Dynamic track stabilisers are now used in 36 countries. Among the latest applications is a combination of a DTS and a three-sleeper tamping machine

Dynamic stabilisation keeps geometry in shape

Long-term trials carried out jointly by German Railway and Plasser & Theurer have shown that dynamic track stabilisation reduces the rate at which track geometry deteriorates

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IN A LONG-TERM trial carried out with German Railway on a main line near Regensburg, 22 sections of track were treated after normal track maintenance with a dynamic track stabiliser (DTS). Precision surveying was carried out before and after maintenance, and after an operating load of 1 and 5 million tonnes, using the EMSAT track survey car. Additional measurements were taken using a DB track recording car before the maintenance work and after the line had been in traffic for one year. Comparison of the results from these measuring runs shows that stabilised sections performed significantly better than the non-stabilised sections.

The results of the investigations show that:

- the fault deterioration rate of the stabilised sections increases more slowly than that of the non-stabilised sections;
- the absolute fault level of the stabilised sections is smaller than that of the non-stabilised sections;
- the disturbance reaction measurement from the DB recording car also shows greater durability on the stabilised sections;
- dynamic track stabilisation leads to an improvement of the long-wave durability.

One method for making an objective assessment of track geometry is to take the standard deviation of the longitudinal fault level over a given length of track, typically a 100 m section. Another option is to calculate a weighted track quality figure on the basis of various track fault parameters. Track geometry faults alone do not suffice for an objective assessment, and they need to be examined in conjunction with the reactions and effects caused by the trains.

German Railway uses a special track assessment method known as the disturbance reaction (SR) technique. Reactions are calculated from the measured parameters for specified train configurations. The track geometry faults are recorded, and an assessment made of how the fault develops over time and its effects. DB's method is based on a linear vehicle model with a car body on two bogies.

Geometry measured

The typical curve for track geometry quality is shown in Fig 1 where the measurement used is the standard deviation of the longitudinal level fault. The track geometry quality curve at the top left is typical for a secondary line, and the lower curve for a main line or high speed route.

The threshold for taking action (Q_{SN}) on the secondary line is somewhat higher than that for a main line (Q_{SH}). Note that the deterioration rate progresses more steeply for secondary lines. This is because better quality and heavier track materials are used with formation protection layers, and also because higher standards are required for faster running.

If the initial quality can be improved by -ΔQ using better maintenance or technology such as the dynamic track stabiliser, the track deterioration lines, shown in red, are displaced downwards, indicating better durability of the track geometry. However, it is clear that the same improvement in initial quality on a main line track extends the durability in absolute terms. This highlights the economic significance of using up-to-date maintenance technologies, particularly on main lines where the absolute gain is greatest.

On the right of Fig 1 is a comparison of the longitudinal level of a typical secondary line with that on a main or high speed line. Track quality is represented by the standard deviation measured at intervals of 100 m using track recording cars. By evaluating these figures it is possible, as well as the absolute standard devia-

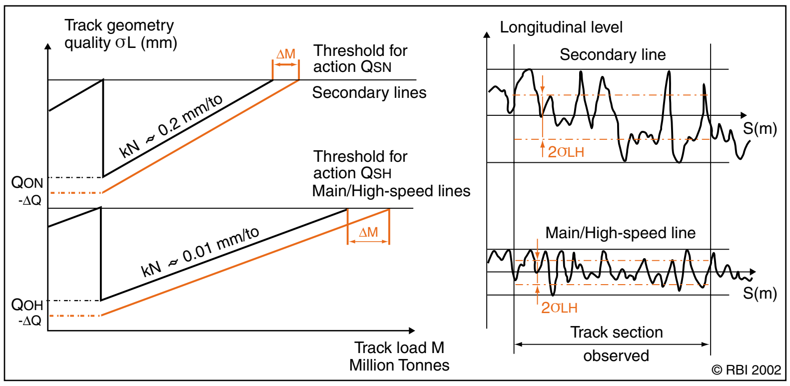


Fig 1. Comparison of track geometry under load on secondary and main lines measured using the standard deviation of the longitudinal level fault

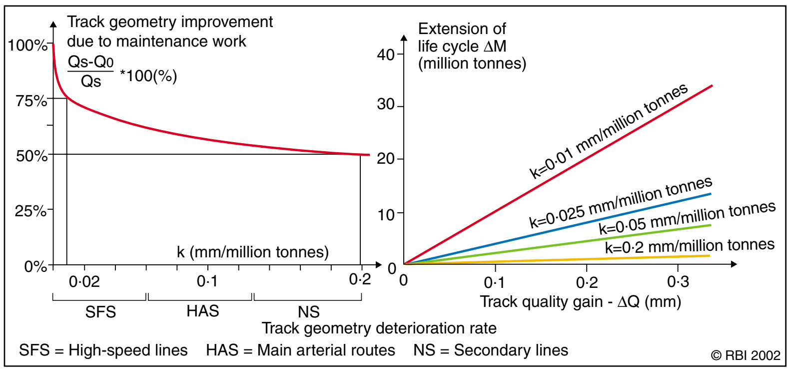


Fig 2. The relationship between track geometry and the rate of deterioration (left) and the extension of the life cycle possible with an improvement in track quality

tion of the track geometry fault, to calculate the development trend and thus the remaining load over the track before the threshold for action is reached. This is a great help for planning and co-ordinating track maintenance.

Investigations[1] have shown that the potential to improve the geometry of good track is higher than for poor track. This relationship is shown in the left-hand diagram in Fig 2. A track geometry deterioration rate with a gradual slope is a feature of high quality track. A track with a geometry deterioration rate of only 0·01 mm per million tonnes can be improved by 75% by tamping. For example, if the threshold for action is 1 mm, the standard deviation of the remaining residual fault can be improved up to 0·25 mm by tamping. In contrast, on a secondary track with 0·2 mm per million tonnes, the fault could only be reduced by 50%, in this case from a threshold for action of 2 mm to 1 mm.

The diagram on the right of Fig 2 shows the service life extension ΔM in million tonnes, which is produced by a certain track quality gain at a defined track geometry deterioration rate k. Use of a DTS avoids some of the irregular settlement following tamping caused by traffic loadings, and so the geometry deterioration rate is displaced downwards by 0·3 mm in this example. On track where geometry deteriorates at a rate of 0·01 mm per million tonnes, service life would be extended by around 30 million tonnes.

Effectiveness of the DTS

Over 300 DTS machines are in service in 36 countries. The DTS is equipped with two oscillating units that hold both rails with roller clamps and put the track into horizontal oscillation while applying a vertical load. Extensive tests carried out by the Technical University of Graz[2] have determined optimum settings for load, frequency, application time and amplitude.

The tests also revealed that consolidation of the ballast with horizontal oscillations is up to seven times more efficient than using vertical oscillations. During tamping the sleeper end and sleeper crib consolidation is only effective locally, but the DTS stabilises and homogenises the entire ballast bed. Therefore the term 'thorough volumetric' consolidation[3] is used, meaning that stability is produced in all three dimensions.

In effect, the DTS anticipates part of the load needed to stabilise the track, restoring the resistance to lateral displacement. This enables the track to be reopened at full line speed after maintenance[4,5].

Uniform settlement

In contrast to the loading effect of trains, the application of a sinusoidal horizontal oscillating frequency and a levelling control brings about uniform settlement. This will lead to an extension of the maintenance cycle.

Loose stone is best consolidated in layers. Whether on new track, during renewal or after ballast cleaning, the most durable track geometry is achieved by tamping and stabilising the separate ballast layers, which may be 70 to 100 mm thick.

Investigations of the effects of dynamic stabilisation on the subsoil have shown that even with very unfavourable material such as loess, fine sand, silt or clay[6], the DTS causes no damage.

The ballast pressure induced by the DTS acts mainly in the vertical direction and is purely static. It applies a much lower strain than the axles of a rail vehicle where the vertical load is typically distributed over four axles.

As the DTS anticipates traffic loads in a controlled way and with comparatively low stresses on the ballast bed, it has been proven that it has no more adverse effect on the vertical elasticity of the ballast bed than the traffic passing over it[7].

Many other studies document that there is a slight influence on the track environment. With regard to stresses on rail fastenings and signalling or telecoms installations, the use of the DTS has no effect on safety.

The typical pattern of settlement after maintenance sees the track stabilise itself under the first 1 million tonnes of traffic, allowing full line speed to be resumed. Irregular settlements then develop, and part of the geometry improvement is lost relatively quickly. The reason for this is that the ballast stones are more densely packed, sharp points of the stones break off, and so on. After this exponential phase of deterioration, the linear portion of track geometry deterioration begins. This is signifi-

Table I. Parameters of the Mirskofen – Neufahrn test section

Weekly load Mirskofen – Neufahrn *tonnes*	130 000
Weekly load Neufahrn – Mirskofen *tonnes*	150 000
Sleeper type Mirskofen – Neufahrn	B58, K54
Sleeper type Neufahrn – Mirskofen	B70, W54
Sleepers, year of manufacture	1960-68
Rail (in good condition), year of manufacture	1976-77
Most recent ballast clean	1977
Maintenance work with/without DTS	September 23 1999
Measurement after 1 million gross tonnes	November 17 1999
Measurement after 5 million gross tonnes	June 13 2000

La stabilisation dynamique maintient en forme la géométrie de la voie

En Allemagne, des essais à long terme ont montré que la stabilisation dynamique de la voie réduit le taux de détérioration de sa géométrie. Des mesures de précision ont été menées sur 22 sections de voie près de Regensburg et des comparaisons effectuées entre des sections stabilisées et non stabilisées. A la fois le nombre de défauts et le taux de détérioration des défauts étaient inférieurs sur les sections traîtées

Dynamische Stabilisierung hält Gleisgeometrie zusammen

Langzeitversuche in Deutschland haben gezeigt, dass dynamische Gleisstabilisierung die Geschwindigkeit der Verschlechterung der Gleisgeometrie verlangsamt. Präzisionsmessungen wurden an 22 Gleisabschnitten in der Nähe von Regensburg durchgeführt, und Vergleiche zwischen stabilisierten und nicht stabilisierten Abschnitte vorgenommen. Sowohl die Anzahl Fehler und die Verschlimmerungsrate der Fehler waren in den behandelten Abschnitten geringer

La estabilización dinámica mantiene la geometría de la vía en buen estado

En Alemania, se han llevado a cabo experimentos a largo plazo demostrando que la estabilización dinámica reduce el índice de deterioro de la geometría de la vía. Se han realizado mediciones de precisión en 22 secciones de vía cerca de Regensburg así como estudios comparativos entre las secciones estabilizadas y las que no lo están. Tanto el índice de fallos como el nivel de deterioro fueron menores en las secciones tratadas

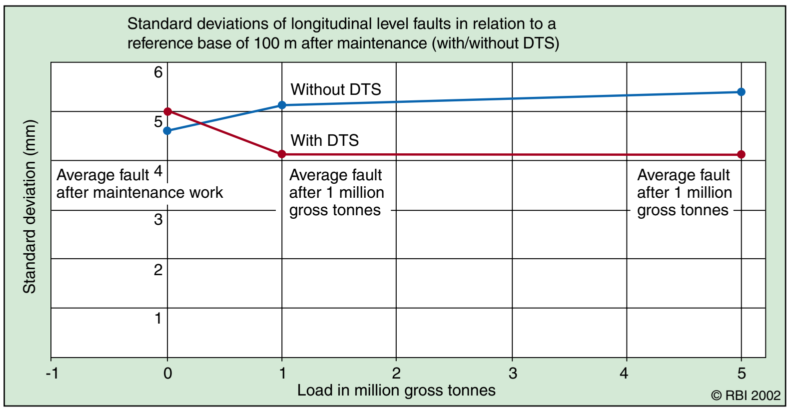


Fig 3. Development of track geometry faults in stabilised and non-stabilised test sections on DB's München – Regensburg line

cant for the durability of track geometry correction.

Many studies have shown that the slope of the linear deterioration is typical for a given section of track and so will remain the same after further maintenance. These values show considerable scatter from section to section, even though the same materials and techniques may have been used during construction.

With the DTS it is possible to reduce the initial rapid deterioration of the track geometry. This means that the deterioration curves in the sections treated by DTS are lower, leading to a 30% longer service life.

Tests in Germany

The aim of the long-term trials carried out with German Railway was to prove that use of a DTS could extend track service life. DB picked the 100 m long test sections on the main line between München and Regensburg, and these were alternately stabilised and not stabilised. To prevent the results being influenced by activity in the adjacent test section, a 50 m length was left between each section.

Each test section was measured with an EMSAT recording car using a laser reference chord before maintenance, immediately afterwards and then after 1 and 5 million tonnes had passed over it (Table I). From these measurements it was possible to derive the standard deviation of the longitudinal level. Besides the short-wave faults, the measurements also recorded long-wave faults. This explains the apparently large value of the standard deviation – long-wave faults always occur with greater amplitude than short-wave faults.

Taking the records from the laser reference chord, the average lift over the individual sections, the settlement induced by the DTS and the settlement from traffic, it was possible to calculate the standard deviation of the longitudinal level faults for the 22 sections.

The results are summarised in Table II. The high settlement value of around 60% of the average lift on the DTS treated sections is striking. Particularly large settlement occurred in the Mirskofen – Neufahrn direction. This indicates that the angle of friction of the ballast stones has been lowered by fouling – hardly surprising given that the last ballast clean was 22 years earlier.

It can also be seen that the standard deviation of the track fault after maintenance in the DTS sections was slight at first (5 mm) and then worse than in unstabilised sections (4·6 mm). However, after 1 million gross tonnes the fault improved in the treated sections while it worsened in the untreated sections. After a further 4 million gross tonnes the average track fault in the stabilised sections remained the same and that in the non-stabilised sections deteriorated further.

Fig 4 compares the density of track irregularities after 5 million gross tonnes for the stabilised and non-stabilised sections. The average track faults in the stabilised sections are clearly less than in the non-stabilised sections, particularly in the long-wave sector. That indicates that the DTS also improves the stability of the longer-wave faults and demonstrates the effect of extending the life cycle by use of a DTS. It can be expected that the non-stabilised sections will continue to deteriorate more rapidly under load than the treated sections.

Evaluation

Figs 5 and 6 compare DB's SR measurements in the non-stabilised and stabilised sections before maintenance and after one year of traffic, clearly demonstrating the improvement on the stabilised sections. When all sections are compared, there was an average improvement of only 9·9% in the non-stabilised sections, but in the stabilised sections the average improvement was 21·2%.

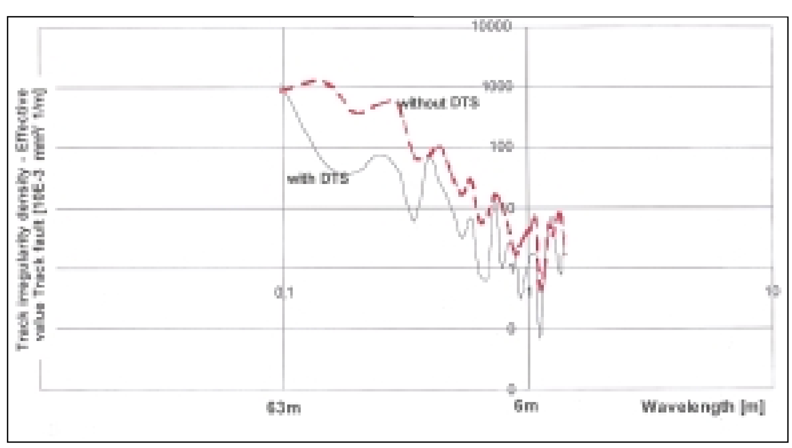
Other railways can point to similar improvements. Spoornet in South Africa, for example, has demonstrated the positive effects of using a DTS[8]. On a track carrying 100 million tonnes/year, stabilisation led to a 60% higher durability of the track superelevation, while the general durability of track geometry increased from 6 months to 18 months.

Cost efficiency

In a calculation of life-cycle costs[9], the model used combines life-cycle costs with dynamic profitability calculations, whereby the capital value function forms the major assessment parameter.

A number of assumptions had to be made. For example, Austrian prices were used for the cost of stabilisation, track renewal, maintenance and

Fig 4. Density of track irregularities on stabilised and non-stabilised track sections



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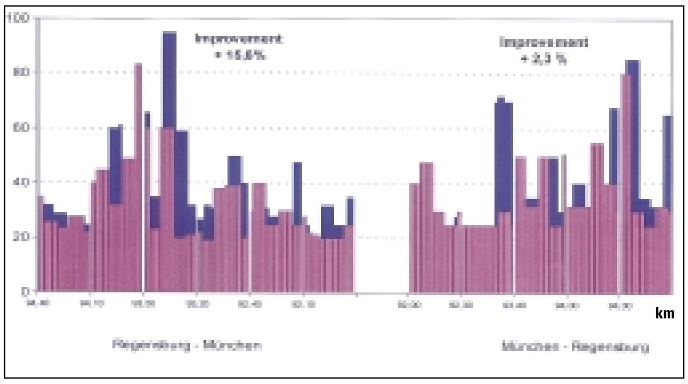

Fig 5. Comparison of track geometry on unstabilised test sections measured using DB's SR disturbance analysis method before maintenance (blue) and after one year of traffic (pink)

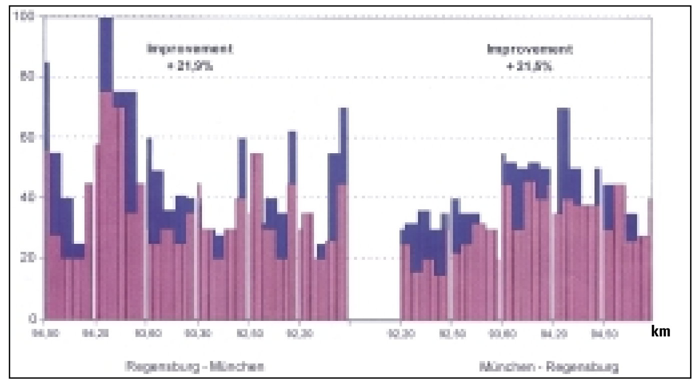

Fig 6. Significant improvement is evident in this comparison of track geometry on stabilised test sections. Measurements were taken before maintenance (blue) and after one year of traffic (pink)

ballast cleaning. The disruption cost of possessions was excluded, track service life was assumed to be 35 years, tamping intervals were taken to be four years with stabilisation and three years without, and ballast bed cleaning was performed halfway through the service life.

The result of this calculation is extremely positive. The rate of interest which the invested capital would yield is 484%, the total saving over the 35 year track life is around 15 000 €/km and the annual saving is 430 €/km. Clearly there are significant economic advantages to be gained from using dynamic track stabilisation, which would indicate that the comprehensive application of this maintenance technology is particularly urgent. ■

Table II. Results from trials on Mirskofen – Neufahrn line

	Sections with DTS	Sections without DTS
Average lift of tamping machine *mm*	23	17·1
Average settlement due to DTS *mm*	13·5	-
Standard deviation fault after maintenance *mm*	5·0	4·6
Standard deviation fault after 1 million tonnes *mm*	4·1	5·1
Standard deviation fault after 5 million tonnes *mm*	4·1	5·4
Average rise in fault growth in total *mm/million tonnes*	–0·2mm/million gross tonnes fault reduction	+0·8mm/million gross tonnes fault growth