr

HOOKE'S LAW

- **The stress within an elastic solid is proportional to the strain responsible for it**

- **Tensional stiffness of a uniform bar**
- We may view a rod of any elastic material as a linear spring. The rod has length *L* and cross-sectional area *A*. Its extension (strain) is linearly proportional to its tensile stress *σ*, by a constant factor, the inverse of its modulus of elasticity, *E*, hence,

.

E = stress / strain = σ / ε
σ = E ε

Where Strain $\varepsilon = \dfrac{\Delta L}{L}$

This may also be expressed as: $$\Delta L = \frac{F}{EA} L = \frac{\sigma}{E} L.$$

STRESS FORCE IN THE RAIL

$$P = EA\alpha(T_R - T_N)$$

T_N = Neutral Temperature

T_R = Temperature at relaying or laying

E = Modulus of elasticity = 30 x 10^6 psi= 0.207 x 10^6 N/m^2 = 0.207 MPa

A = Cross Sectional Area of Rail

α = coefficient of linear expansion for steel

= 0.000012 (m/m ^{o}C)

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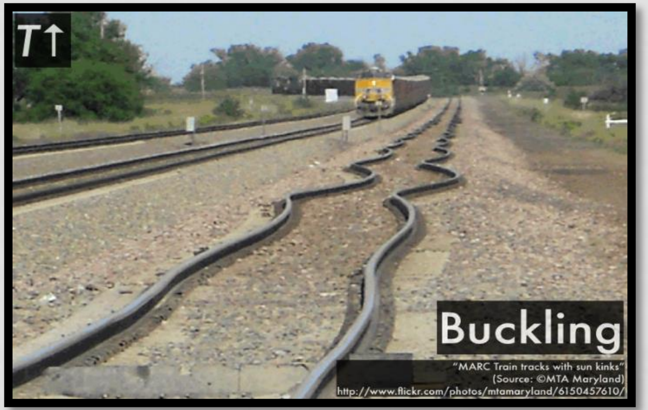
TRACK BUCKLING

TRACK BUCKLING PHOTOS



ADVANTAGES OF CWR

- 30-35% longer rail life
- Reduce on-track maintenance costs by 50%
- Reduction in rail breakages (esp. bolt-hole star crack fracture)
- 5% savings in traction energy costs
- Increase track life
- Better ride quality
- Allows higher speeds
- Reduce rolling stock spring breakages
- Reduce noise and vibration

Ref: British Railway Track

ADVANTAGES OF CWR

- However, the continuity of the track has got to be broken on either side of the railway stations for the transmission of the electrical signals, which are used to avoid accidents like collisions and derailments.

- These disadvantages of the conventionally insulated joints were overcome by the introduction of Insulated Glued Rail Joints. In this joint, rails, fish plates, bolts and nuts are permanently bonded together with an insulating epoxy adhesive. Such Insulated Glued Rail Joints have a life of several years if properly maintained and are more economical in the long run, although initially costlier.

REQUIREMENTS FOR LWR &CWR

- Profile:

  Conformance to adequate standard ballast profile

- Formation:

  Formation shall be stable. Stretches of bad formation shall be stabilised before laying LWR/CWR.

- Ballast:

  The minimum cushion below the bottom of sleepers shall be 250 mm of stone ballast. Shoulder width shall be:

  - On straight or inside of curve 310 mm.
  - On outside of curve 460 mm.

  Shoulders on both sides shall be humped to the extent of 100 mm.

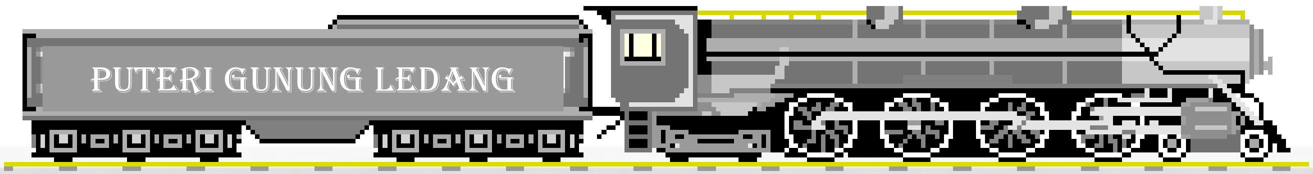
REQUIREMENTS FOR LWR &CWR

Sleepers:

- Concrete or wooden sleepers with elastic fastenings shall be used. The sleeper density shall conform to the standards specified for Class 1. Spacing of sleepers not more than 700mm.

Rails:

- CWR/LWR shall be laid with 80 pounds or heavier rail. New rails shall be without fish-bolt holes,
- In cases of conversion of existing fish-plated track into LWR, it shall be ensured that:
  - Defective rail ends are cropped.
  - Only those rails tested ultrasonically and found without flaws are used.



"That's it....

Thank you....."

Any questions?