

CODE OF PRACTICE

Track Stability

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Foreword

This code of practice is intended to support the standard AS 7643 – Railway Infrastructure - Track Stability on Track Stability, and should be read in conjunction with it.

1 Introduction

1.1 Application

This code of practice applies to tracks constructed on sleepers in open ballasted track with rails which are continuously welded, long welded or mechanically jointed.

Direct fixation track system such as those on track slabs have their own performance characteristics and are not included in the scope of this document.

The code covers rail networks classified in AS 7630 Railway Infrastructure – Track Classification for all track gauges.

1.2 Acronyms

The following acronyms have been used in this document:

CWR Continuously Welded Rail

LWR Long Welded Rail

SFT Stress Free Temperature

DNT Design Neutral Temperature

1.3 Definitions

Continuous Welded Rail (CWR): A continuous rail length, welded or a single string, which requires management of residual stress-free temperature (SFT) by a rail adjustment procedure to address variance between ambient rail temperature and the design SFT.

The minimum length to be treated as CWR shall be declared by the RIM. (This is generally considered to be for rail lengths greater than 220 metres; however, circumstances may require shorter lengths to be included)

Long Welded Rail (LWR): A rail, longer than standard production length but less than RIM defined CWR, joined by fishplates where expansion and contraction may still be managed through rail gap management.

LWR will be of lengths greater than 27.4 metres up to a minimum length stated by the RIM to be CWR.

Jointed Rail: Rails of a standard production length, jointed continuously by fishplates. Expansion and contraction is wholly addressed by management of rail gaps prescribed for ambient rail temperature

Production of standard rail length generally is provided in lengths of 27.4 metres.

2 Track planning and design

2.1 Track instability

Longitudinal and lateral movements of the track are constrained by the rail, fastenings, sleepers, and ballast. If the resistance provided by these track components are insufficient, then the track is likely to buckle under the high longitudinal compressive forces developed in the rails.

- Factors that can contribute to track instability include the following:
- Cross-sectional area of the rail and continuously welded length.
- Actual SFT of CWR.
- Geometry and gradient of track.
- Rail temperature.
- Rail creep and any fixed points
- Axle loads.
- Track disturbances.
- Unrectified previous buckle/misalignment
- Track speed.
- Train frequency.
- Train length.
- Train braking action
- Rail surface irregularities
- Single direction tonnage or traffic
- Condition and profile of the ballast.
- Type and condition of sleepers.
- Types and effectiveness of rail fastenings including rail anchors.
- Frequency, gap and effectiveness of rail joints.

2.2 Ballast

Ballast in the cribs and on shoulders provides the most resistance to track buckling. There should also be sufficient depth of ballast under the sleepers to provide adequate support for the loads imposed on it.

The minimum ballast shoulder width should be 400 mm for CWR and LWR track. For curved tracks with tight radius of 400m or less, it is recommended that the ballast shoulder be enhanced by the addition of a surcharge or windrow of ballast on the ballast shoulder.

The effectiveness of increased width of the ballast shoulder beyond 400mm may be limited.

For maximum track stability, the ballast needs to be angular, well graded and compacted. The ballast also needs to be well drained and clean in order to provide frictional resistance to anchor the track. Ballast shall comply with the requirements of AS 2758.7 – Aggregates and rock for engineering purposes Part 7: Railway ballast.

2.3 Sleepers

Contribution by sleepers to the stability of the tracks varies with the types of sleepers, i.e. timber, concrete, etc. The tendency of the track to buckle laterally due to thermal loads is resisted by the lateral passive forces from the ballast exerted through the sleepers, and by the frictional forces at the interface of the ballast with the underside and sides of the sleepers.

Due to their weight, shape and dimensions, full-depth concrete sleepers tend to provide the most effective resistance to longitudinal and lateral movements of the track under traction, braking and thermal forces, compared to other sleepers. They are therefore preferred over other types of sleepers for track stability. Timber sleepers also tend to provide better resistance than steel sleepers.

A decrease in sleeper spacing will improve both longitudinal and lateral resistance of the track.

The addition of lateral resistance end plates on concrete or timber sleepers will increase their lateral stability, typically used on tight radius curves.

2.4 Rails

Rails on tracks are either jointed using mechanical connections like fishplates, or welded into longer lengths such as LWR which are usually between 110m and 300m, or as CWR which has no joints.

Different sized rails will develop the same thermal expansions and contractions in the rail, but induces different thermal forces due to the different cross-sectional areas. So, while an increase in rail size, and therefore also an increase in its stiffness in both the vertical and horizontal planes may be able to support heavier traffic, it will be at the expense of lowering the buckling resistance of the track. The design for track stability should take this into consideration when assessing the capacity of the track for heavier axle loads.

2.5 Rail fastenings

2.5.1 Holding down fasteners

Resilient fasteners should be used on all types of sleepers where economically viable as they provide the most effective restraints for preventing track buckling. The high rotational effect between rail and sleeper means that constraint provided by non-resilient types such as dogspikes in timber sleepers is relatively ineffective compared to resilient fasteners, in these cases rail anchors will be required to be used.

2.5.2 Fasteners for longitudinal restraint

Rails should be correctly restrained on sleepers to limit longitudinal movement. Rail anchors should be used with timber sleepers where no resilient fasteners are used, to help arrest this longitudinal movement. Resilient fasteners perform the same longitudinal resisting function as rail anchors. However, resilient fastening system tends to reduce the effectiveness of rail joints as it restrains rail expansion.

Rail anchors should not be applied to rails on bridges with elastomeric bearings, except on ballasted tracks, unless approved by the Track Manager.

The installation requirements for the types of fasteners and the quantity required for LWR, CWR and jointed rails are usually specified by the Track Manager. Fastening systems shall comply with AS 7639 Railway Infrastructure – Track Structure and Support and AS 1085 Railway Track Materials.

2.6 Rail joints

Rail joints should not be located:

- Within 5 m of bridge abutments.
- Within the road pavement in level crossings.
- In any sleeper transition zones.

Sleeper transition zones are sections of track where the stiffness of the track bed changes considerably over a short distance as different types of sleepers are interspersed over a short distance. Sudden changes can also occur in the transition from open track to a bridge, or from a ballasted track to a slab track.

2.7 Track geometry and structure

Track alignment design needs to take into consideration the likely track geometry and locations where track buckling may occur. CWR has a higher likelihood of buckling especially on tight radius curves. The recommended minimum radius for CWR generally varies from 160 m to 400 m.

The presence of sag and crest on the track affect the SFT. Steep gradient on vertical curves can result in excessive longitudinal forces in the rails due to bunching and stretching of the rails caused by braking and tractive efforts of rail vehicles.

At locations where the track support structure changes, particularly where the interface between two types of track structure may cause a significant change in restraints against rail buckling (e.g. a change from timber sleepers to concrete sleepers, a change in rail size, a change from plain track to a turnout, or a change of fastening systems), the design shall provide for a progressive change in stiffness of the track. Changes in track structure should not be located on tight curves (of 400 m radius, say), including transitions, approaches to transom top bridges, and level crossings.

2.8 Rail temperature

2.8.1 Design stress free temperature

Thermal forces induced in rails are controlled by designing the rails to a stress free condition taking into consideration the desired SFT in the types of environment the rails will be laid, e.g. in open air environment or in tunnels.

SFT is the rail temperature in the rail at which the longitudinal stresses in the rail is zero, i.e. the rail is neither in compression nor tension.

It is the control temperature where:

- The compressive load at the highest summer rail temperature will not buckle the rail.
- The tensile load at the lowest winter rail temperature will not initiate pull-apart or tensile fracture.

The SFT can change over time due to heating and cooling cycles. It can also differ between two rails on the same track.

The design stress free temperature is generally between 35° C and 40° C. The correct SFT should be chosen to suit the climate, i.e. the maximum and minimum rail temperature as well as the temperature

frequency distribution. The criteria for the selection of the appropriate design SFT should be specified by the Track Manager.

The factors to be considered in determining the design SFT should include the following:

- Expected minimum and maximum rail temperatures.
- Local and seasonal conditions which may affect the rail temperature.
- Track structure and condition.
- History of track buckles, track shifts and pull-aparts.

There are a number of methods used to determine the preferred design SFT, all of which will require the selection of the expected maximum and minimum rail temperatures.

The following is an empirical procedure to determine the preferred design SFT (T_{SFT}):

1. Determine the expected rail temperature range (T_{Δ}) by subtracting the expected minimum rail temperature (T_{min}) from the expected maximum rail temperature (T_{max}), i.e.

$$T_{\Delta} = T_{max} - T_{min}$$
2. Determine the upper limit (T_{upper}) of the design SFT range by adding five sevenths ($5/7$) of the expected rail temperature range (T_{Δ}) to the expected minimum rail temperature (T_{min}), i.e.

$$T_{upper} = T_{min} + (5/7) T_{\Delta}$$
3. Determine the lower limit (T_{lower}) of the design SFT by subtracting half ($1/2$) of the expected rail temperature range (T_{Δ}) from the expected maximum rail temperature (T_{max}), i.e.

$$T_{lower} = T_{max} - (1/2) T_{\Delta}$$
4. Determine the preferred design SFT (T_{SFT}) by adding the lower limit (T_{lower}) to three-quarters of the difference between the lower limit (T_{lower}) and upper (T_{upper}), i.e.

$$T_{SFT} = T_{lower} + (3/4) (T_{upper} - T_{lower})$$

Isothermal maps (After Hagaman and Kathagen, 1988) of maximum and minimum expected rail temperatures in Australia can be used as an aid in determining the SFT. The maps are shown in the following figure:

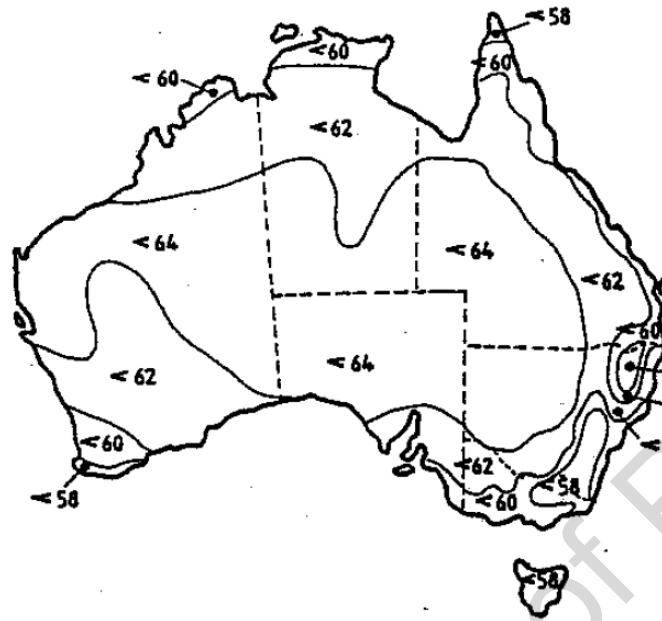


Figure 1 - Maximum expected rail temperature

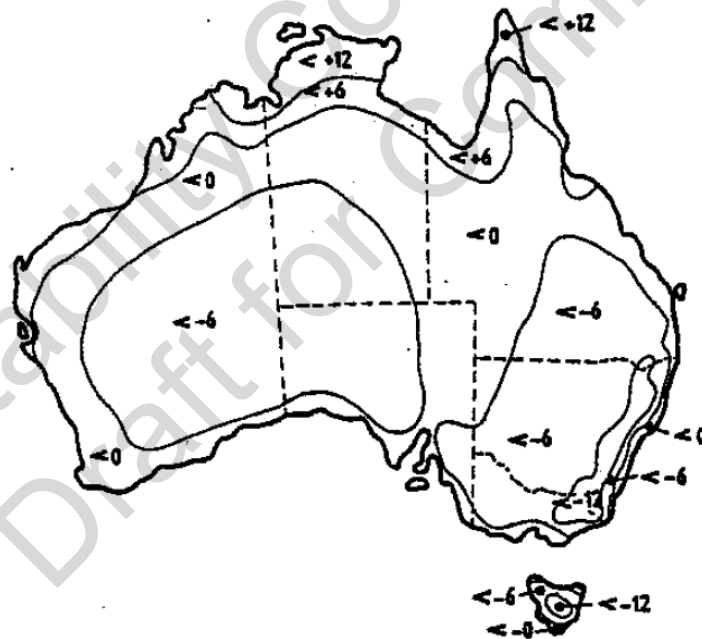


Figure 2 - Minimum expected rail temperature

2.8.2 CWR track

For continuously welded rail (CWR), the following equation is generally used to determine the design SFT:

$$T_{SFT} = (T_{max} + T_{min}) + 5$$

where $T_{\max}$ = maximum rail temperature (°C)
 $T_{\min}$ = minimum rail temperature (°C)

In CWR there will always be compression when the rail temperature is more than the SFT, if the rails are correctly adjusted. Similarly, there will always be tension in correctly adjusted CWR when the rail temperature is less than the SFT.

The exact gap (or Theoretical rail gap) required to adjust the rail to the SFT in CWR can be determined by the following method:

$$\text{Theoretical rail gap} = (T_{\text{SFT}} - T) \alpha L$$

where T_{SFT} = design SFT (°C)
 T = shade (actual) rail temperature (°C)
 α = coefficient of thermal expansion for steel (0.0115 mm/m)
 L = length of free rail (m)

The total gap required is the theoretical rail gap plus the welding gap. The gap required for the weld is dependent on the type of weld, and is usually between 12 and 20mm, depending on the type of welds.

The theoretical rail gap can also be determined graphically. Figure 3 shows a Rail Adjustment Graph for various rail lengths at a SFT of 35° C.

To use the graph,

1. Determine the exact rail temperature and rail length.
2. From the selected value of the exact rail temperature in the abscissa, trace vertically to intersect the line relevant to the rail length required.
3. From the point of intersection, trace a line to the ordinate on the left to obtain the exact gap required to be pulled up with a tensor. To this must be added the gap required for the weld.

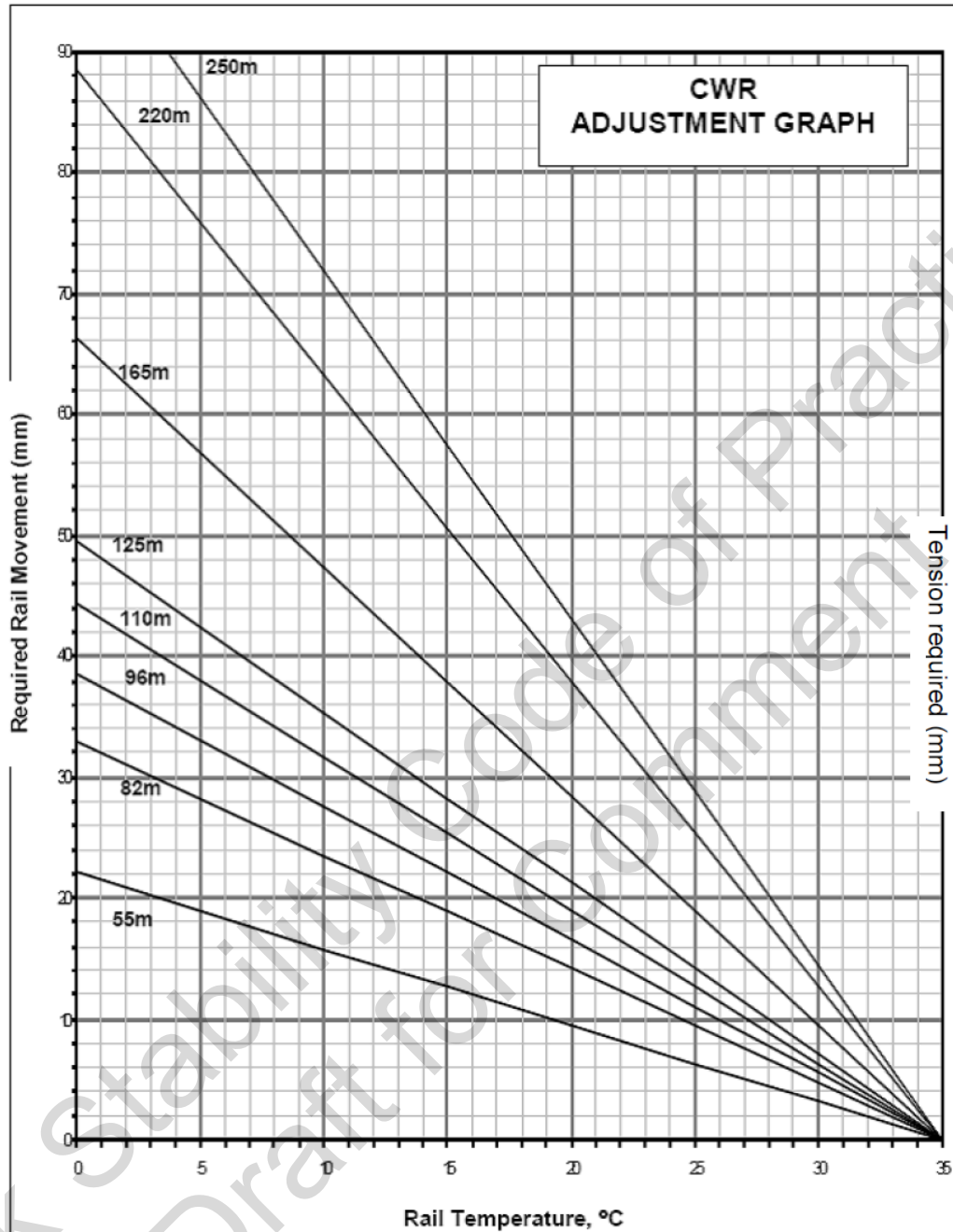


Figure 3 - Rail adjustment graph for CWR

2.8.3 Jointed rail and LWR

Jointed rails with joints fully closed, i.e. no gap, will be in compression. To overcome this, an additional allowance (preferred gap) should be added to the expected extension of the rail due to the difference in temperature between the SFT and the rail temperature. Alternatively, the compressive rail forces can be controlled by adding additional ballast on the shoulders.

This theoretical rail gap can be determined from the following equation based on a preferred gap specified by the Track Manager:

$$\text{Theoretical rail gap} = W_{\text{gap}} + (T_{\text{SFT}} - T) \alpha L$$

where

W_{gap} = preferred gap (mm)

T_{SFT} = design SFT (°C)

T = shade (actual) rail temperature (°C)

α = coefficient of thermal expansion for steel (0.0115 mm/m)

L = length of free rail (m)

The preferred gap is usually 5mm to 6mm nominally.

This can also be determined graphically. The following shows a Rail Gap Chart for various rail lengths based on a theoretical gap of 6 mm at a SFT of 35 °C.

To use this chart,

1. Determine the exact rail temperature and rail length.
2. From the selected value of rail temperature in the abscissa, trace vertically to intersect the line relevant to the rail length required.
3. From the point of intersection, trace a line to the ordinate on the left to obtain the exact expansion gap required.

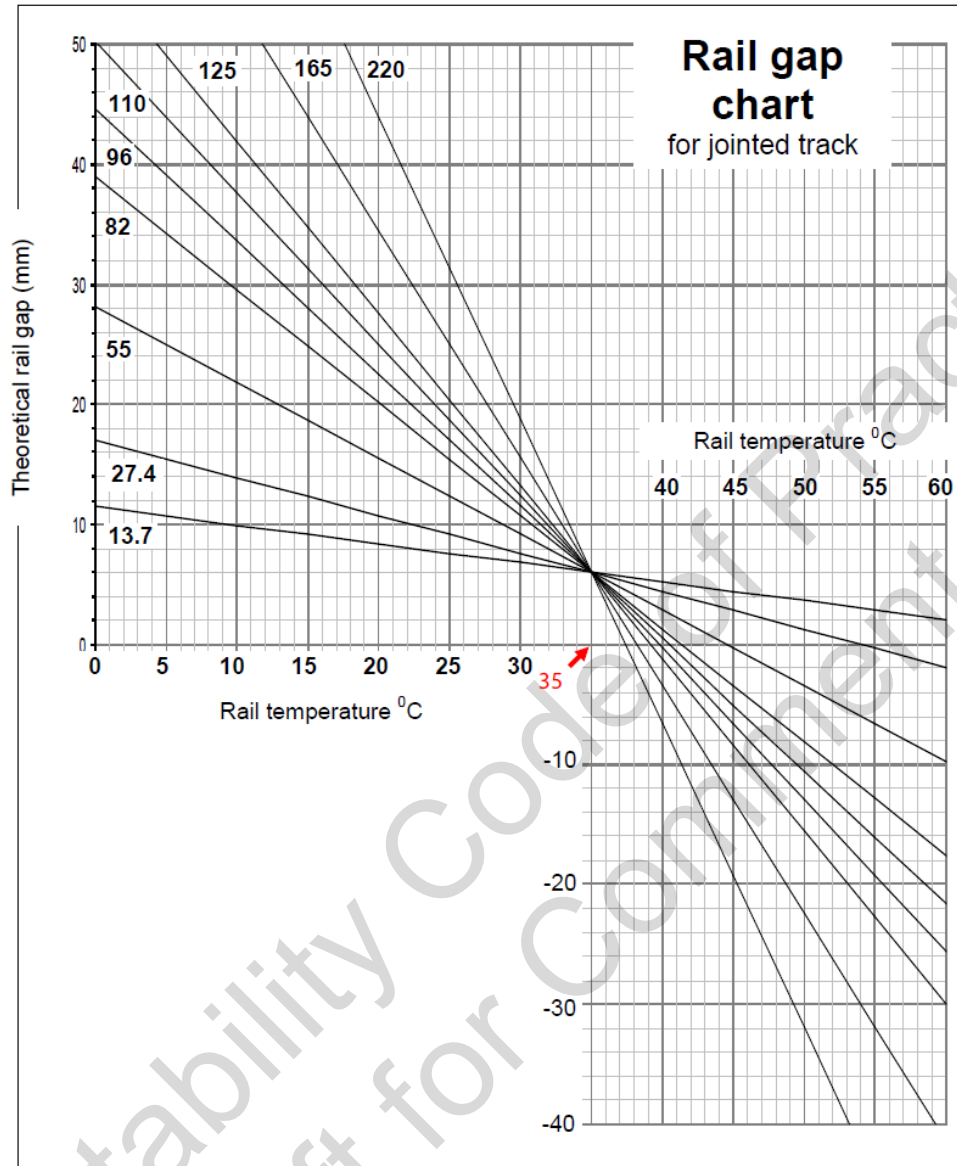


Figure 4 - Theoretical rail joint gaps for varying rail temperature and rail length

2.9 Rail creep

Rail creep is the longitudinal movement of rails due to movement between the rail foot and sleeper and/or the sleeper and ballast. It occurs when rail temperature changes, and when the train dynamic forces due to braking and traction exceed the longitudinal resistance of the track. It is more predominant in sags at the bottom of steep gradients in tracks where they are more susceptible to heavy braking and tractive effort; and also near fixed points due to bunching of the rail by the passage of rail vehicles.

Creep will gradually cause the actual SFT of the rail to deviate from the design SFT over time.

Creep is resisted by:

- The friction between rail and sleeper.
- The friction between sleeper and ballast.
- The grip of the rail to the sleeper fastening assembly.

The most common method of constraining creep in mechanically jointed rail is the installation of additional anchors to the rail foot, or the use of improved (resilient) fastenings.

2.10 Axle loads and speeds

Increased axle loads, in conjunction with high temperature, tend to reduce the upper limit of the temperature at which buckling occurs. It has very little influence at the lower temperature.

Speed restrictions are sometimes imposed during hot weather to reduce the stresses imposed on CWR and LWR by trains as a precaution against track buckling. They are also applied after any track disturbing work because of the reduced lateral resistance of the track, until such time the track can be stabilised.

It is the responsibility of the Track Manager to determine the threshold temperature, duration and procedure for applying speed restrictions.

3 Track construction and maintenance

3.1 General

Construction and maintenance of track to reduce the risk of track instability are generally targeted at the following elements:

3.2 Ballast

Ballast should be placed on a prepared formation bed of engineered material as specified by the Track Manager. Ballast depth can vary depending on the class of track.

The ballast shoulder profile should be level with the top of sleepers for a width of 400mm outward from the end of sleepers. Additional ballast shoulder surcharge may be necessary in areas of tight curves or poor track lateral stability. Although a good and well compacted ballast shoulder assists in lateral stability, too much ballast can retard drainage.

Fouled ballast will lead to poor drainage of the formation, and will cause the pumping of sleepers in the track, thereby severely reducing the ability of the ballast to resist buckling forces. Foul ballast should be replaced or cleaned.

Track disturbing works, such as tamping, reduces the mechanical interlock of the ballast particles. The effect of disturbing work is typically short term and the interlock is gradually restored as rail traffic progressively traverses the track.

3.3 Sleepers and fastenings

The condition of the sleepers and fastenings should be checked and replaced where necessary. This is particularly important if track disturbing work is to be carried out during the summer months on buckle prone sections of track. It is recommended to limit the number of sleepers removed at any one time to a maximum of 1 in 6 or 3 in a row.

Fastenings should not be loose to require tightening or replacement before any maintenance work is undertaken.

Anchor maintenance is an important part of maintaining lateral track stability. Missing or defective anchors should be replaced in each maintenance cycle, and intercycle, when found. Rail anchor pattern must be maintained. The process and procedures for the installation of rail anchors and the minimum anchoring pattern shall be specified by the Track Manager.

3.4 Track disturbance

All track disturbing works such as tamping, resleepering, rerailing and resurfacing involve disturbance to sleepers and ballast, which will reduce the SFT. The lateral resistance of the track can be reduced by as much as half during these operations.

Locations where the track has been disturbed should be closely monitored or protected by Temporary Speed Restrictions until at least 250,000 gross tonnes have passed over to consolidate the ballast. Alternately, the ballast should be compacted with a crib and shoulder compaction machine.

The removal of speed restrictions after track disturbance should be gradual as the passage of train gross tonnage increases, i.e. start with a speed restriction of 40km/h for some days, then if all is satisfactory, the speed limit could be increased to 60km/hr until line speed is re-established after 250,000 gross tonnes have traversed the track. The use of a Dynamic Track Stabiliser negates the need for any TSR's for ballast consolidation.

The Track Manager shall determine whether the track is safe for the passage of trains at normal speed or whether a speed restriction is required and the duration the speed restriction is to stay in force.

3.5 Rail stress management

CWR and jointed rail must be laid to the design SFT. Expansion gaps must be provided between rail ends for jointed rails and CWR. In CWR, these are temporary and will be removed when rail is welded.

It is important that any changes from the design SFT can be detected and the rail adjusted when required to prevent track misalignments and buckling. Measurements of expansion gaps in jointed rails and creep markers in CWR are the usual control measures to monitor the changes.

Rail stress assessment and if necessary, adjustment should be carried out to maintain the design SFT, when one of the following events occurs:

- Construction of new track.
- Track realignment works, e.g. slewing or lifting of track.
- Modification in track structure, e.g. changing existing mechanically jointed track into LWR or CWR
- Defect removal and it is more than 2 years since the track was last stressed.
- Installation of new or serviceable rail.
- Significant rail misalignment.
- Excessive rail creep.
- Track buckles.
- Pull-aparts.
- Mechanical joint failures (for jointed rails).
- Alteration or adjustment of the stress free temperature.
- Rail was last de-stressed more than 15 years ago (assuming 1 deg. loss per year).

In CWR, the rail stress adjustment process involves destressing the rail by cutting and adjusting rail length to reset the rail's SFT. The existing SFT of the rail can be determined by measuring the change in length after relaxing the rail by cutting it free. There are several proprietary devices available which can determine the approximate rail stress without cutting the rail on defined sections of track. Their use should be subject to the approval of the Track Manager.

When rail is unrestrained, i.e. not clipped up or restrained, its stress-free value is equal to the current rail temperature.

To ensure the actual SFT is equals the design value, adjustment is made by determining the extension gap required, then pulling the rail together with a tensor to be welded.

Rail expansion gap adjustments should be carried out on LWR and mechanically jointed tracks as required.

3.6 Stress control

3.6.1 General

All stress control in track elements and conditions should be controlled in accordance with the following practices, which are described in detail in RISSB Code of Practice, Volume 4 of Track, Civil and Electrical Infrastructure, Part 3: Infrastructure Guidelines.

3.6.2 Stress control—maintenance of the current rail stress condition

This control method is primarily used for the replacement of sections of rail in jointed track, including LWR, where the length of rail to be adjusted does not warrant the disturbance of the track. The length of rail to be inserted should not exceed 15 m.

Reference points for stress retention should be established on the rail outside the insert length prior to cutting. The distance between the reference points prior to cutting the rail, and after the rail has been stressed and welded into track, should be the same.

3.6.3 Stress control—stress adjustment of CWR

Rail stress assessment, and if necessary adjustment, should be carried out whenever the following events occur:

- Rail is being laid into track.
- Signs of buckles or pull-aparts and mechanical joint failure in track.
- Significant rail creep.
- Significant change in track alignment.
- Rail is cut.

CWR that is being stressed should be subject to the following limits:

- The maximum adjustment length should not exceed 500 m, i.e. length between anchor blocks.
- The finished SFT should be within ± 2 °C of the design SFT.

Procedures for the adjustment of the rail stress shall be subject to the approval of the Track Manager.

4 Monitoring processes

4.1 Identification of vulnerable locations and history

Track sections that exhibit a history of proneness to lateral track instability or pull-apart failures should be identified and managed as special locations, as defined in RISSB Code of Practice, Volume 4 of Track, Civil and Electrical Infrastructure, Part 1: Infrastructure Management.

Locations where a potential reduction in track stability could occur include:

- Locations with a buckling history.
- Locations with rail fracture/pull-apart history.
- Track alignment not to monuments
- Degraded track, e.g. foul or inadequate ballast, deficient sleepers and poor drainage and formation.
- Sites of recent maintenance or renewal works.
- Tight curves.
- Winter repaired and readjusted rail segments.
- Locations consistent with heavy braking and traction forces, such as at bottom of steep grades.
- Locations with excessive rail movement or bunching.
- Locations with sudden changes in longitudinal resistance, such as at bridges, track crossing work and level crossings.
- Locations exposed to significant temperature fluctuation or differential, such as in deep cuttings and tunnels.

4.2 Measurement of rail creep

The presence of creep in mechanically jointed rail can be readily detected by observing the rail joint gaps and in CWR or LWR, by measuring movement of rail relative to a fixed point.

Rail creep monitoring stations should be established at locations along the track that are susceptible to track buckling. Where creep measurement is used to assess the stress-free temperature, it shall be carried out at a predetermined frequency as determined by the Track Manager.

Measurements should be collected over time to identify the general trends in the rate and direction at which the rails are moving.

Creep monitoring could comprise permanent reference marks on the rails, and their positions along the track measured relative to a fixed reference point or monument beside the track but square to it. It is recommended that the fixed reference point or monument be at least 3.5m from the track centreline, far away from any possibility of being disturbed during track maintenance. Creep monitoring locations should be established at defined intervals along sections of track to be monitored for creep.

It is generally accepted that rails should be restressed if the creep exceeds 50mm in any 500m length of track.

4.3 Measurement of stress free temperature

Rail force is estimated from the difference between rail temperature and the SFT. The SFT is usually determined by either destructive tests, e.g. requiring rail cuts, or by non-destructive methods, on the rail.

A number of proprietary systems for non-destructive methods are available. Each uses different technology, and has their own limitations and peculiar requirements for determining the SFT.

Any method of measuring the SFT shall be subject to the approval of the Track Manager.

4.4 Monitoring of rail expansion gap

Rails in jointed track, excluding LWR, shall be laid or adjusted to provide the required expansion gap at the joints when the rail is at the SFT. This gap shall be increased by 1mm for every 7° C in the rail temperature below the SFT, and decreased by 1mm for every 7° C increase in the rail temperature above the SFT.

Expansion gaps at all joints on or near open deck bridges should also be measured and recorded as part of the creep monitoring. Near bridges, the monitoring location should not be within quarter point of the bridge span.

In jointed track, at the SFT, the average gap of each joint in a track section should be at the preferred gap, as designed.

5 Lateral track stability

5.1 Contributing factors

There are numerous factors that contribute to the instability of track.

In terms of CWR, contributory factors and preventative remedies include:

- Stress free temperature incorrect, due to incorrect stressing, or to creep. Remedy: Restress.
- Stress free temperature incorrect, due to curve pull-in. Remedy: Realign curve to survey and restress.
- Insufficient superelevation or sharp "kink" in curves. Remedy: Adjust cross level to designed measurements and put curve on correct alignment. Poor alignment will cause poor superelevation. Poor superelevation will cause poor alignment.

As a result of one or more of the above conditions, the track stability may be reduced.

This instability may develop rapidly into a buckle due to dynamic loading from trains. In other cases, buckles develop with increased temperature or higher variance in temperature over a period of days or weeks. During this time, evidence of reducing stability may be observed as slight variations in alignment. While increased temperature will increase the compressive forces in the track and initiate a buckle, any resulting buckle is "caused" by lack of stability due to the factors listed above, not the increased temperature.

Where there are multiple contributory factors present, buckles may occur at relatively low ambient temperatures. On sharp curves, the risk of buckling is significantly greater than on straight track or large radius curves.

5.2 Procedures for train operation following track maintenance or disturbance

Following resurfacing works (or equivalent track disturbance), the Track Manager should determine the speed at which the track is safe for the passage of trains at normal speed and whether a Temporary Speed Restriction (TSR) is required. If a TSR is required, the Track Manager should determine the intended duration.

Further details regarding train operations following track maintenance or disturbance are documented in the RISSB Code of Practice Track Stability.

5.3 Monitoring processes

5.3.1 Identification of vulnerable locations and history

The keeping of good records will include the locations where CWR has been installed at the correct DSFT, as well as Creep monitoring marks of significant points in addition to kilometre and half kilometre points. In addition, identification of areas vulnerable to alignment and stability issues begins with maintaining good records of the following:

- Measurements of creep, rail stress and records of the track alignment in curves in the areas where CWR adjustment is located. It is typical that no alignment measurements are required on tangent track.
- Locations of bridges and track slabs with elastomeric bearings.
- Review out-of-tolerance alignment measurements to determine suitability for adjustment.
- Rails that are not on correct alignment.

In addition, management & reporting of welded track stability should:

- Establish programs to measure welded track stability prior to the summer season, and, where it has been identified that curve pull-ins are a problem, prior to winter works programs.
- Ensure that all staff involved in measurement have appropriate tools -thermometers, gap gauges, alignment survey data etc. and that all tools are checked and calibrated. Ensure that all staff involved in measurement are aware of requirements for consistency in measuring and recording and have copies of measurement procedures.
- Establish programs to analyse welded track stability prior to the summer season, including.
- Analysis software tested and/or readied for use
- Technical staff appropriately schooled in use of the software, data entry and checking of information
- Establish a recording system to monitor progress of measurement, analysis and removal of priority stability locations.
- Monitor the recording system regularly to verify accuracy.
- Ensure analysis is completed, including an analysis of bunching points.
- Determine locations where analysis and assessment of lengths <500m is to be used. It is appropriate to assess anomalous sections such as locations where adjustments are uncharacteristic of the average result for the section.
- Have systems in place to ensure that any area where adjustment control has been found to be lost is classified as non-standard track.
- Have systems in place to ensure that potential stability issues are identified.

- Ensure that any errors in welding during the year are considered in the track stability analysis process.
- Analysis of all priority locations to determine appropriate corrective action. This may include CWR on timber sleepers, steel sleepers or interspersed steel sleepers where:
 - traffic is predominantly unidirectional at speeds > 40 km/h, or
 - traffic includes passenger trains at speeds > 100 km/h.
 - Is adjacent to overbridges.
- Arrange check of track alignment on sharp curves that:
 - Have a history of winter pull-in (check in mid to late November)
 - Have been disturbed by resleepering/ resurfacing etc (check in mid to late November or one week after the activity whichever is the later)
 - Appear to have pulled in from visual inspection on track patrol (check when observed).
- Inspections for welded track stability are typically carried out in July – September each year. Curves may pull in after initial measurements are taken. Curves may also pull in after track resurfacing and resleepering has occurred.
- Arrange alternative centre line or beside track marking of curves if the initial track position is established.
- Instruct track inspectors to check for track movement during routine patrols.
- Review stability analysis if curves have pulled into the curve significantly.
- Establish programs to correct identified priority locations.
 - Verify that competent staff and other resources are available.
 - Field staff to be given refresher training in corrective techniques -track adjustment, ballasting etc, where required.
 - Strategies in place for dealing with fire bans, equipment for firefighting.
- Provide weekly reports detailing progress in measurement, analysis of track and correction of analysis priorities.
- Establish contingency planning to prevent the occurrence of, or moderate the impact of, misalignments.
- Establish programs to provide protection at locations of suspected instability during hot weather. Protective actions can include speed restrictions.
- Other appropriate actions in accordance with local factors.
- Ensure arrangements are in place for liaison with visiting teams for compliance to requirements.
- Brief patrol staff on monitoring track in summer i.e. disturbance, damage, loss of profile, heat wiggles.
- Arrange staff seminars to reinforce work methods to be used for work in hot weather and to gain commitment for action plans.

5.4 Records from track stability assessment

An annual review of the capacity of the track to provide adequate lateral stability should include review of the following:

- Track elements and conditions changing longitudinal stress and affecting the lateral track stability controlled through:
 - stress control of CWR, and
 - track geometry.
- Rail stress assessment and if necessary adjustment carried out when one of the following occurs:
 - It is shown to be necessary by for track stability assessment.
 - Track buckle or significant heat misalignment occurs.
 - Pull-apart occurs.

5.5 Adjustment and repair

5.5.1 Adjusting CWR

Field welding of rails into continuous lengths during relaying or when making subsequent repairs to CWR has to ensure that the rail is in an unstressed condition at the SFT.

For CWR, the maximum length of track that can be adjusted is 250 m. On curves under 600 m radius, the maximum length is 125m.

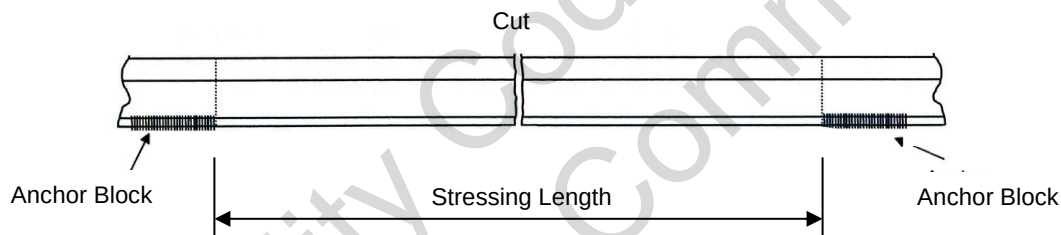


Figure 6 - Relative location of anchor blocks and cut point in CWR

The general principles to be employed in effecting the stress adjustment and completing the final rail closure, with reference to Figure 5, are:

1. The final closure is to be as near as practicable to the centre of the section of track in which the stress is being adjusted.
2. Cropping, closing, welding and anchoring to standard are to be completed ahead at least to the point where the next stress adjustment and closure is to be made.
3. Prior to commencing the stress adjustment and closure, at least every second sleepers in the 60 sleepers beyond each end of the length of rail to be stress-adjusted should be anchored to form the anchor block to prevent movement. All the anchors within the length of rail to be stress-adjusted should be removed.
4. After cutting a short length of 50 mm or greater, out of the rail, relieve any residual compressive stress in the rail by putting the rail into tension (closing the gap by 50 mm) using a tensor, and then releasing the tensor. The rail should then be tapped lightly on the web with a spiking hammer until the gap stops opening.
5. When tensing, the quarter points of the rail length must be marked and measured to ensure that the rail is moving freely and evenly. A check should also be made to ensure that there is no movement at the anchor block end.

6. Cut out a length of rail of 3 m minimum length for the final closure.
7. Install and weld the final closure rail at one end leaving a nominal 6mm gap at the other end. After the weld has cooled to a black heat, the rail should again be tapped throughout its length, commencing from the anchor block ends and finishing at the pulling end.
8. If the rail temperature is higher than the SFT, the free end of the closure rail is to be cut to give the required welding gap, and the closing weld completed.
9. If the rail temperature is less than the SFT, the free end of the closure rail is to be cut (after the first weld has cooled) to leave a closing gap equal to the theoretical rail gap plus the welding gap. The rail is then pulled using the tensor to reduce the closing gap back to the welding gap, and the weld completed.
10. The final closure should not be made if the rail temperature exceeds the SFT by more than 2 °C at the time of measuring for the final closure.
11. The tensor is to remain in place for 20 minutes after the weld trimming is completed before being released.
12. All rail anchors and/or resilient fasteners can then be reinstated.

It is recommended that a closure rail always be available during destressing operations regardless of rail temperature as a precaution against any unforeseen events during destressing.

5.5.2 Repairs to CWR

Where repairs, such as removal of rail flaws, are required to be made to CWR, the procedures for that as described below, is similar to that described for the stress adjustment, but with some exceptions:

1. Prior to cutting the rail, the field side of the rail head clear of the rail repair area is to be punched marked in two places approximately 8 to 9 paces apart one on each side of the flaw to be removed.
2. The distance between the punch marks is to be measured accurately with a steel tape. The tape is to remain extended and placed clear of the track but in the same environment of the track being repaired. The rail temperature at the time of measuring is also to be measured and recorded.
3. At least every second sleeper in the 60 sleepers beyond each end of the length of rail to be stress-adjusted should be anchored to form the anchor block. All the anchors within the length of rail to be stress-adjusted should be removed.
4. Cut a minimum 2.2 m out of the rail, to include the rail flaw. Relieve any residual compressive stress in the rail by tapping lightly on the web with a spiking hammer until the rail stops moving.
5. To enable rail movement to be observed and to ensure that the rail is moving freely and evenly, the quarter points of the rail length must be marked and frequently checked during the tensing process. A check should also be made to ensure that there is no movement at the anchor block end.
6. A closure rail approximately the same length as the amount of rail removed is then placed in the gap and welded at one end leaving a nominal 6 mm gap at the other end

7. If the rail temperature is higher than the SFT, the closing weld should be delayed until the rail cools to below the SFT.
8. If the rail temperature is less than the SFT, the free end of the closure rail is to be trimmed (after the first weld has cooled) to leave a closing gap equal to the theoretical rail gap plus the welding gap, such that the same length of rail removed after adjustment to any changes in rail temperature, will be replaced.
9. The rail ends are then pulled towards each other, using the tensor, to reduce the closing gap to the width of the welding gap. The distance between the punch marks should be measured and checked against the measurement recorded prior to cutting the rail. These measurements must be the same and if not should be adjusted using the tensor. If the gap is less than the required weld gap, trim one end of the rail. The rails can then be welded together.
10. The final closure should not be made if the rail temperature exceeds the SFT by more than 2 °C at the time of measuring for the final closure.
11. The tensor is to remain in place for 20 minutes after the weld trimming is completed before being released.
12. All rail anchors and/or resilient fasteners can then be reinstated.

5.5.3 LWR and jointed rail

In LWR and jointed rail, the maximum rail temperature at which adjustment can be made, depends on the rail length. Since it is difficult to put the rails in compression by pushing them apart in the field, the maximum adjustment temperature will be the rail temperature at which the joint gaps in correctly adjusted rails will be zero.

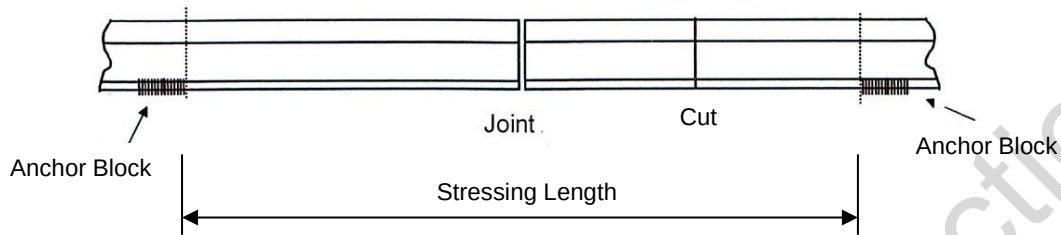
As an example, for a preferred gap of 6 mm and a SFT of 35 °C, the joint gap will be zero for the following rail lengths and temperatures:

Table 1 - Rail length and temperature at zero joint gap

Rail length	Rail temperature
13.7 m	73 °C
27.4 m	54 °C
55 m	44 °C
82 m	41 °C
96 m	40 °C
110 m	40 °C
125 m	39 °C
165 m	38 °C
220 m	37 °C

A general procedure to adjust LWR and jointed rail, with reference to the diagram in Figure 6, is as follows:

Figure 7 - Relative location of anchor blocks and cut point in jointed weld rail



1. Check that the rail temperature is less than the SFT before adjusting the rail. The rail length determines the maximum rail temperature at which adjustment can take place. Adjustment cannot be made after the joint closes up.
2. Determine the joint along the rail to be adjusted.
3. Establish anchor block on the rail at the required distance from each side of the joint.
4. Remove the fishbolts and check joint for condition and free movement. Replace the bolts in one end only so that the rail can move freely.
5. Cut the rail at a minimum distance of 2.2 m from where the joint was. The cut location should be in-between two sleepers.
6. Unfasten the rail by removing rail anchors and/or resilient rail fasteners between the anchor blocks.
7. Vibrate the rail between the anchor blocks.
8. Measure the gap between the joint and the cut.
9. Calculate the theoretical gap.
10. Cut a closure rail to suit the theoretical rail gap, the appropriate expansion gap and welding gap (The length of the closure should be the distance of the gap between the rail ends less the theoretical gap, expansion gap and welding gap).
11. Insert the closure rail and assemble the rail joint.
12. Open by using wedges the joint to achieve the expansion gap.
13. Trim the other end of the closure rail to the theoretical gap plus the welding gap.
14. Use tensor to pull the rail up to the joint, release it and pull up again, tapping the rail all the time.
15. Check the width of the weld gap, and if it is not correct, trim the rail again to suit.
16. Weld the cut joint.
17. The tensor is to remain in place for at least 20 minutes after the weld trimming is completed before being released.
18. Reinstate the rail anchors and/or rail fasteners.

5.5.4 Buckle repair

Depending on the cause of the track buckle, typical repairs may comprise of the following:

- Increase width of ballast shoulder.
- Replace foul ballast.
- Reduce sleeper spacing.
- Increase effective cross-section of sleepers.
- Increase track curvature.
- Correct ballast profile.
- Cutting rail to relieve stress
- Restressing the CWR to the correct SFT.
- Apply rail anchors to jointed track.

5.5.5 Pull-apart repair

When high tensile forces dominate under cold temperature conditions, rail defect growth can cause rail fractures, weld failures and rail joints to pull apart. When pull-apart occurs, repairs are achieved by cutting the rail on each side of the defect and inserting a rail closure. The installation procedure is the same as for rail adjustment.

The minimum length of a closure to be welded back into track is normally 2.2 m, which is over 3 sleepers for support. Generally, closures range from 3 m to 5 m, but should be no longer than 15 m.

6 Temperature related restrictions

6.1 Hot weather train operations

Speed restrictions are sometimes imposed during hot weather when the stress induced by the heat on the welded rails is high, as a precautionary step to reduce the additional stresses that will be imposed by train induced vibration and voiding.

The threshold for the imposition of speed restriction on tracks is dependent on the SFT in the rail, and also the track structure. The allowable temperature extremes depend on the robustness of the track. Generally, a higher threshold is appropriate to concrete sleepered track.

The critical rail temperature is the allowable temperature above the SFT, and for an undisturbed, fully ballasted track, the rail temperature can be up to 32° C higher than the SFT of the track. This margin can reduce to 10 °C for tracks with poor ballast or other factors. The critical temperature and duration for applying speed restrictions in hot weather and the procedure to apply them is the responsibility of the Track Manager.

Where tracks have shifted due to hot weather, structure clearance will need to be assessed in locations where passing clearance is restricted.

6.2 Track work during extremes of hot or cold weather

Track disturbing works, such as tamping and resleepering, reduces the stability of track, and speed restrictions are normally imposed during the works. In periods of hot weather, the track instability can be exacerbated due to a weak track structure after track disturbing works. Any work resulting in disturbance

of the track during high temperature should be kept to a minimum and be completed during the cooler part of the day.

If necessary, it may be possible to minimize the disturbance to all track components while working on days of high temperature, such as:

- Restricting removal of sleepers to not more than one sleeper in any 9 m length of track length when resleepering.
- Avoiding restressing a track that has been lifted or lowered by 75 mm or more.
- Using ballast compactors immediately after tamping or resleepering.

It is recommended that track disturbing work should not commence when the air temperature reaches 38 °C. If the air temperature rises above 32 °C after the work has commenced, the work should stop as soon as practicable.