A NEW SAFETY PHILOSOPHY FOR CWR

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From 1992 to 1997 the ERRI Committee D 202 carried out an extensive study on the behaviour of continuous welded rail (CWR) track. This work consisted of the development of various programs, amongst others for longitudinal force distribution and buckling analysis. A new safety criterion was proposed for implementation in the international UIC standard 720.

Key words: Safety, buckling, stability, longitudinal forces.

1. INTRODUCTION

The ERRI work carried out in the period 1992 – 1997 consisted of the following main points:

1. Specifying a uniform safety philosophy for CWR
2. Guidelines and recommendations for the laying, maintenance and diagnosis of CWR track, as the basis for modifying UIC Leaflet 720 R and adding more detail to it.
3. Information regarding any excessive safety margins, with the aim either of reducing track construction costs, or of using the reserve for such purposes as eddy current brakes
4. Recommendations for the development of a measuring technique which is likely to be of benefit.

This paper primarily deals with a description of the calculational tools and the back ground and testing of the safety criteria proposed by the ERRI Committee D 202 [5].

2. MODELS

CWERRI, developed by TU Delft [1], allows the longitudinal, vertical and lateral behaviour of CWR track to be modeled and calculated integrally in a user-friendly environment. The basic features of the model are as follows:

- Three-dimensional modelling and calculation tool
- Longitudinal, lateral and vertical forces
- Lateral and vertical track stability
- Thermal and mechanical loads
- Complete train loads, taking uplift waves into account
- Three-dimensional ballast yield, taking the influence of vertical loads into account
- Track/bridge interaction, including the effects of end rotation
- Multi-span bridges with parallel tracks

It is widely assumed that track buckling depends on the external addition of energy to the buckled track, e.g. by a moving train. The amount of buckling energy can be calculated by a program called CWR-Buckle which was developed by Volpe/DOT in the USA [2].

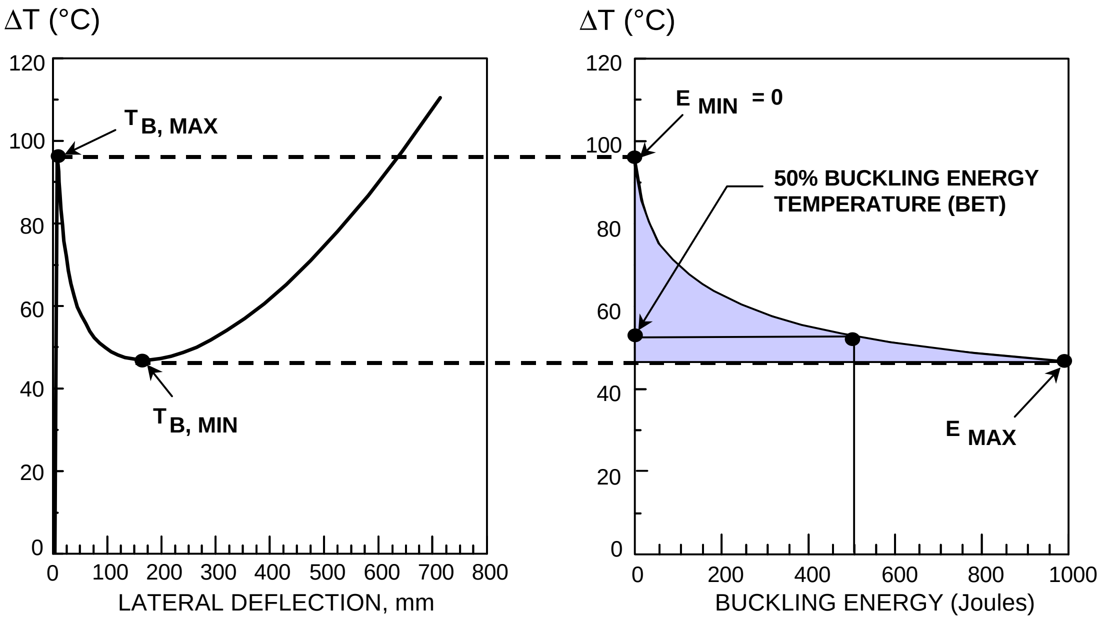
A major application of CWERRI is its use as a tool for safety analyses. Together with CWR-BUCKLE, a large number of calculations has been performed in developing safety criteria to be implemented in the new edition of UIC Leaflet 720.

3. SAFETY CRITERIA

For track safety, $T_{allowable}$ is the maximum allowable temperature above the neutral temperature of the rail that is considered safe as far as track buckling is concerned. $T_{allowable}$ can be seen as a buffer with regard to many phenomena that increase rail temperature or an equivalent axial compressive stress in the rail, pushing it into the dangerous “buckling” range. These phenomena are:

- Air temperature
- Sunlight
- Eddy current brakes
- Interaction with other structures, such as bridges

The first and second items generally take up about 30°C to 40°C of the available temperature buffer, depending on local circumstances. This means that specific structures with a $T_{allowable}$ value lower than 40°C will certainly encounter buckling problems in summer or under other high-temperature conditions. With $T_{allowable}$ above 40°C, structures can be exposed to eddy current brakes or to external forces from other structures, as long as the equivalent temperature increase remains within the calculated buffer of degrees.



PARAMETERS:

***RAIL:* UIC 60; *SLEEPER TYPE:* CONCRETE; *MISALIGNMENT:* 12mm in 8 m; *R* = 300m;**
***TORSIONAL RESISTANCE:* MEDIUM; *LONGITUDINAL RESISTANCE:* MEDIUM;**
***AXLE LOADS:* UIC/D4**

Figure 1: Temperature vs. lateral displacement and corresponding buckling energy

The allowable value of the temperature $T_{allowable}$ is basically determined by the components $T_{b,max}$ and $T_{b,min}$, which are explained in left hand part of Figure 1. The left graph comprises three branches: a linear elastic deformation line starting at the origin, a non-stable branch starting from $T_{b,max}$ with a minimum value called $T_{b,min}$, followed by the stable post-buckling branch right of $T_{b,min}$.

In the right hand part of figure 1 the corresponding buckling energy is presented. It is obvious that the energy needed to buckle out the track decreases rapidly when increasing the temperature from $T_{b,min}$ to $T_{b,max}$. Investigations of the ERRI committee D 202 have shown that the temperature at 50 % of the buckling energy roughly corresponds to the value $T_{b,min}+0.25\ (T_{b,max}-T_{b,min})$

For track safety calculations the ERRI D 202 [3] committee proposed the following criteria:

If $\Delta T > 20$ °C:	$T_{allow} = T_{b,min}$+25% of ΔT
If 5 °C < ΔT < 20 °C:	$T_{allow} = T_{b,min}$
If 0 °C < ΔT < 5 °C:	$T_{allow} = T_{b,min} - 5$ °C
If $\Delta T < 0$ °C:	not allowable in main lines.

In these expressions ΔT is defined by $(T_{b,max}-T_{b,min})$

4. CASE STUDIES

To test the above criteria D 202 carried out a series of case studies both with the program CWERRI and the program CWR-Buckle[4]. The results of the calculations with CWERRI are expressed in terms of the temperature of the rail above the neutral temperature.
The parametric studies on track buckling [3] were carried out for the following structures:

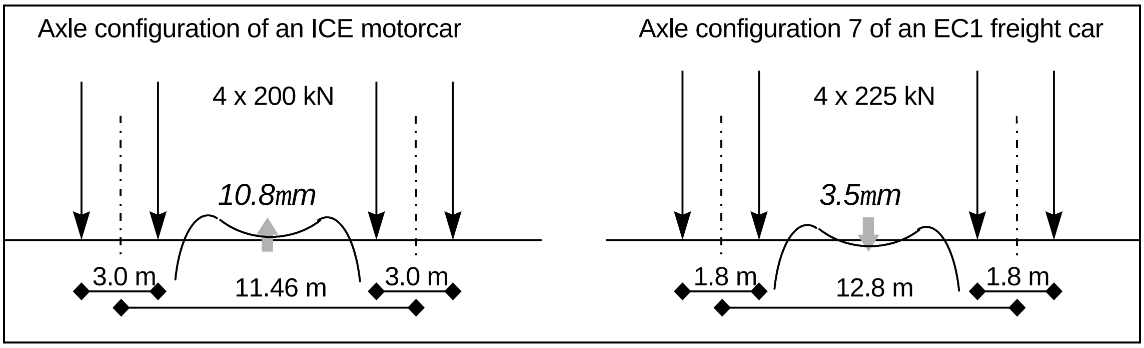


Figure 2: Axle configurations for passenger and freight vehicles

1	High speed track	tangent	concrete sleepers
2	Main line track	radius 900 m	concrete sleepers
3	Main line track	radius 900 m	wooden sleepers
4	Secondary line track	radius 600 m	concrete sleeper
5	Secondary line track	radius 600 m	wooden sleepers
6	Freight line track	radius 300 m	concrete sleeper
7	Freight line track	radius 300 m	wooden sleepers

Each structure was analyzed for three different misalignments with lengths of 8 m, 10 m and 12 m. The magnitudes (twice the amplitude) were:
Structure 1: total misalignments: 8/12/16 mm
Structures 2 and 3: total misalignments: 10/14/18 mm
Structures 4 and 5: total misalignments: 14/18/22 mm
Structures 6 and 7: total misalignments: 14/22/30 mm

For each misalignment, the quality of the ballast material (expressed in F_p (peak) and F_l (limit) values) was altered three times: low, average and high quality. The parametric values were expressed in terms of the force required to move a 1-metre track panel laterally through the ballast over a predefined number of millimeters (w_p: 2 mm or 5 mm).
Concrete sleepers: 10/10, 15/12 and 20/16 kN/m'
Wooden sleepers: 7/7, 10/10 and 15/12 kN/m'

In addition, the influence of the rail fastening system in the lateral direction was altered twice: a small, rigid fixture resisting torsion can be taken into account as k_t in terms of the required moment per radian per meter track. Again, the values depend on the sleeper type.
Concrete sleepers: 75 and 150 kNm/rad/m'
Wooden sleepers: 150 and 250 kNm/rad/m'

The parametric values for the friction coefficient for lateral resistance between ballast and sleeper were:
Concrete sleepers: $\varphi = 0.86$
Wooden sleepers: $\varphi = 1.2$
The vertical track stiffness values k_v, expressed per meter of track, were:
Structures 1, 2 and 3: 100 MN/m/m'
Structures 4, 5, 6 and 7: 70 MN/m/m'

For the seven structures, two different vehicles were chosen. The most severe cases of track buckling occur if the axle configuration of the vehicle leads to significant lifting of the track according to the (static) deflection curve. The following combinations of vehicle and structure were chosen:

Structures 1, 2 and 3: ICE power car
Structures 4, 5, 6 and 7: EC 1 vehicle axle configuration 7 for wagons

In total, 252 calculations were carried out.

5. SAFETY LIMITS

For the structures discussed previously, the safety margins in terms of $T_{allowable}$ were determined as follows:

Case	Calculations performed with…
1: $T_{allowable} = T_{b,min}$	All 252 CWERRI calculations were divided into categories based on this criterion.
2: $T_{allowable} = T_{b,min} + 0.25\,(T_{b,max} - T_{b,min})$	126 CWERRI calculations with w_p = 5 mm were divided into the same categories based on this criterion.
3: $T_{allowable}$ is the temperature at which the energy required to buckle the track structure is 50% of the energy required to buckle the track structure at $T_{b,min}$. In fact, $T_{allowable} = T_{b,min} + \Delta T$.	CWR-Buckle calculations for almost similar structures as were used for Case 2.

Figures 3 and 4 show the results of the calculations in Cases 2 and 3, for passenger and freight track. It is remarkable that the differences in the results for similar structures with small, moderate and large misalignments are quite small (range < 5°C) while the differences for low, average and high ballast quality are almost constant (8.5°C - 10°C for CWERRI results, 6°C - 9°C for CWR-Buckle results). These differences between two ballast qualities are larger than the differences between $T_{b,min}$ values for two ballast qualities

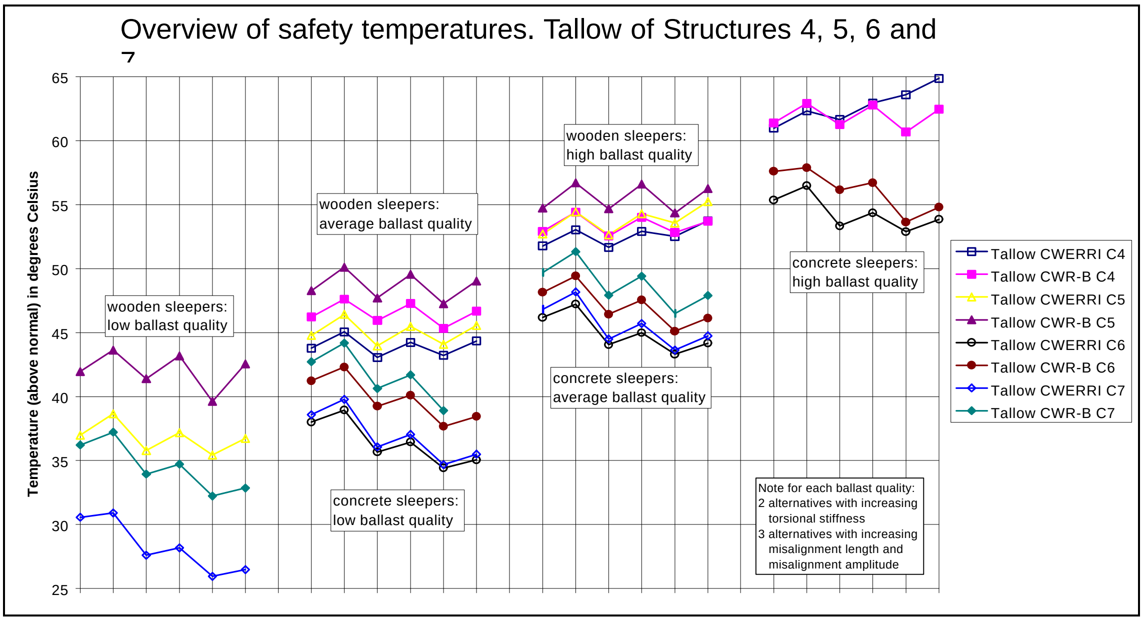


Figure 3: Overview of freight track safety temperatures

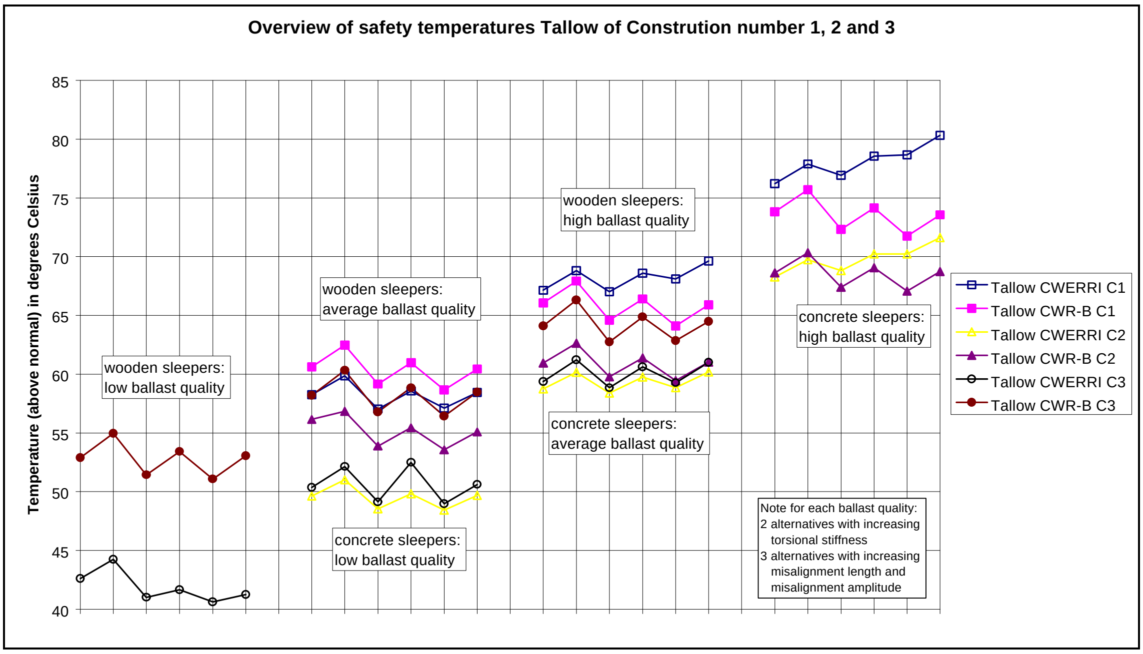


Figure 4: Overview of passenger track safety temperatures

described in Case 1. It can be concluded that the values of $T_{b,max}$ and energy for specific structures increase (more than linearly) if $T_{b,min}$ increases. The differences in the results for concrete and wooden sleepers are almost negligible.

Figures 3 and 4 reveal that there is a difference of approximately 10°C between low, average and high quality.

6. CONCLUSIONS

On the basis of the previously discussed calculations, the ERRI D 202 Specialists' Committee concluded the following:

- A safety criterion based solely on $T_{b,max}$ is not acceptable
- A safety criterion based on $T_{b,min}$ is too conservative and not acceptable for existing railway practice
- UIC Committee 7G would be advised to adopt the following safety criterion for UIC Leaflet 720 [4]: $T_{allowable} = T_{b,min} + 0.25\ (T_{b,max} - T_{b,min})$
  The calculations carried out with CWERRI and CWR-Buckle show this criterion to correspond to a reserve of approximately 50% of the maximum buckling energy.

7. REFERENCES

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