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Laying and Maintenance of CWR Track

Pose et maintenance de la voie en longs rails soudés

Verlegung und Instandhaltung von lückenlosem Gleis



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INTERNATIONALER EISENBAHNVERBAND
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Summary

This leaflet contains guidelines for the use, installation and inspection of ballasted track with continuous welded rails (CWR), and also lists the associated safety criteria. It is based on the practical experience of several railways and a large number of tests and theoretical studies carried out over a period of more than 40 years. It also includes the results of studies undertaken by *ERRI Committee D 202*.

The leaflet has been enhanced by inclusion of a point on safety aspects and a point on case studies conducted using the CWERRI and CWR-BUCKLE models. A new safety criterion has been formulated on the basis of maximum and minimum buckling temperatures ($T_{b,max}$ and $T_{b,min}$). The parameters were selected to reflect a maximum temperature which corresponds to 50% of the buckling energy level. In addition, a concept of buckling safety based on risk assessment methodology has been introduced.

The case studies include examples of high-speed, main-line passenger tracks on both concrete and wooden sleepers, together with secondary and freight tracks.

Permissible rail temperatures for the various scenarios studied are presented graphically.

1 - Introduction

1.1 - Purpose

This leaflet contains guidelines for the installation and use of ballasted track incorporating continuous welded rails (CWR), together with details of inspection methods and safety criteria. It is based on the practical experience of several railways and a large number of tests and theoretical studies undertaken over more than 40 years. It also includes the results of international work on this topic carried out by *ERRI Committee D 202*. This leaflet replaces UIC Leaflet 720, 1st edition, dated 1986 on the same topic.

1.2 - Scope

1.2.1 - Use of CWR track

CWR is now in widespread use on most railways, since, although the construction costs of CWR are similar to those of jointed track, CWR has important technical, ecological and economic advantages, in particular, a significant reduction in maintenance costs.

CWR is also a prerequisite for high-speed services.

1.2.2 - Advantages of CWR track

The main advantages of CWR track are:

- reduced maintenance costs,
- fewer rail defects and failures,
- reduced wear on vehicles,
- reduced noise and vibration emissions,
- better ride comfort,
- lower energy costs for traction,
- easier mechanisation of track installation and maintenance.

All these features translate into reduced life cycle costs compared to jointed track.

1.2.3 - Consequences

The use of CWR requires precautions in the design of the track structure, and in its installation, maintenance and inspection. It also requires an understanding of the effects of temperature, rolling-stock and track features, on track stability and rail failures.

1.3 - Definition

1.3.1 - CWR track

CWR track is track in which the free expansion and contraction of the rails caused by temperature changes are constrained, by artificially introducing a controlled expansion into the rails prior to installation of the track fastenings.

Consequently high longitudinal forces are induced in the rails as a result of temperature changes.

Resistance to longitudinal movement of the rails, under the action of these forces, is secured through the clamping action of the rail fastenings and the restraining effect of the boxing ballast.

Total longitudinal force P in the track, either tensile or compressive, is given by:

$$P = 2\alpha EA\Delta T$$

where: α = coefficient of expansion of steel
 E = Young's modulus of steel
 A = rail cross-sectional area
 ΔT = change in temperature from the "stress-free temperature"

The longitudinal stresses in each rail are given by:

$$\sigma = \alpha E\Delta T$$

The change in temperature from the "stress-free" condition can reach values as high as 40-45°C resulting in rail forces of 800 kN and rail stresses of up to 100 N/mm² in UIC 60 rails.

1.3.2 - Aim of the leaflet

The aim of the leaflet is to explain the parameters affecting track stability and to set out the methodology for ensuring the stability and safety of CWR track.

1.3.3 - Structure of the leaflet

The leaflet is structured around the following points:

2. Key parameters	Effect of track structure, layout, geometry and temperature on track stability.
3. Additional parameters	Effect of rolling stock, bridges, switches and crossings, substructure, etc.
4. Installation of CWR track	Requirements for installation.
5. Maintenance	Requirements for maintenance, inspection and repair.
6. Elimination of problems	Track buckling and distortion.
Appendix A. Safety	Methodology for risk assessment and establishment of safety criteria.
Appendix B. Case studies	Case studies using mathematical model CWERRI: examples and application of results.

2 - Key parameters

2.1 - Rails

All flat-bottom rail profiles are suitable for CWR track.

It is recommended that intermediate section rails are introduced where it is required to join rails having cross sectional areas which differ by more than 22%.

New rails should not be drilled.

It is recommended that serviceable rails undergo ultrasonic examination prior to CWR conversion.

Existing fishbolt holes should preferably be removed prior to CWR conversion but this is not essential, particularly in lower-speed and lower-tonnage track categories.

2.2 - Fastenings

Only fastening systems which provide adequate guaranteed longitudinal and torsional resistance to rail movement relative to the sleepers, shall be used in CWR.

The end of a CWR section of track over which rail movement can occur is called "the breathing length".

Expansion switches can be fitted at the end of a section of CWR track where it abuts an adjoining section of jointed track or at a specific location such as a bridge, etc.

2.3 - Type and spacing of sleepers

Concrete, wooden or steel sleepers are suitable for use in CWR. However, the type and shape of the sleeper can have a significant effect on the lateral resistance and stability of the track.

The mass of the sleeper, the surface area of the sleeper end and the sleeper spacing, have a major effect on the lateral resistance. Steel sleepers require a particular tamping technique to ensure that the ballast penetrates the hollow underside of the sleeper completely.

2.4 - Ballast-bed dimensions

Satisfactory longitudinal and lateral resistance of the track depends on the mass, particle size, shape, cleanliness and compaction of the ballast.

The particle size shall be within the range 22,4/63 mm and the individual particles shall be sharp-edged and uniformly distributed.

The recommended minimum depth of ballast below the sleeper soffit is 300 mm, and not less than 200 mm.

The recommended minimum width of ballast shoulder, i.e. the horizontal distance between the end of the sleeper and the slope of the ballast, is 400 mm for speeds up to 160 km/h and 500 mm for higher speeds. The top of the ballast shoulder shall be at least level with the top of the sleeper.

The width of the ballast shoulder may, with advantage, also be increased to the higher value in sharp radius curves or where tilting trains operate.

The lateral resistance of the track can be increased to a limited extent by widening and raising the level of the ballast at the sleeper ends.

The lateral and longitudinal resistance of the track depends to a large extent on the degree of compaction of the ballast, being greatest when the ballast is fully compacted and least when the ballast is freshly tamped (see also point 3.3 - page 9).

The depth of the ballast and the width of the ballast shoulder may, during installation, fall below the above recommendations temporarily, provided high ambient temperatures can be guaranteed not to occur, or a temporary speed restriction is imposed. However, the full ballast dimensions should be obtained prior to commencement of operating at line speed.

2.5 - Alignment

The quality of the alignment has a significant effect on the lateral resistance of CWR track. A greater degree of misalignment is usually found in curves compared with straight track.

The minimum curve radius in which CWR track may be safely installed depends on the rail section, the fastenings, the type of sleeper, the ballast profile and the anticipated longitudinal thermal stresses. CWR may be installed on curves sharper than 300 m radius provided special measures, such as fitting anchoring devices to the sleepers, are taken.

2.6 - Track geometry

Major errors in alignment can lead to track buckling at high rail temperatures. It is essential therefore that alignment errors should be minimised by correct maintenance procedures. The magnitude of the maximum permissible alignment error in any section of CWR track depends on the rail section, sleeper type, fastening type, ballast condition, stability of the ballast bed and the prevailing temperature.

2.7 - Important rail temperatures

The following rail temperatures must be known prior to the installation of CWR track:

2.7.1 - Mean rail temperature

The mean rail temperature T_m is the arithmetic mean between the maximum rail temperature T_{max} and the minimum rail temperature T_{min} .

$$T_m = \frac{T_{max} + T_{min}}{2}$$

NB : These temperatures are not generally the same as the maximum and minimum air temperatures.

2.7.2 - Nominal rail temperature

The nominal rail temperature T_s is the optimum temperature at which the track should be fastened down. It should be several degrees above the mean rail temperature in order to limit the magnitude of compressive stresses.

$$T_s = T_m + X \text{ (where } X \text{ ranges between } 0 \text{ and } 10^\circ\text{C)}$$

2.7.3 - Notional temperature

The notional rail temperature is the temperature of the rails prior to the commencement of work.

2.7.4 - Installation temperature range

The installation temperature range is the nominal temperature $\pm 3^\circ\text{C}$ (for example).

2.7.5 - Installation temperature

The installation temperature T_f is the specified equivalent rail temperature at which the fastenings shall be tensioned. It is, by definition, within the range specified in point 2.7.4.

2.7.6 - Initial temperature

The initial temperature is the rail temperature immediately prior to the commencement of stressing the rails.

2.7.7 - Stress-free temperature

The stress-free temperature T_n is the temperature at which there are no thermal stresses in the rails.

2.7.8 - Maximum temperature

The maximum rail temperature $T_{\max}$ is the maximum expected in a particular location.

2.7.9 - Minimum temperature

The minimum rail temperature $T_{\min}$ is the minimum expected in a particular location

2.8 - Additional temperature characteristics

The following additional temperature characteristics may be known prior to commencement of work and may be laid down in rules or calculated from mathematical modelling:

2.8.1 - Maximum Critical Temperature

The maximum critical temperature $T_{b,\max}$ is the predicted rail temperature from mathematical modelling at which track buckling is almost a certainty.

2.8.2 - Minimum Critical Temperature

The minimum critical temperature $T_{b,min}$ is the predicted rail temperature from mathematical modelling below which track buckling is unlikely to occur.

2.8.3 - Allowable Temperature

The allowable temperature T_{all} is the temperature which provides a margin of safety against a predicted likelihood of track buckling.

2.8.4 - Increment

Increment ΔT is an incremental margin from the allowable temperature, either up or down, which provides either a lesser or greater margin of safety against buckling.

3 - Additional parameters

3.1 - Subgrade

The characteristics of the subgrade shall be such as to ensure the long-term stability of the CWR track.

On soft ground (e.g. peat), the technical feasibility of using CWR track shall be established and, if possible, special precautions shall be taken. It is not recommended to install CWR in locations which are affected by subsidence (e.g. coal mining areas, etc.) since large uncontrolled stresses or deformations can occur in the track.

The following subgrade characteristics are of particular importance:

- good stability, little likelihood of subsidence, unaffected by frost;
- adequate bearing capacity for the type of track and traffic carried;
- good drainage.

3.2 - Vehicle parameters

The following vehicle characteristics may affect the stability of CWR track:

- Axle load, wheel base and bogie centres may affect both lateral bending of the track and the precessional uplift wave. The resistance to lateral displacement may be affected by the stiffness and mass of the track panel.
- The transverse forces (ΣY) generated by the vehicles should be less than the lateral resistance of the track in the loaded state in order to prevent displacement of the track under the moving train (for more information, refer to *UIC Leaflet 518*).
- Heating of the rails by, for example, eddy-current brakes may affect the stability of the track.

3.3 - Maintenance work

(See also point [5.3 - page 15](#)).

Consolidation of the ballast will be necessary after tamping in order to restore the full lateral resistance of the track. This may be achieved naturally by the action of traffic or by other measures e.g. use of a dynamic track stabiliser.

During the period of reduced lateral resistance of the track, imposition of a temporary speed restriction may be necessary until the track is sufficiently stable, particularly when it is anticipated that high temperatures will occur immediately after tamping.

3.4 - Bridges

The following factors will affect the longitudinal forces in CWR track in the vicinity of bridges:

- changes in the track modulus adjacent to the bridge abutments,
- end rotation of the bridge as a result of the load imposed on the structure,
- changes in the length of the structure caused by temperature changes,
- longitudinal displacement of the structure caused by braking and acceleration.

UIC Leaflet 717 and *UIC Leaflet 774-3* provide advice on the effects of forces generated within bridge/abutment transition zones, on the track alignment and the stability of CWR track. The leaflets also provide advice on the use of CWR track without expansion joints on bridges.

CWR should ideally be installed on bridges when the bridge itself is in a stress-free condition in order to minimise the effect of expansion of the bridge on the longitudinal forces in the rails.

Switches should not be located over bridge bearings.

Care should be taken to ensure that the presence of check rails or guard rails does not generate additional longitudinal forces in CWR track.

3.5 - Tunnels, gradients and braking

In locations where large or uneven changes in rail temperature are experienced, longitudinal movement of the sleepers in the ballast or of the rails relative to the sleepers may alter the original stress-free temperature of the track.

The effect will depend on the characteristics of the ballast, the type of sleeper or the creep resistance of the fastenings.

The longitudinal forces generated by vehicles may produce similar effects.

Such effects may occur particularly:

- in the vicinity of tunnel portals and in deep cuttings,
- on rising and falling gradients,
- in long continuous curves,
- on tracks where eddy-current brakes are in use.

In order to minimise the effect on the stress-free temperature and the consequential reduction in stability of CWR track, the above situations shall be subjected to particularly careful monitoring. Appropriate additional measures shall be taken to improve the stability of the track where this is considered necessary.

3.6 - Switches

The presence of additional rails of the diverted track can create increased longitudinal forces in switches particularly at, and in advance of the switch toe. The lateral resistance at these locations may be enhanced using anchoring devices or other measures.

3.7 - Variation of gauge

Variations in gauge have only a minor effect on track stability and can usually be ignored in this context.