FTIA TAMPING DAY

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27 March 2024

INTERNATIONAL UNION
OF RAILWAYS

DRAFT AGENDA

- Track Geometry recording and tamping intervention levels/Parameters for determining the relevance and extent of tamping (lining and levelling) works
- Geometry quality levels/Characterization od track geometry quality
- Tamping processes for optimum geometry durability
- Current use of ballast consolidators and Dynamic Track Stabilizers (DTS) with maintenance tamping
- Results of tamping durability

Track Geometry recording and tamping intervention levels/Parameters for determining the relevance and extent of tamping (lining and levelling) works

Track Geometry recording and tamping for intervention levels

1. Measured parameters

All IM inspect their track geometry on a regular basis. The parameter that usually drives the need for track geometry maintenance is the short wavelength longitudinal level measurement. This consists of measurements of single isolated track geometry defects and their overall standard deviation based on a short section of the track (typically some 200 min length).

1. **Measured parameters**

Principal track geometric parameters (according EN 13848-1):

- **Track gauge**
- **Longitudinal level**
- **Cross level**
- **Alignment**
- **Twist**

2. Definitions of intervention levels (according EN 13848-1)

The values of these limits are usually given as a function of speed, which is an important factor for the evaluation of track quality. Each IM has its own limits, usually defined as follows:

Immediate Action Limit (IAL):

Refers to the value which, if exceeded, requires taking measures to reduce the risk of derailment to an acceptable level. This can be done either by closing the line, reducing speed or by correction of track geometry.

2. Definitions of intervention levels (according EN 13848-1)

Intervention Limit (IL):

Refers to the value which, if exceeded, requires corrective maintenance in order that the immediate action limit shall not be reached before the next inspection.

Alert Limit (AL)

Refers to the value which, if exceeded, requires that the track geometry condition is analysed and considered in the regularly planned maintenance operations.

2. Definitions of intervention levels (according EN 13848-1)

The Inspection strategy in general should focus on the IL. If the limiting values of the IL are exceeded, corrective maintenance needs to be done in order that the immediate action limit shall not be reached before the next inspection.

However, the IL value should also recognise the overall likely deterioration rate of the track quality. This track quality must be monitored to enable forecasting of when the IL is likely to be reached, and thus facilitate the planning of remedial works.

Track Geometry recording and tamping for intervention levels

3. Comparison of Administrations' Intervention limits (IL) and immediate action limits (IAL)

General comparisons of all IMs intervention limits are therefore not easily made. However, an attempt was made at comparing data based on two specific track categories, and on the parameter that usually drives the need for track geometry maintenance (short wavelength longitudinal level):

a) High tonnage (>30.000 tonnes/day) and speed 140 km/h

b) High tonnage (>30.000 tonnes/day) and speed 250 km/h.

Track Geometry recording and tamping for intervention levels

3. Comparison of Administrations' Intervention limits (IL) and immediate action limits (IAL)

However, permitting the track quality to deteriorate beyond the IL until the IAL is reached, means that the initial track quality cannot be achieved again with normal maintenance tamping.

More than one tamping operation will therefore be required to achieve the initial track geometry quality but note that this will increase the deterioration rate. Therefore, it is not economic to allow track geometry quality to deteriorate beyond the IL until the IAL is reached.

4. Attainment of track quality over successive tamping cycles

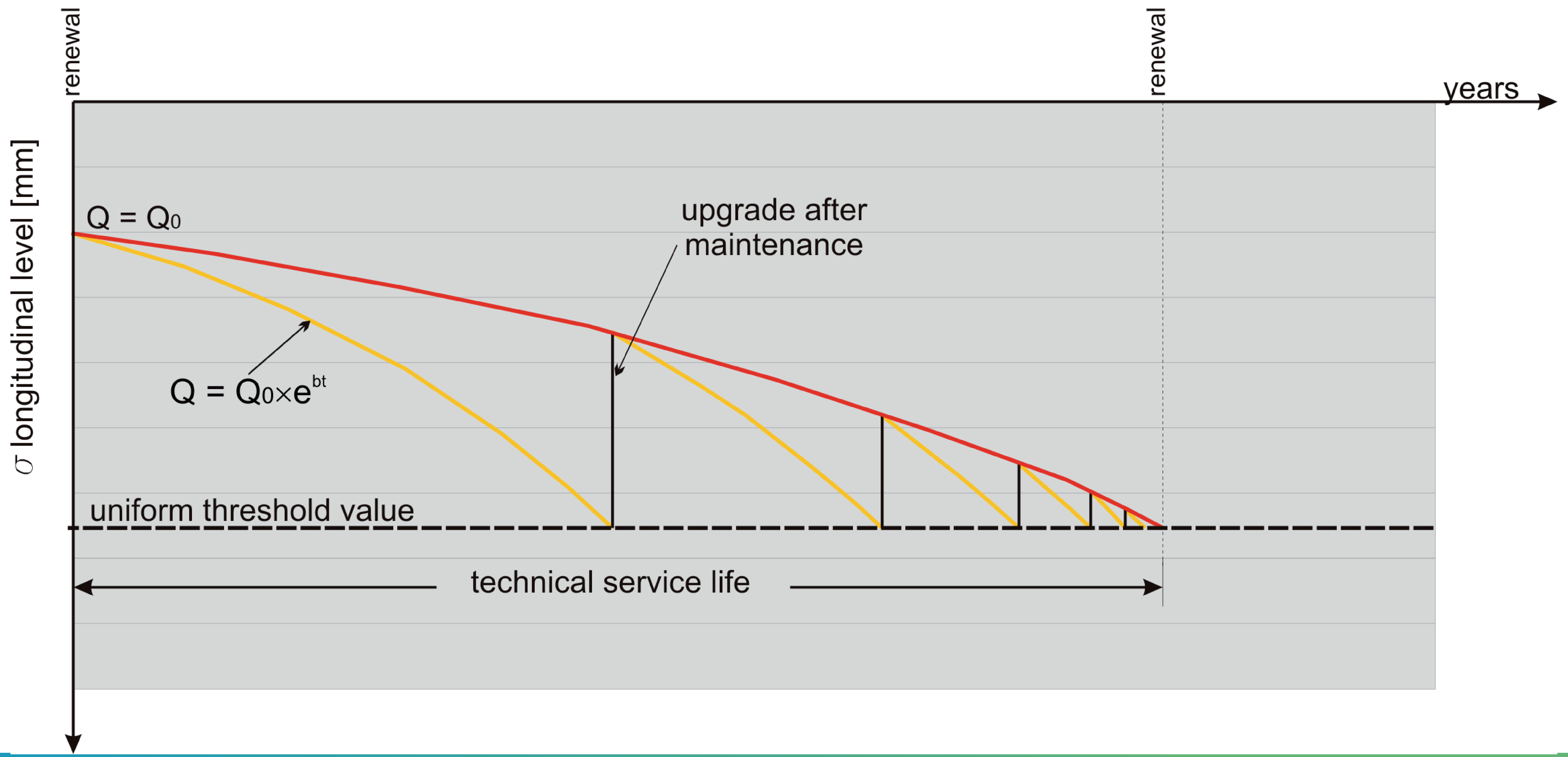
With time and traffic (and therefore the associated deterioration of the ballast and substructure), it proves ever more difficult for tamping to obtain the track geometry quality of a new track.

Eventually the track geometry quality deteriorates to a level at which track ballast and track components require replacing. Also, the amount of improvement achieved after tamping is essentially influenced by the local conditions (good/bad).

4. Attainment of track quality over successive tamping cycles

Taking track quality behaviour and maintenance actions into account, the deterioration rate of that quality is shown in figure below:

Life Cycle Behaviour of Track Geometry Quality



4. Attainment of track quality over successive tamping cycles

In the figure before, a constant threshold (intervention) value is assumed for instigating maintenance actions, from which is depicted the technical service life of track. Close to the end of the technical service life the time interval between successive maintenance cycles becomes much shorter, and at that stage the track becomes uneconomic to maintain.

Track Geometry recording and tamping for intervention levels

5. Attainment of track quality – influence of ballast and formation conditions

The basic requirement for new track is to install it to the best initial quality; this will provide the best and most durable track geometry possible. In addition, it is necessary to provide a sustainable and properly drained substructure, with an adequate depth of good quality ballast.

A basic principle of new track construction should always be to minimise the number of subsequent tamping cycles required as the total amount of amount of traffic tonnage increases. This tamping cycle will shorten as the tonnage carried (and therefore damage to the ballast) increases, even when subject to good substructure und track maintenance conditions.

5. Attainment of track quality – influence of ballast and formation conditions

The amount of improvement after tamping intervention for good/bad substructures and ballast conditions has been found (in Austria) to lie within the values shown in figure below, that shows the enormous increase of deterioration as soon as subsoil and drainage conditions are not fit for purpose. In the graph also assumes that the tamping process itself is carried out properly, otherwise the results will be even worse than those illustrated.

Insert figure 2

5. **The relationship between ride quality, speed and track quality**

The optimum Intervention Levels for tamping must take into account the correlation between the riding comfort of wagons (springs and dampers), track geometry quality, and speed, where the speed relationship = $v^{0,65}$.

Insert figure 3

5. The relationship between ride quality, speed and track quality

The values above correspond to track geometry quality levels QN 1, QN 2 and QN 3, which are set out in EN 14363 concerning the running characteristics of railway vehicles, which are based on track maintenance criteria:

- **Quality level QN 1: necessitates observing a track section or taking maintenance measures within the frame of normal operations scheduling,**
- **Quality level QN 2: necessitates taking short-term maintenance measures,**
- **Quality level QN 3: characterises track sections which do not exhibit the usual track geometry quality. Quality level QN 3, however, does not represent the most adverse but still tolerable maintenance status.**

Track Geometry recording and tamping for intervention levels

6. **Optimum tamping threshold level.**

The use of threshold levels based on maintaining quite high track qualities, leads to a long service life, while threshold levels based on lower track qualities will initially reduce the amount of tamping intervention, but will also reduce the service life of the track.

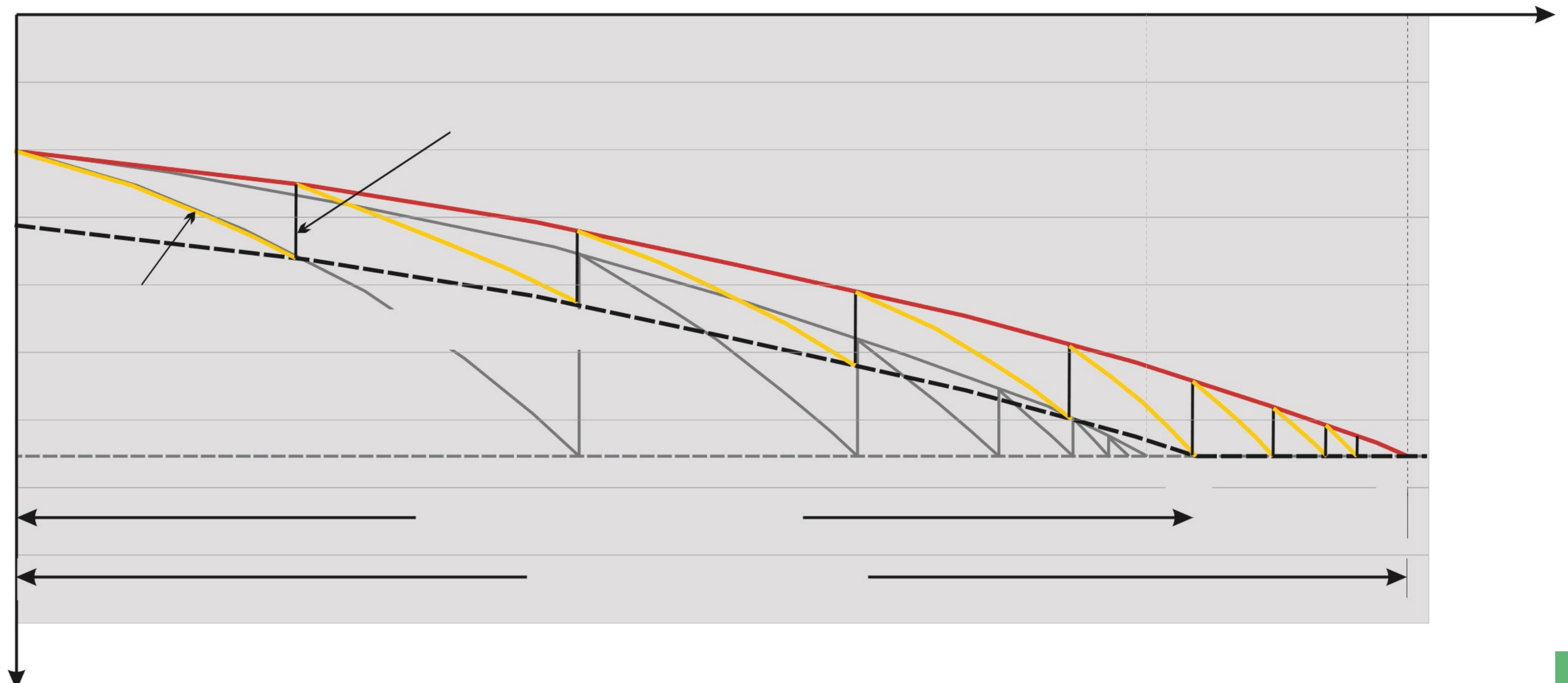
However, threshold levels based on high track qualities lead to the minimum life cycle costs of track.

The positive economic effects of a tamping strategy based on high quality levels and a conform threshold value results in an increased service life, and therefore reduced life cycle track cost.

6. Optimum tamping threshold level.

The achievable increase of track quality due to tamping is higher, depending upon the initial track quality before tamping. However, the range of accepted deterioration (difference between the total quality function and the conform threshold value) must be defi ned by LCC calculations taking the specifications of track and traffic into account, which influences the deterioration rate “b”. This principle is shown in Figure below.

Life Cycle Behaviour of Track Geometry Quality



6. Optimum tamping threshold level.

In theory the conform threshold value is defi ned as a constant difference to the total quality function and is shown as the curved dotted line shown ending at point “A”. The threshold value itself remains constant, shown as a horizontal line which also passes through point “A.”

This principle may lead to a higher amount of tamping, but becomes economic if the cost of the increased tamping is less than the value of increasing the service life from A to B.

6. Optimum tamping threshold level.

It is therefore essential that each railway administration carefully considers the following factors in order to determine the optimum tamping intervention levels for its individual lines:

- Track quality achieved of track renewals/new track,
- Position of individual portion of track within its own life cycle,
- Likely attainment of track quality over successive tamping cycles,
- Influence of ballast and formation conditions upon attainment of that track quality,
- Relationship of required ride quality with speed and track quality,
- Life cycle costs.

Geometry quality levels / Characterization of track geometry quality

Geometry quality levels / Characterization of track geometry quality

1. **Geometry quality levels (according EN 13848-5)**

The track geometry limits AL, IL and IAL differ from the 3 vehicle acceptance levels QN1, QN2 and QN3 used in EN 14363. More particularly QN3 is quite different from IAL because, according to EN 14363, it characterises track sections which do not exhibit the usual track geometry quality. Quality level QN3, however, does not represent the most adverse but still tolerable maintenance status which still allows regular train operations.

Geometry quality levels / Characterization of track geometry quality

1. Geometry quality levels (according EN 13848-5)

Immediate action limits:

- Track gauge – Table 2 - IAL – Isolated defects – Nominal track gauge to peak value and Table 3 – IAL – Nominal track gauge to mean track gauge over 100 m
- Longitudinal level - Table 5 – IAL – Isolated defects – Mean to peak value
- Cross level – no values given by this standard
- Alignment - Table 6 – IAL – Isolated defects – Mean to peak value status which still allows regular train operations
- Twist

Geometry quality levels / Characterization of track geometry quality

1. Geometry quality levels (according EN 13848-5)

Alert and intervention limit:

Unlike immediate action limits, which take into account the track/vehicle interaction, as well as the risk of unexpected events, the other quality levels are mainly linked with maintenance policy.

Maintenance policy may be directed either at upholding safety alone or at achieving good ride quality, lower life cycle cost or more attractive (higher speed) services in addition to safety.

2. Characterization of track geometry quality (according EN 13848-6)

Track geometry quality can be characterized by various TQIs according to the level of aggregation they are used for. The TQIs represent the current state-of-the-art of description of track geometry quality.

The standard deviation (SD) is one of the most used TQIs by European Railway Networks. It represents the dispersion of a signal over a given track section, in relation to the mean value of this signal over the considered section.

$$SD = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \overline{x})}{N-1}}$$

Geometry quality levels / Characterization of track geometry quality

2. Characterization of track geometry quality (according EN 13848-6)

SD is commonly calculated for the following parameters:

- **Longitudinal level D1**
- **Alignment D1**

It is also calculated for other parameters such as:

- **Twist**
- **Track gauge**
- **Cross level**
- **Longitudinal level D2**
- **Alignment D2**

Geometry quality levels / Characterization of track geometry quality

2. Characterization of track geometry quality (according EN 13848-6)

For longitudinal level and alignment are recommended to calculate SD separately for each rail. It may also be calculated differently (for example: mean of both rails, worst or best of either rail or outer rail in curves).

When calculating SD for twist, track gauge and cross level attention should be paid on the possible influence of the quasi-static part of the signals.

Geometry quality levels / Characterization of track geometry quality

2. Characterization of track geometry quality (according EN 13848-6)

Isolated defects may present a derailment risk, however counting the number of isolated defects exceeding a specified threshold such as intervention limit and alert limit on a given fixed length of track can be representative of the track geometry quality.

The number of isolated defects is commonly counted for the following parameters:

- Longitudinal level D1
- Alignment D1
- Twist
- Track gauge
- Cross level

Geometry quality levels / Characterization of track geometry quality

2. Characterization of track geometry quality (according EN 13848-6)

Combined standard deviation (CoSD)

Assessment of the overall track geometry quality of a track section (200 m, 1 000 m...) can be done by a combination of weighted standard deviations of individual geometric parameters.

An example of such a TQI is:

$$CoSD = \sqrt{w_{\overline{AL}}SD_{\overline{AL}}^{2} + w_{G}SD_{G}^{2} + w_{CL}SD_{CL}^{2} + w_{\overline{LL}}SD_{\overline{LL}}^{2}}$$

AL - alignment, average of left and right rails

G - track gauge

CL - cross level

LL - longitudinal level, average of left and right rails.

Tamping processes for optimum durability

Tamping processes for optimum durability

1. Components

- <u>Sleeper spacing and squareness</u> must be uniform longitudinally, and square to the rail, to facilitate correct tamping
- <u>Ballast size</u> - for maximum ballast consolidation, there is a relationship between the tamping tine's vibration frequency and ballast size. The tamping frequency adopted is 35 Hz (*Plasser*), and 40-45 Hz (*Matisa*). Both manufacturers recommend a nominal ballast size of 30 mm – 60 mm of angular ballast that is as hard as possible, to obviate it breaking down under pressure from the tamping tines and/or traffic and allow good drainage of surface water by the lack of fines/small ballast particles in the ballast.

Tamping processes for optimum durability

1. Components

- Obstructions to tamping - all track obstructions that prevent the tamper's tines from penetrating the ballast, or the tamper's rail lifting clamps from lifting the rail, must be removed prior to tamping. If it is not possible to tamp all the sleepers, then differential track settlement will occur, and adversely affect the durability of track geometry maintenance.
- Ballast quantity - adequate ballast should be present to ensure that, as the tamper lifts the track and squeezes the ballast under the sleeper, sufficient additional adjacent ballast flows into the voids created by the squeezing action, to ensure that all the ballast is constrained as a homogeneous mass by the lack of fines/small ballast particles in the ballast.

Tamping processes for optimum durability

2. Tamping parameters

- Tamping tine depth - for optimum ballast compaction the distance from bottom of sleeper to top of tine must be 10 - 20 mm only. Therefore, the tamper operator needs to be informed of the correct depth to insert his tines, and also to have any changes of this distance marked up on site (i.e., where the track construction depth changes).

Tamping processes for optimum durability

2. Tamping parameters

- Longitudinal position of tines - For maximum ballast consolidation, the tamping tines must be inserted at no more than the middle of the crib, otherwise the ballast will be pulled under the leading sleeper by the first bank of tines, and then pulled back under the second sleeper by the next bank of tines. It is also very important for the tines to be spaced equidistant longitudinally between the sleepers to ensure that all individual sleepers have the same load bearing capacity. Modern tampers can therefore adjust their tamping bank spacing electronically to suit different sleeper spacings.

2. Tamping parameters

- <u>Lateral position of tines</u> - the tines should be positioned laterally; equally each side of the rail head to ensure that uniform consolidation and load bearing capacity is provided by the tamping action each side of the rail, and to eliminate any possibility of the side of the tine hitting the rail foot, especially on sharp curves where this latter distance is reduced.
- <u>Tamping tine wear and type</u> - the tamping tines should all be checked for unacceptable wear by using a tine gauge which is a simple “go/no go” gauge designed to show whether the tine is worn below acceptable limits. All tines should be present, without damage, and of the correct size and type for their individual location within the tamping bank as specified by the manufacturer.

Tamping processes for optimum durability

2. Tamping parameters

- Tamping squeeze pressure - this should be adjusted to the maximum pressure possible without lifting the sleepers beyond their design lift. The squeeze pressure also needs careful adjustment for individual site conditions (e.g. loose or consolidated ballast) to ensure that the maximum pressure is always applied.
- Tamping squeeze time - This should be between 1.2-1.5 secs for maintenance tamping. Note that adequate consolidation can take up to 2.5-3.0 secs on loose, unconsolidated ballast.
- Double tamping of sleepers - where track lifts > 25 mm, double tamping is required to ensure adequate ballast consolidation.

Tamping processes for optimum durability

2. Tamping parameters

- **Minimum track lift** - the minimum recommended track lift applied should be approx. 20-25 mm, representing a dimension of 50 % of the nominal stone size to facilitate the movement of fresh ballast beneath the sleeper during tamping. The absolute minimum lift must be at least 3-10 mm on high spots (to allow for cross level corrections etc). The manufacturers always recommend minimum tamping lifts of 15 mm to achieve proper ballast consolidation.
- **Maximum track lift** - The maximum track lift recommended is 60 mm, beyond this it is not possible to obtain adequate ballast consolidation, nor to provide sufficient additional adjacent ballast such that it flows into the voids created by the lifting and squeezing operations of the tamper.

Tamping processes for optimum durability

3. S&C Tamping

- S&C tamping - due to their design, switches and crossings (S&C) are subject to higher track forces than plain line. Deficiencies in the longitudinal level will always occur in the area of the frog because of the impact effects of traffic. Lateral impacts, caused by the wheels being forced between rail and check rail are the main reason for the occurrence of alignment faults. A correct track geometry position is therefore an absolute necessity, not only for switches located on main through routes, but also for the layout's remaining switches and crossings, in order to ensure operational safety and a long service life. To improve geometry quality in S&C it is recommended to tamp always both routes (main line and branch line) within S&C.

3. S&C Tamping

- Types of S&C tamper - the main characteristic of an S&C tamping machine is the individually lateral tiltable tamping tines. The tamping units can be displaced laterally on horizontal guide columns, so that the tamping tools are centred exactly over the area to be tamped – even in narrow sections between converging rails. Modern top-range S&C tampers are capable of tamping virtually all the sleepers within an S&C layout. At S&C with concrete bearers, a synchronous lifting of the turnout rail using the tamper's two telescopic arms (one each side of the tamper) is possible. The resultant synchronous 3-rail lift ensures that the outer rail of the branching line is lifted together with the two rails of the main line in the area of the long sleepers. Thus, the forces are evenly distributed on all rail fastenings and unstable geometric levelling conditions

3. S&C Tamping

- S&C Tamping Methods - S&C is tamped by either the relative (smoothing) or absolute (design) method. The absolute method is also used to return the track to its Absolute Track Geometry.
- 3.1 Relative tamping of S&C - This is performed using the "compensation method" when the exact longitudinal level (design level) of the track or the main geodetic points within S&C are unknown.
- 3.2 Absolute tamping of S&C - This is performed using the "precision method". To return the track to its exact designed geometric position, its current position in relation to this must be determined beforehand and marked in the fi eld by fixed points.

3. S&C Tamping

- <u>S&C tamping of Long concrete bearers</u> - where long concrete bearers or wood sleepers are used spanning more than one track, then special care must be used to ensure that the geometry corrections applied to one track will not adversely affect the other track tied to it by the long bearer: this applies to both vertical and horizontal track alignments. Gauge variations and bowing or hogging of the long bearers must also be taken into consideration when producing the final track geometry design. It is therefore very difficult indeed to tamp such layouts with only a single S&C tamper, unless an external means (e.g. PALAS) is fitted to the tamper to always provide an external reference for the design track geometry. An alternative is to tamp both tracks simultaneously using two tampers, since valid designs can then be produced that recognise the relative

Tamping processes for optimum durability

3. S&C Tamping

- Track construction depth - it is essential that any variance in construction depth is reflected in changes to the depth of the tamping tines.
- Maximum track lift - In general, S&C layouts are not lifted vertically to the same extent as plain line. Apart from the greater weight of the layout itself, extra care must be taken to ensure that the sensitive drive mechanisms (especially if of the mechanical type) are not unduly stressed by the tamper's lifting operation. The maximum track lift through S&C should not therefore exceed 40 mm.

Current use of ballast consolidators and Dynamic Track Stabilisers with maintenance tamping

Current use of ballast consolidators and DTS with maintenance tamping

1. Introduction

During tamping the tines of the tamping machines only achieve ballast compaction within that vicinity. It is thought to be desirable (to achieve good durability of track geometry) for compaction to take place also within the cribs and at sleeper ends. Track machine manufacturers offer several solutions for this, as follows:

- **sleeper-end consolidators**
- **ballast crib and shoulder consolidators**
- **dynamical track stabilisers (DTS).**

Current use of ballast consolidators and DTS with maintenance tamping

2. Tampers fitted with sleeper-end consolidators

Many European tampers are fitted by their manufacturers with sleeper end consolidators to compact the ballast immediately after tamping; ideally, of course, all the surrounding ballast should be compacted at the same time as the tamping operation itself.

Sleeper-end consolidators are vibrating plates, which are lowered at the end of the sleepers during the tamping, parallel with the axis of the track. These sleeper-end consolidators compact the ballast lane at the end of the sleepers. The prescribed min. horizontal width of this lane is generally 40 cm.

Current use of ballast consolidators and DTS with maintenance tamping

2. Tampers fitted with sleeper-end consolidators

Current use of ballast consolidators and DTS with maintenance tamping

3. Purpose-built ballast crib and shoulder consolidators

The aim of crib compaction is to fi ll the cavities which are left by the tamping tines in the cribs, and to compact the ballast in the space between the sleepers. Crib compaction increases lateral resistance by around 7%. The aim of ballast shoulder compaction is to ensure that the track stays in its newly-realigned horizontal position. This process also improves the lateral resistance by around 4%. Among the Infrastructure Managers taking part in this project, both Switzerland and Hungary use ballast crib and shoulder compactors. Switzerland uses specialised machines designed specifically for ballast shoulder and crib compaction. To optimise their efficiency, the consolidating unit is incorporated in a ballast regulator (profiling & sweeping) unit.

3. Dynamic track stabiliser (DTS)

The DTS is used instead of crib and ballast shoulder consolidators by some Infrastructure Managers. The purpose of using a dynamic track stabiliser is essentially to achieve 3 objectives:

- **Advance consolidation of part of the otherwise very large initial settlement of newly tamped track which may settle unevenly under the operating load of rail traffic. This is particularly important in the case of renewals work in which large quantities of new ballast are used. Operation of the DTS is stated by the manufacturers to provide the equivalent consolidation of approximately 100,000 gross tons of traffic.**

Current use of ballast consolidators and DTS with maintenance tamping

3. Dynamic track stabiliser (DTS)

- Increased resistance to lateral displacement of the track, which can fall to about half its normal service value after being disturbed by tamping the track. Using the DTS restores some of the resistance to lateral displacement, and therefore allows the track to be immediately used at increased speeds up the full line speed.
- Increasing the durability of maintenance tamping work with the object of extending the time interval between tamping interventions, and thereby improving life cycle costs (LCC) over the entire life of the track.

4. Operational theory of DTS

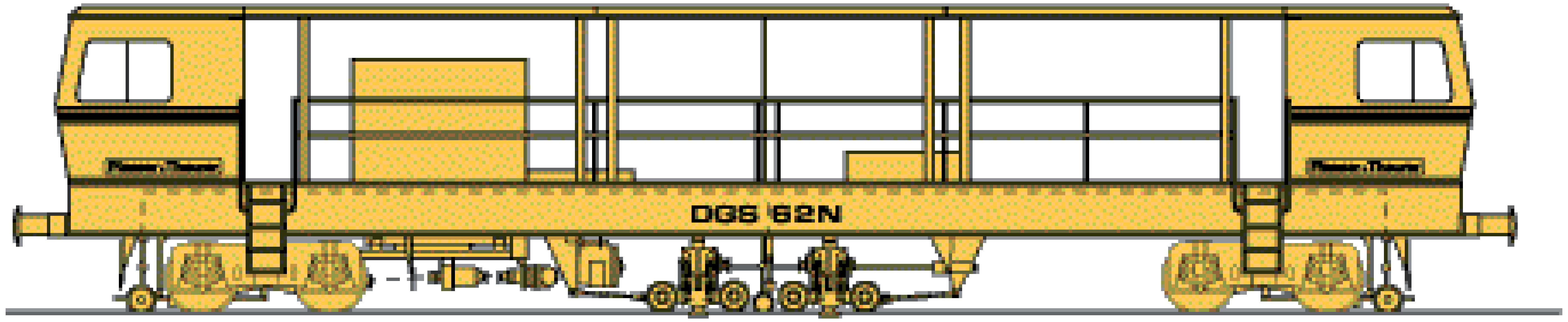
Extensive tests carried out by the Technical University in Graz served to establish the ideal setting values for load and frequency. These tests for example led to the recognition that consolidation of the ballast stones using horizontal vibrations is seven times more efficient than using vertical vibrations.

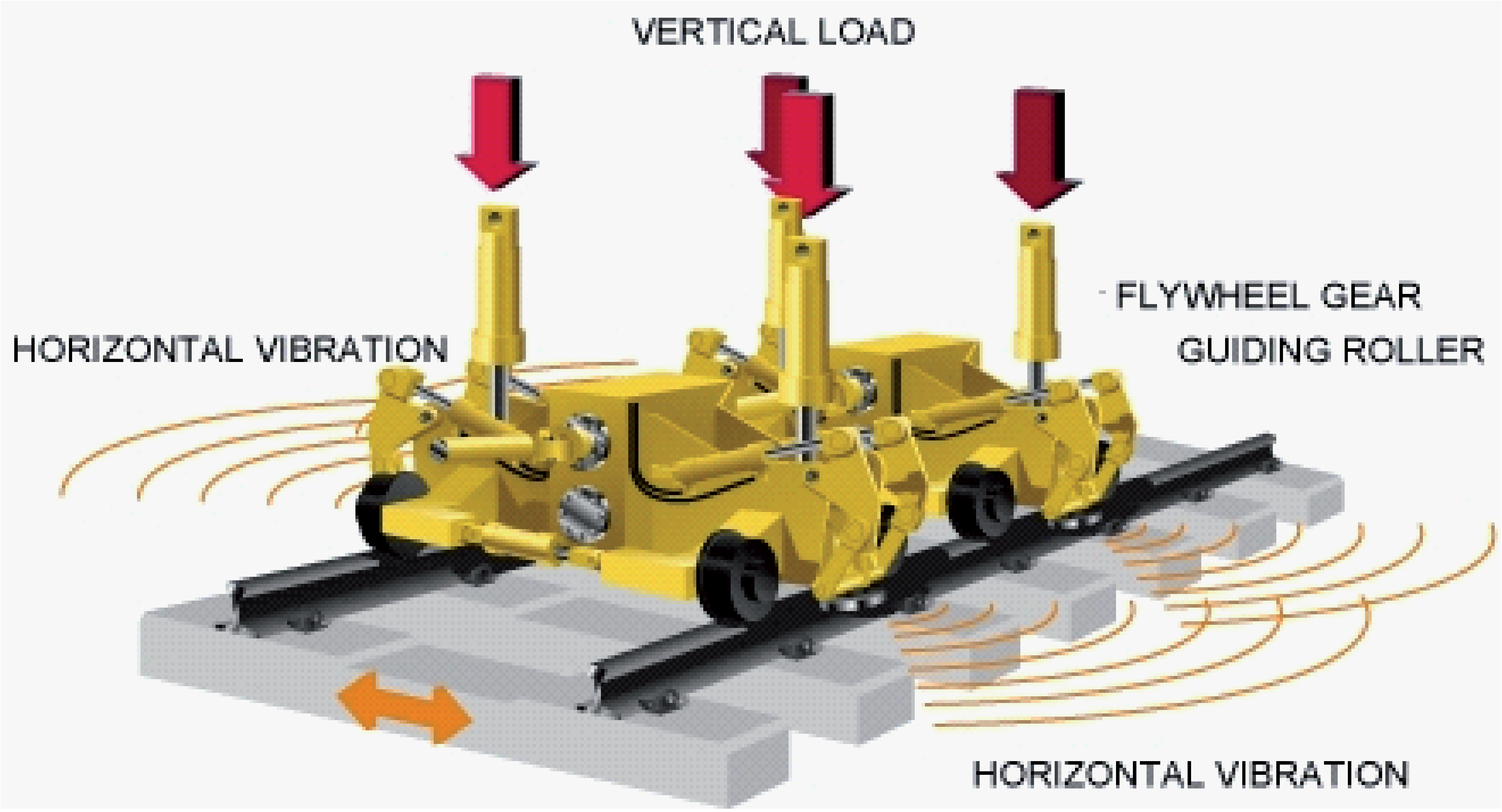
The dynamic track stabiliser can be either:

- stand-alone machines, or
- a dynamic stabilisation wagon which can be attached to a tamper.

Current use of ballast consolidators and DTS with maintenance tamping

4. Operational theory of DTS





Current use of ballast consolidators and DTS with maintenance tamping

5. Limitation on DTS deployment

Most Infrastructure Managers limit the use of the DTS, where the vibration induced into the track and its supporting infrastructure may have a detrimental effect on that infrastructure. This is typically upon some types of bridge and culverts, and upon S&C, where the vibration may also affect adversely the sensitive signalling fittings etc.

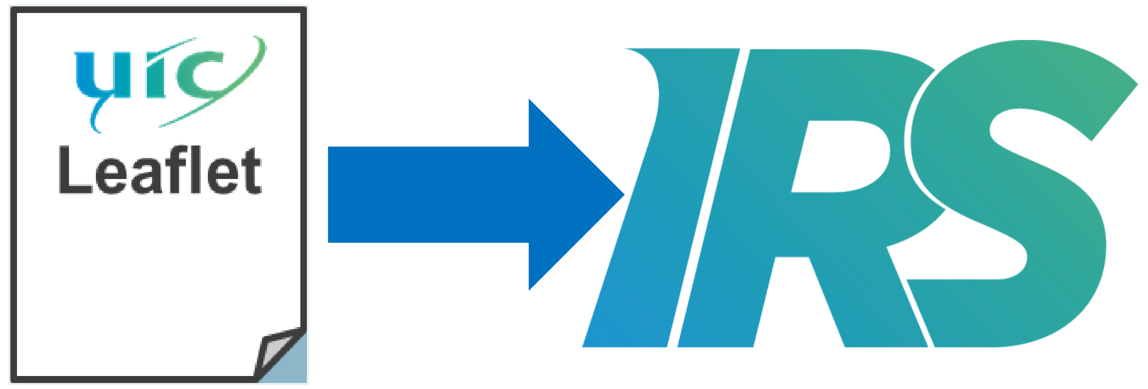
Track Expert Group

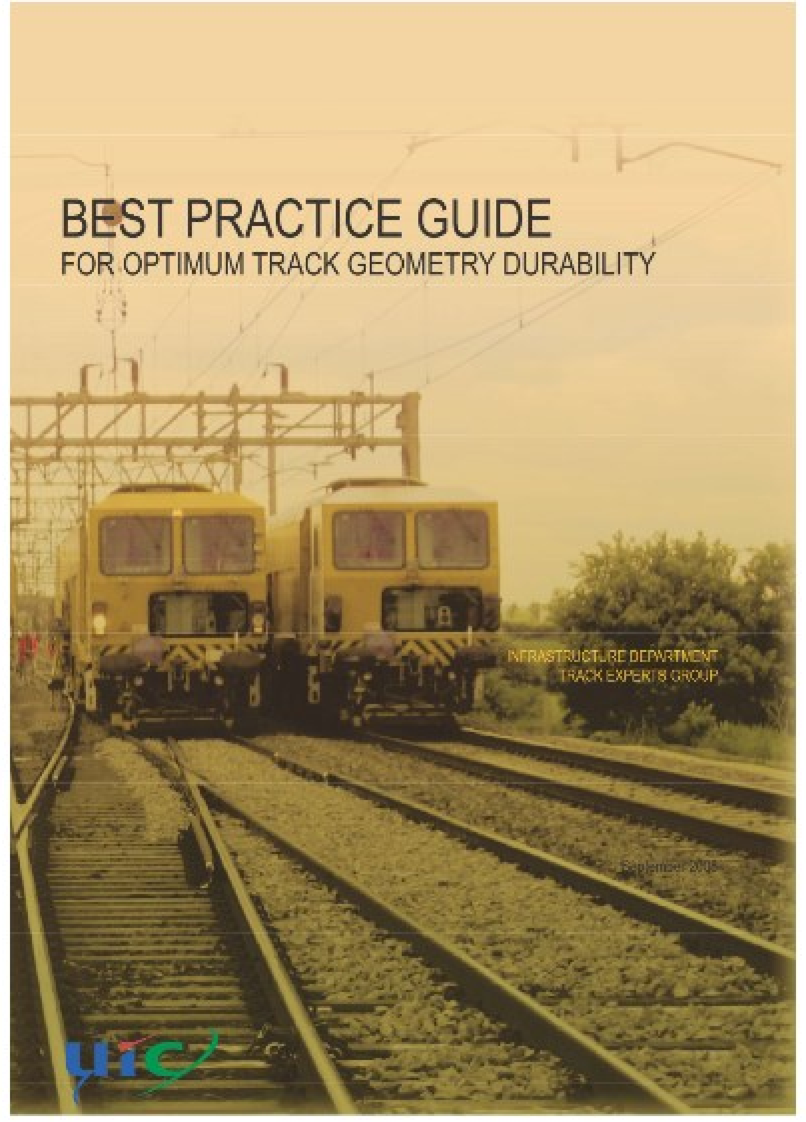
Panel of Structural Experts

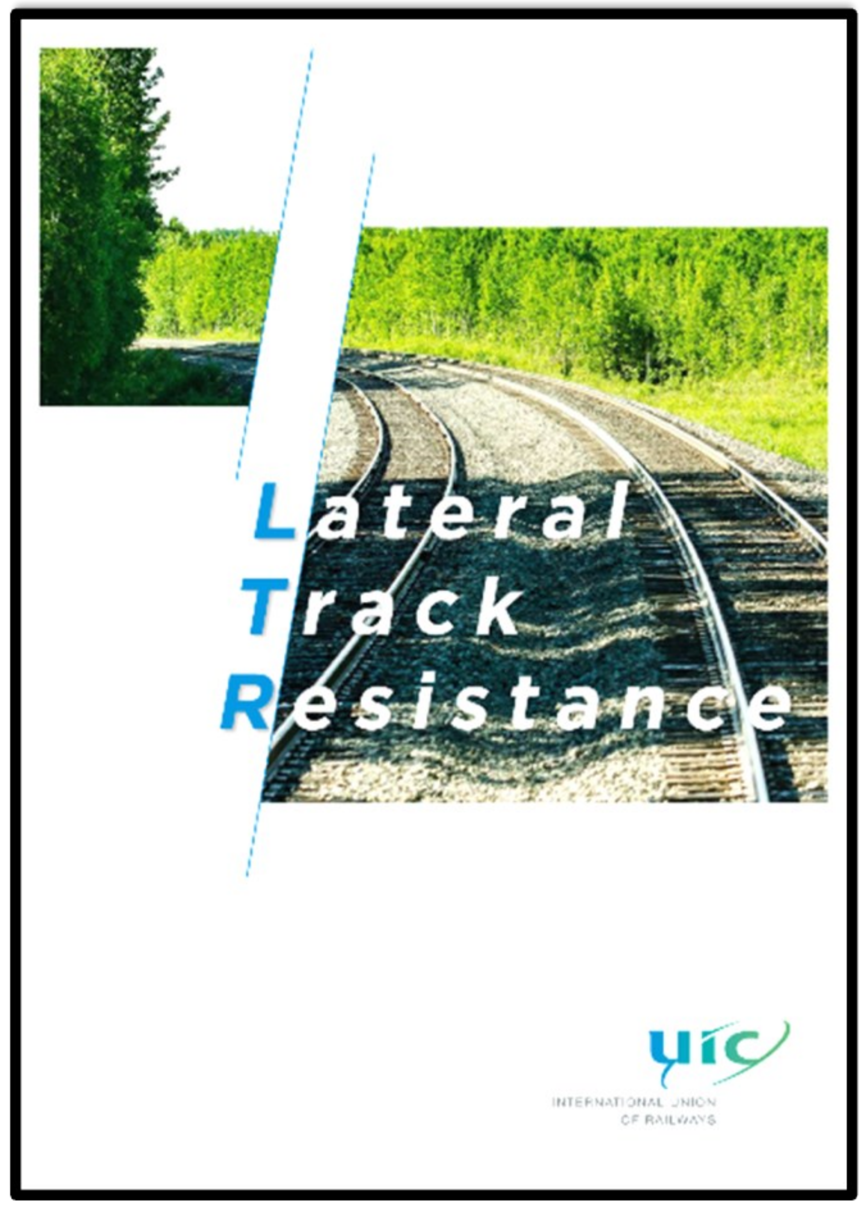
UIC documents about Maintenance of Infrastructure

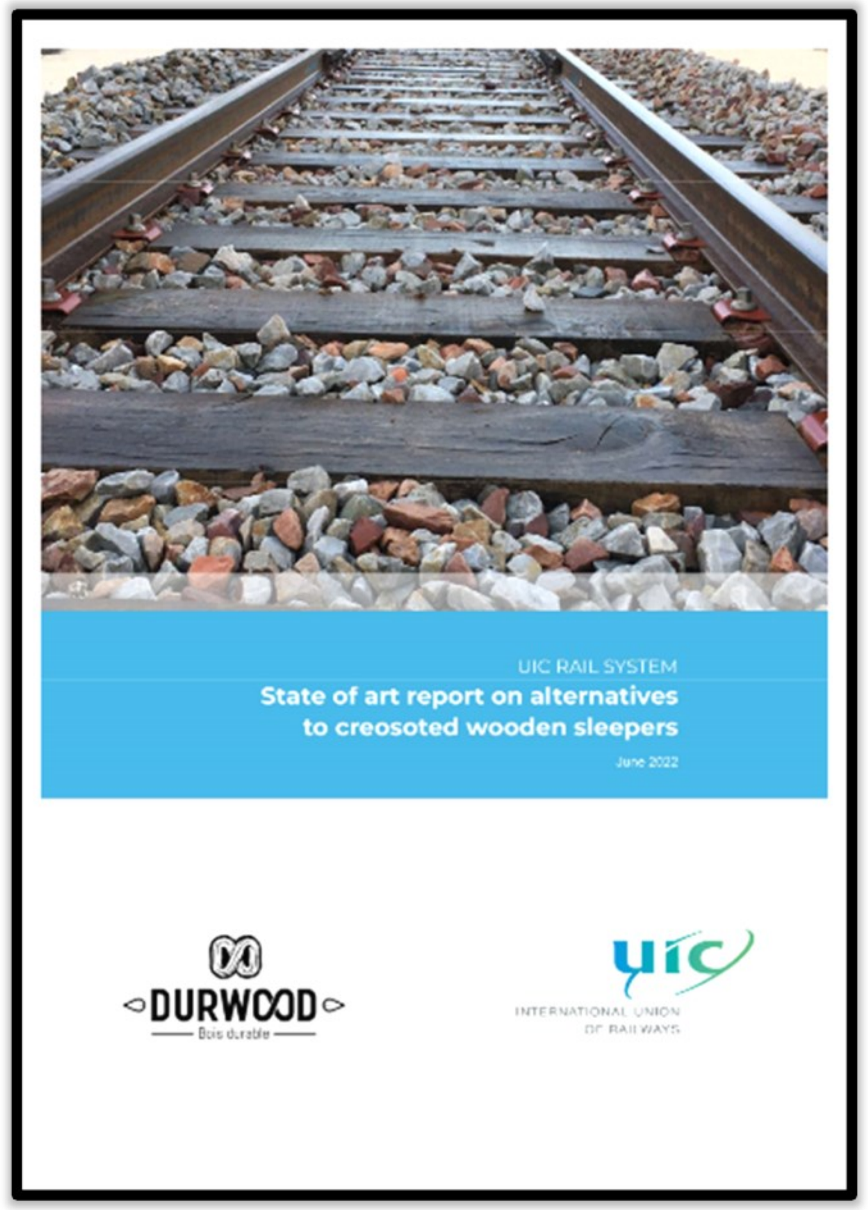
Generically, there is two types of documents:

- **The UIC Leaflets, progressively migrated to IRS**
- **Technical Reports, Guidelines or Specifications**









Results for tamping durability

Results for tamping durability

1. **Limitation on DTS deployment**

Most Infrastructure Managers limit the use of the DTS, where the vibration induced into the track and its supporting infrastructure may have a detrimental effect on that infrastructure. This is typically upon some types of bridge and culverts, and upon S&C, where the vibration may also affect adversely the sensitive signalling fittings etc.

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