40 Years of "Dynamic Track Stabilisation"

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1 Introduction

Dynamic track stabilisation is nowadays an indispensable part of track maintenance. After tamping, the use of a stabiliser ensures that an optimum sustainable result is achieved. Despite this, there is still concern about the use of this technology which is incomprehensible in view of its forty-year success story. Over 900 machines in 45 countries speak for themselves.
As the result of track stabilisation cannot be seen directly, but only becomes evident from the better durability of the track geometry (horizontal and vertical), numerous tests have been carried out over the years the majority of which have confirmed expectations. Below we provide a summary of what is known about dynamic track stabilisation.

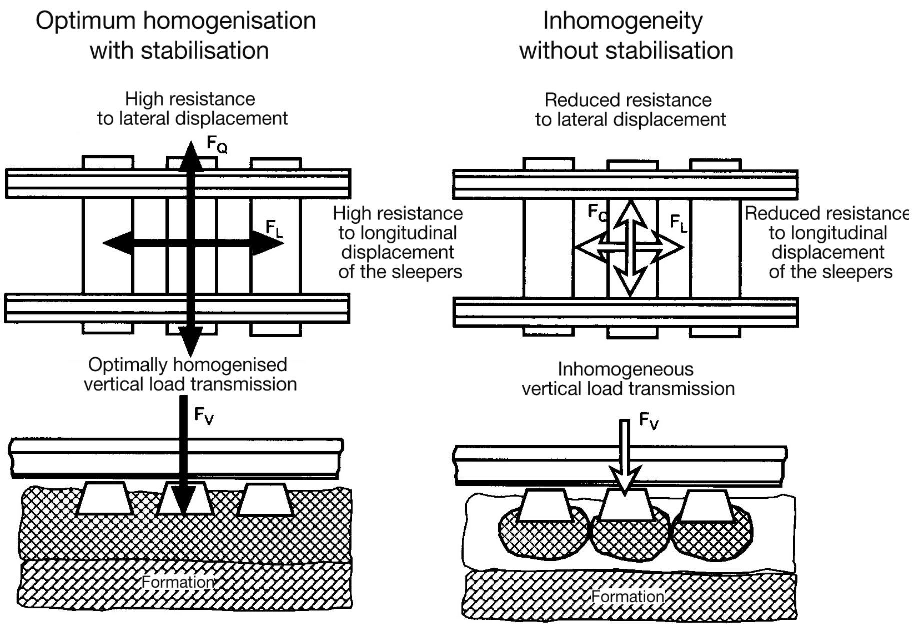

Fig. 1: Homogenising the ballast bed by means of dynamic track stabilisation

2 The Principle of Dynamic Track Stabilisation

During tamping the ballast under the sleepers is rearranged and consolidated. The ballast thus supports the track in its corrected geometry. As the tamping tools penetrate into the space between the sleepers and are then pulled out again after squeezing and consolidating, there remains an unconsolidated area. The ballast is not moved in front of the sleeper shoulders, but a gap results at the sleeper ends due to the lining movement. The track geometry has thus been corrected by levelling, lining and tamping, however, the ballast loses stability and becomes inhomogeneous. Following tamping, the Dynamic Track Stabiliser moves continuously across the track and causes the track to vibrate laterally. At the same time the track is loaded perpendicularly (Fig. 2). The lateral vibration has the effect that the ballast rearranges itself without impact effect and fits together better. Thus, the complete ballast bed is homogenised and consolidated (Fig. 1). The consolidation effect is increased by the vertical load which can also affect the level. After stabilisation, the track has a greater stability; the track geometry keeps for longer and the lateral stability, i.e. the resistance to lateral track displacement, is increased.

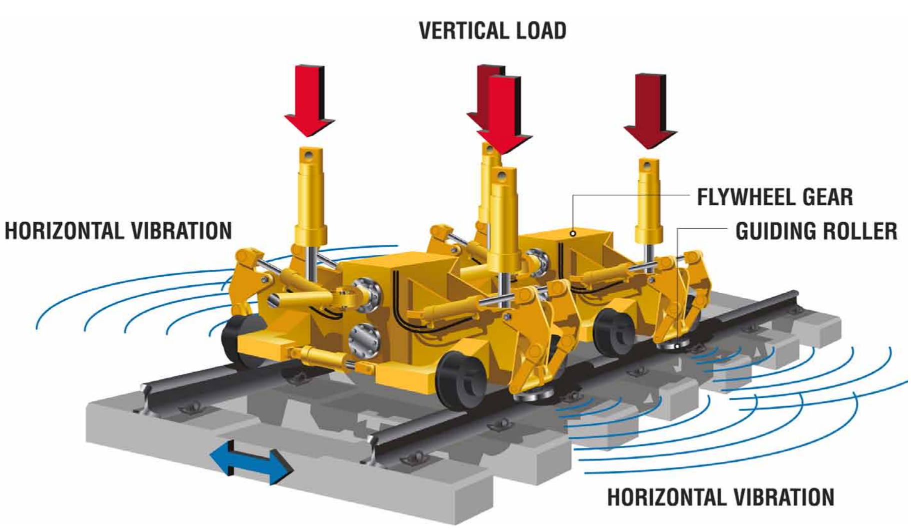

Fig. 2: The Principle of Dynamic Track Stabilisation

3 The beginning – 1975 to 1980

3.1 Track stability

After the destruction caused during WWII, the railway system was able to regain its pre-war technical capabilities from about 1950. The running speed was still determined by steam traction, but electrification made continuous progress.
From 1955, road transport started to become a serious competitor and was noticeably gaining market share. It became necessary to improve the rail services offered, the running speed could be successively increased in addition to new trains being put into service. As it was not possible to even consider building new railway lines – the attention was almost exclusively on

Fig. 3: MDZ in 1968 at ÖBB

building motorways – everything possible was done to get the most out of the existing tracks by fine tuning the route parameters. Initially the values for the maximum permissible lateral acceleration and their change (jolting) which passengers and restaurant car could be expected to put up with were limiting factors, but soon other phenomena of track construction not known well thus far became apparent as limitations on higher speeds.

Intensive research by the French Railways SNCF had resulted in a bearable ratio of lateral to vertically acting forces for ballasted track (Prud'homme criterion [16]) Initiated by Munich Technical University (Meier, Eisenmann), historical calculation methods to determine proper design of tracks, which had almost been forgotten, were updated, checked scientifically and embedded in the permanent way regulations of the German Federal Railways (DB).

At the same time, new technologies for track maintenance using special machines were developed. Not only did these result in immense savings in labour, but they also served as a replacement for track maintenance staff who were migrating in large numbers into the stationary industry.

For these reasons the progress in mechanising track work was rapid. The first commercial tamping machine of 1945 was followed by a fleet of rail-mounted construction machines for numerous individual and combined work procedures after 1955.

The idea of a "mechanised work train" (MDZ) originated in Austria. This combined a line tamping machine, an impact tamping machine, a ballast regulator and a consolidator into one operational group (Fig. 3).

It was found that rails with joints required a higher level of maintenance due to their inhomogeneity. The introduction of continuously welded rails spread over several decades and was accompanied by intensive research. When, at the end of the 1960s, it was finally realised that the 49E1(S 49) rail normally used at that time would not meet the requirements of German main lines in the longer term, the move to the heavier 60E1 (UIC 60) rails was made around 1970. It was clear that the problem of a reliable lateral track geometry would become more urgent. The regulations at that time only permitted welding of rails from a radius of >300 m.

With regard to the work methods used it was recognised that the combination of lifting of a track panel and subsequent tamping led to a weakening of the lateral anchoring of the track in the ballast. The development of machines for the subsequent compacting of the ballast bed with the aim of ensuring as high a resistance to lateral track displacement (QVW) as possible started with the construction of the consolidator (VDM) which pressed vibration loaded plungers onto the ballast between the sleepers. Ballast consolidation in the sleeper cribs together with sleeper end consolidation increases the QVW after tamping by about 11 % (7+4 %) [17]. These machines were then added as a fourth work unit into the MDZ.

Finally, two developments lead to a renewed consideration of lateral track stability:

Accidents showed on the one hand that tracks may indeed not be sufficiently well anchored laterally. The clearing of the sleeper cribs during track maintenance combined with high rail temperatures can bring about such situations.

On the other hand, a working group of specialists had formed under the "Research Office (ORE) of the International Railway Association (UIC)" and they looked into practicable solutions for this accepted problem. Here, it was SNCF in particular who

Fig. 4: The first Dynamic Track Stabiliser, designed as tamper trailer

Fig. 5: The first self-propelled DTS 32 N in test use near Kraubath, Austria

Fig. 6: First production version - the DTS 42 N

looked for a reliable method to ensure a satisfactory level of safety for the planned Paris – Lyon high-speed rail line and who carried out experiments in a test facility themselves (Vibrogir St. Ouen).

3.2 Dynamic Track Stabilisation

The research and testing department of Plasser & Theurer followed two approaches:

- Concrete sleepers could be manufactured with appropriate shuttering in a form that increased the QVW itself. Manufacturing using the single sleeper production method is of benefit here. These sleepers were named “Schubert’sche Ohrenschwellen” (lugged sleepers) after their inventor and installed on a few test sections of the Austrian Federal Railways (ÖBB) in place of wooden sleepers. They proved their effectiveness in increasing lateral track stability, but were not able to solve the already known problems of badly drained substrate of low bearing strength (for which they were not intended!).
- “Dynamic track stabilisation” was developed by Plasser & Theurer in a long series of tests (1974–1978). As early as 1975 the first Dynamic Track Stabiliser (DTS) was presented at the VDEI Permanent Way Conference (now: iaf) in Frankfurt (Fig. 4). Initially, the main parameters affecting ballast consolidation, i.e. vibration frequency, impact power and static vertical load, had been identified. However, the major difficulty during the development phase consisted of an assessment of the “lateral track stability”.

With machines correcting track geometry, such as levelling and tamping machines and track lining machines, the work result can be assessed visually; line of sight and versine measurements can confirm the first impression. But what about “track stability”?

By collecting what (few) experiences the railways had gained in carrying out such measurements, a method of comparative measurement of the QVW finally resulted, which made it possible to carry out a number of measurements sufficient for a statistical analysis over a short period. In this way it was possible to limit the required track possessions to a comparatively short duration. It goes without saying that the railway companies’ management had only limited patience for this research.

This is the background to the fact that the numerous QVW measurements cannot be compared to each other as different methods were generally used. Therefore, only the measurements within a self-contained measurement project can be compared. All tests proved a noticeable improvement of QVW by the DTS.

Right from the start there was great interest in the “Dynamic Track Stabiliser”, in particular from the track engineers responsible for safety and research. It was found that every European railway company had a different question and hence the DTS prototype was sent through Europe on a “Tour de Recherche”.

In the Austrian tests, the most suitable frequency for the horizontal vibration of the track was found to be about 35–38 Hz after a few tests. This is also a confirmation of the tamping tool frequency used by tamping machines. At a lower frequency, the vibration amplitude generated in the track falls with reduced impact force; at higher frequencies the ballast develops a life of its own which results in an (increasingly) uncontrollable longitudinal level of the track. Furthermore, it turned out that the wheel base of the machine has to be chosen such that a largely unhindered formation of the horizontal flexure curve is possible. For this reason, the trailer of a tamping machine originally used for the tests was extended from a wheel base of 6,000 mm to a wheel base of 8,000 mm.

Experience was also gained with the size of vertical load. The prototype of the “Dynamic Track Stabiliser” was originally a light trailer; the forces pressing on the vibrating units were supported by the machine frame and lifted it. Thus the machine got stuck several times, in particular in canted curves. A first remedy was obtained by arranging counterweights, in later designs the self-propelled machine type was also chosen with regard to its greater weight. Figure 5 shows such a three-axle machine during a test run. Finally, a design was chosen which consisted of a two-axle traction engine and a heavy two-axle trailer (Fig. 6).

In Austria, numerous tests and measurements were also carried out on the effects of dynamic track stabilisation on the fasteners. It was possible to prove that this track treatment did not pose any danger to the rail fasteners.

The French Railways SNCF observed the efforts regarding the post-consolidation of the ballast with particular interest. Staff of the “Recherche Voie” department visited Austria with some equipment to carry out research on the effect of the innovative technology on a newly laid track with cleaned ballast, made properly fit for traffic, on the section of the Südbahn, near Kraubath station (Fig. 5), even while the machine was still being developed. The measurements were integrated into the tightly organised construction work, which gained ÖBB the respect of SNCF.

Initial DTS Research (1976–1979)	
Aim of tests	Result
Track settlement, increased durability of maintenance	
	The settlement achieved by the stabiliser corresponds to the value which would be obtained after 700,000 load tonnes (Lt). [1]
	Measuring runs in the wake of the stabiliser using the MAUZIN measuring car of SNCF showed that the stabiliser achieved very uniform settlement. [2]
	After track repairs, the stabiliser achieved a settlement of 10–11 mm. Measurements after 1.6 million load tonnes still showed very uniform settling; thus a durable track geometry is achieved by stabilisation. [3]
	The maximum settlement achieved was 12 mm. Stabilisation causes a more uniform ballast coefficient. [4]
	The settlement achieved (12 mm) corresponds to the value which would occur after 140,000 Lt in a non-stabilised track. After 280 Lt, only 1–2 mm settlement occurs in a stabilised track. [5]
	After 100,000 Lt, no worsening of the track geometry is found in stabilised track sections. [6]
	The settling achieved is very uniform and is 8–10 mm. [7]
Influence on the track geometry	
	The work of the stabiliser has no negative effect on the track geometry. [8]
	Due to stabilisation no change in the track geometry occurs after track repairs. Short corrugations (5 m) in track alignment were eliminated. [3] [9]
	The track level after stabilisation is better than it would be after 80,000 Lt. The track alignment is improved by the stabiliser (an individual fault of 5 mm was removed). [10]
	The quality of the track geometry is not changed by the stabiliser; small irregularities are sometimes even removed. [4]
	The stabiliser has no negative effect on the track geometry. [11]
	Use of the stabiliser does not result in a worsening of the track geometry compared to “tamping only”. [12]
	The track geometry is not changed by stabilising. [6]
	No noticeable differences in geometry. Peaks in longitudinal level and alignment removed. [7]
Increase in the resistance to lateral displacement	
	Tests by Plasser & Theurer and SNCF showed an increase in the resistance to lateral displacement after stabilisation – compared to the condition directly after tamping or after ballast consolidation in the sleeper cribs. [1]
	Measurements after stabilisation on the tracks of DB, NS, BR, SNCF showed that the lateral resistance corresponds to the value which is obtained after 100,000 Lt in unconsolidated sections. [2]
	Tests by SNCF showed that the lateral resistance after stabilisation generally corresponds to 100,000 Lt. [4]
	Tests on gravel ballast showed that 50% of the loss of lateral displacement resistance due to tamping is regained by use of the stabiliser. [11]
	About 70–80 % of the original lateral displacement resistance is obtained with the stabiliser (tamping only: 45–50 %). [12]
	The recovery of lateral resistance due to stabilisation is: 100 %, measured without track loading, 67 %, measured with a vertical load of 105 kN [13]
	The lateral resistance corresponds to 100,000 Lt; a clear advantage compared to consolidation of the ballast between sleepers. [7]
Effect on rail fastenings	
	The load on the fasteners by the stabiliser is only 3 % of the torque of the fasteners. [1]
	The forces on bolts and dowels caused by the stabiliser are only 3 % of the tightening force. [2]
	The stabiliser does not overload the fasteners. [4]
	The load on the fasteners by the stabiliser is only 2 % of the traffic load. [14]
	The fastener torque is not changed by the stabiliser. No deformation could be found on dowels. [15]
Speed restrictions	
	After stabilisation, travel at full speed is possible straight away. [2]
	Tests at SNCF point to the fact that speed restrictions after track maintenance can be cut down. [10]
Safety against track distortion	
	The work of the stabiliser relieves stress concentrations in the rails. The work speed of the stabiliser has only a minor effect on the results. [4]
Effect on the adjacent track	
	The work of the stabiliser does not affect the adjacent track. [3] [9]
Rail temperature	
	Tests at SNCF pointed to the fact that track maintenance can also be carried out at higher temperatures. [10]
Working speed	
	The working speed of the stabiliser has no effect on the work result. [16]

Table 1: Summary of major tests from the early days

SNCF had set up its own experiment in a research facility in Paris where it tested the effect of vertical vibrations on ballast consolidation. This "Vibrogir" was (not yet) a machine suitable for track work, but could be placed manually on various sections of the test track. The DTS prototype, however, had already been brought to Paris on its own axles – and surprised the people responsible at SNCF with its results. Even though the section worked on was very short, the high effectiveness in increasing lateral track stability in a very short working time was nonetheless obvious.

SNCF had set up a special track near Ychoux (south of Bordeaux) to trial other components developed for the new Paris – Lyon line. Here, points were trialled for a turnout velocity of V = 260 km/h as well as other track components. The SNCF research department decided to experiment with the DTS on this and, in particular, to use the test equipment which at the time had led to the findings of Prud'homme. The historic "Wagon Derailleur" was used which was able to apply a defined lateral load via the middle one of three axles during running. The track displacements were measured by a number of gauges anchored in the ballast at the side of the rails. These recorded the largest lateral deflection via maximum indicators and displayed the permanent displacement of the track after being traversed. The final statement of these tests equated the effect of the DTS to about 100,000 t train traffic so that running at restricted speed prescribed at the time was no longer necessary after track maintenance. This procedure was eventually declared as the technical standard by SNCF.

The German Railways DB were mainly interested in the effect of the working speed. These tests, carried out jointly by the research departments in Minden (Westphalia) and Munich, found a high level of independence from the working speed; the results for the QVW were the same at 600 m/h as they were at 2400 m/h! However, it was found that the ballast deformed in an uncontrolled manner at lower speeds and that the resulting track geometry became noticeably worse. These experiments demonstrated very clearly the requirement for uniform working, in particular for a uniform working speed.

The fact of settlement, i.e. lowering of the track level due to the "dynamic track stabilisation", caused considerable discussion and the request to correct the level with the DTS. Appropriate tests, however, neither led to a significantly better geometric result, nor to the possibility of specifying a target geometry (as for tamping machines). The levelling system fitted to the DTS only controls the uniformity of settlement. The effect of the DTS can be described best as checking the uniformity of the (preceding) tamping – if this is irregular, the subsequent DTS also leaves an unsatisfactory track level.

In this context, an experiment on a new track of the then new Vienna-Kledering central shunting yard should be mentioned where the DTS was used on a geometry produced by manual tamping. The irregularity of the tamping was mercilessly exposed.

The Netherlands Railways (NS) had shown great interest in subsequent compacting of the ballast for a some time. This was in the context of the use of "broken grind" as track ballast. Moreover, tracks in the Netherlands frequently have a very soft substrate resulting in special problems and this fuelled the fear that the vibrations of the DTS could cause permanent deformation of the track or have other detrimental effects, as the story of the collapsed house (due to the DTS) made the rounds in Europe! Later, the NS track manager, Mr Harmsen, explained that he had only wanted to make a joke during an ORE meeting!

At the time of the DTS tests, the United Kingdom had, according to British Rail (BR) about 80,000 bridges of brickwork which admittedly were not in the best condition. Therefore BR's focus of interest was the effect of the DTS on pre-damaged bridges of this kind. The argument that the DTS might be used as test equipment for the load capacity of such bridges was not pursued as the experiments showed that the DTS did indeed cause not inconsiderable vibration, but that no damage of any type could be observed. Nonetheless – this issue was reflected in the operating instructions for the "Dynamic Track Stabiliser": use of the DTS on bridges is to be carried out either with a reduced frequency – and thus with quadratically reduced impact force – and/or with a reasonable separation from the natural frequencies of these structures. These restrictions also apply to bearing walls and end walls as well as to (old) tunnels.

Finally, the effect of the DTS was compared in the United Kingdom with the findings on normal ballast consolidation under train traffic. Being forced to communicate such results in a simple and clear manner, the effect of the DTS in train traffic was equated with a total tonnage of about 200,000 t, with the QVW and the track settlement observed in the experiment being used for this assessment.

Further trials were carried out in Hungary. The main interest was, on the one hand, in the confirmation of the findings already available, but at the same time the question was raised whether a targeted lowering of the track would be possible with the aid of the DTS. An appropriate experiment had a positive result; however, this idea of a lowering controlled by a levelling system was not developed further.

Italy, too, attempted to use the advantages of dynamic track stabilisation. Trials with accompanying measurements took place on the just completed sections of the "Direttissima" Rome – Florence and on other routes. They largely confirmed the findings already available.

Fig. 7: The four-axle DTS 62 N standard design

4 Proven experience of Dynamic Track Stabilisation

4.1 The DTS 62 N

From 1981, the Dynamic Track Stabiliser received its current form: a four-axle machine of about 60 t (Fig. 7) with its own drive. The maximum vertical load during stabilising is 240 kN (24 t). Even though the load unloads the wheels, sufficient wheel load for the transmission of the drive forces remains. Originally, it was assumed that the operator's cab should be on a separate vehicle to avoid transferring the vibrations of the stabiliser unit into the cab. However, in the new machine design, the vibrations in the cab were kept far below the permissible values with the use of appropriate damping elements.

4.2 Proven success – results from 1980 to the late 1990s

The tests listed in Table 1 had already dealt with the main questions regarding dynamic track stabilisation and had answered them satisfactorily. Numerous further tests were carried out over about 20 years; these confirmed the effectiveness of dynamic track stabilisation. The results have been summarised in numerous publications, for example in 1988 by Egon Schubert. He coined the term "spatial consolidation of the ballast" [18]: i.e. spatially compact ballast is obtained by the interaction of underfilling the lifted sleepers by tamping and the subsequent stabilisation.

Fig. 8: KSP 2002, a combined ballast regulator and consolidator for Japan

DB examined primarily the effect of track stabilisation on new lines [19]. The consolidation effect, the effect on track geometry and the effects on structures and their surroundings were examined. The results proved the high consolidation effect and the low effect on the track environment. Various methods of use, depending on application, ensured optimum ballast consolidation while maintaining the existing track geometry quality.
Dr.Bernhard Lichtberger particularly stresses the homogenising effect of track stabilisation [20] as the basis for a high durability of the corrected track geometry. When working in the scarified ballast bed after ballast cleaning, track maintenance or construction of new track, the track stabiliser must be used after each tamping run.

4.3 Track stabilisation internationally

4.3.1 Application by the railways of the world

Dynamic track stabilisation is currently used in 45 countries. In Austria, it is mandatory after all tamping runs; points, too, are stabilised. For a long time Switzerland (SBB) placed its trust in ballast consolidation in the sleeper cribs; after extensive tests which were completed in August 2005, dynamic track stabilisation was approved as a standard method and also used accordingly.
The financial successes in the United Kingdom are remarkable. In 1987, tests proved that service at 200 km/h can resume on newly ballasted track if the track has been

Investigations on lateral resistance in the USA (1990–2010)

Aim of tests	Result
Increase of lateral resistance by DTS	
	Volpe/Union Pacific tests – concrete sleepers: 33 % QVW increase [21]
	Volpe/Amtrak/FRA tests – concrete sleepers: 31 % QVW increase [22] [23]
	UP/TTCI tests – concrete sleepers (straight track): 60 % QVW increase [24]
Increase of lateral resistance by traffic at reduced speed	
	AAR/TTCI tests – wooden sleepers (straight track): 17% QVW increase after 100,000 Lt; 32% after 1,000,000 Lt - wooden sleepers (5% curve): 9 % QVW increase after 100,000 Lt; 21 % after 1,000,000 Lt [25]
	Volpe/FRAU tests – wooden sleepers (straight track): 26% QVW increase after 100,000 Lt - concrete sleepers (5° curve): 22 % QVW increase after 100,000 Lt [26]
	Volpe/Union Pacific tests – concrete sleepers: 17 % QVW increase after 350,000 Lt [21]
	UP/Foster-Miller tests - wooden sleepers: after 100,000 Lt slight improvement; 28% QVW improvement after 200,000 Lt [27]
	UP/TTCI tests – concrete sleepers: 49 % QVW increase after 100,000 Lt [24]

Table 2: Lateral resistance tests in the USA

stabilised. It was, therefore, no longer necessary to stipulate speed restrictions after ballast and track maintenance work. As previously speed restrictions had been mandatory after weekend work until the following weekend, enormous cost savings resulted from the use of the stabiliser. British Rail calculated annual potential savings of £ 20 million whereupon it procured 11 DTS 62 N Dynamic Track Stabilisers.
Dynamic track stabilisation is used in France and Spain, countries with high-speed lines, as well as in the largest rail networks of the world – China and India.
In Japan, the use of the stabiliser is standard on the high-speed lines (1,435 mm gauge) as well as on classic track (1067 mm gauge). The machines are mainly designed as combined machines used for ballasting and stabilising at the same time (Fig. 8). The motivation for this design is a lower requirement for parking space, fewer operating staff and the technologically advantageous combination of ballasting and stabilising.

4.3.2 Track stabilisation in the USA

Working the track presented a particular challenge in the USA. The greatest interest in “dynamic track stabilisation” was initially at AMTRAK, the national company for passenger transport, which also operates the North-East corridor Boston – New York – Washington.
During the night, heavy goods trains of other companies with up to 35 t axle load travel over its track. Here, too, the lack of track stability had been an issue and thus a DTS was bought which was supplied in it strongest European version in 1983.
In March 1984 a disappointed representative of Plasser American Corp. phoned from the USA and informed us that “the DTS does not have any effect on the track, as had been ascertained by a measurement team of a university”. An examination of the situation revealed the following:
At that time (as today), heavy European tracks were fitted with 60 E1 (UIC 60) rails and B70 concrete sleepers with a mass of about 300 kg and a sleeper distance of 60 cm.
In the USA, however, even heavier AREA 140 rails, concrete sleepers of 400 kg with a sleeper distance of 20” (50 cm) were laid. On this track, the DTS did shake itself, and was in fact not in a position to vibrate the track.
An increase in the unbalanced mass was agreed at lunchtime, this was delivered overnight by private plane and installed. In this way it was possible to achieve the desired amplitude of +/–3 mm on the heavy track – and subsequent measurements proved the effectiveness of the “Dynamic Track Stabiliser” which had already been established in Europe.
Work on American tracks with wooden sleepers were initially not assumed to be very promising as the normal rail fastening with rail spikes permitted lateral play. However, the tie plates incorporated into the wood in conjunction with the vertical force applied by the DTS are obviously sufficient for an adequate frictional connection between rail and wooden sleeper – the mechanism works. The intended increase in the resistance to lateral displacement (QVW) has been proven many times.
As track maintenance in the USA is carried out strictly as necessary, an appreciable lengthening of the maintenance intervals by about one third has been realised. [28]

Fig. 9: Record-breaking run of 574.8 km with a double-decker TGV

Today, about 90 Dynamic Track Stabilisers are in regular use in the USA and Canada. It was decisive for this success that the QVW required was reinstated by the DTS after tamping and that this was accepted by the DOT (Department of Transportation) [29]. Speed restrictions which are particularly expensive for the long and heavy US trains are no longer required. Table 2 lists the major investigations on lateral resistance in the USA. It is striking that the DTS obviously has a better effect on the lateral resistance than 100,000 load tonnes.

4.3.3 High speed and track stabilisation

High-speed tests can be carried out on newly laid track only if a sufficient stability of the track geometry has been achieved. In 1955, SNCF set a world speed record of 355 km/h. The engineers where shocked to find that the track geometry had been destroyed by this record-breaking run. The track geometry at that time had been produced manually by soufflage (manual tamping).
For world record runs since 1981, the track geometry has always been produced by Plasser & Theurer machines, and the DTS has provided the necessary stability. From then on, the track geometry has stood up to the high stresses of record runs. The records in detail:

- 1981, SNCF, 380 km/h on the Paris – Lyon line, France
- 1988, DB, over 400 km/h for the first time: 406 km/h on the Würzburg – Hanover line, Germany
- 1990, SNCF, over 500 km/h: 515.3 km/h with the TGV Atlantique between Vendome and Tours
- 2007, SNCF, the speed record of Maglev trains is only just missed: 574.8 km/h on the high-speed section between Paris and Strasbourg (Fig. 9)

4.4 Track stabilisation and flying ballast

Initially one was at a loss as to how prevent “flying ballast” which impacts on parts of the running gear with great force and also is a danger for the surroundings. When investigating the causes, it was found that the suction effect underneath trains travelling at high speed together with the air turbulence was part of the cause. A second issue was the presence of ballast on the sleepers between the rails which started to jump due to the increasing vibration of the sleeper when a high-speed train was approaching, lost its hold and was carried along by the air flow. It was not possible to clarify unam-

biguously whether ballast stones were torn off the (loose) ballast surface between the sleepers.
The fact is that the use of the Dynamic Track Stabiliser induces the ballast stones

- to slide off the vibrating sleeper surfaces and
- to compact and consolidate the complete ballast bed, in particular the upper layers.

This consolidation effect can be ascertained empirically during each re-ballasting. One only needs to step on a freshly tamped and filled space between the sleepers before the deployment of the Dynamic Track Stabiliser and then do the same after the deployment of the DTS.
The effective ballast consolidation lets the ballast sink so that the ballast surface is slightly below the sleeper surface. There are many indications that the regular use of the DTS prevents ballast flying caused by the air flow, but information in this respect is usually vague and unreliable. Other phenomena, such as the impact of ice lumps falling from fast running trains into the ballast, are subsumed.

5. Dynamic Track Stabilisation Today

5.1 Corroboration by new research

Empirical experience with the lengthening of maintenance cycles due to the DTS is definitely positive. On average a lengthening of the cycle of 30 % is expected. In a UIC project, the effect of the DTS on a longer durability of the track geometry was investigated by various railways; the results were also positive. However, it was also found that it is often difficult to create test conditions in which the same conditions prevail for all applications [30].
Belgium, Austria and Switzerland arrived at the conclusion that the rate of deterioration with post-consolidation is lower than without. The results were clearest in Switzerland. The superiority of the DTS compared to ballast consolidation in the sleeper cribs was determined. The positive effect on the QWV is undisputed. The use of sleeper end consolidators in the tamping area is nonetheless recommended.
Adif, Spain, ascertained 20 % savings in tamping work on high-speed lines with good ballast; there was also a positive effect for bad ballast, but it was not quantifiable. The required QWV was improved in any case.

Fig. 10: MDZ with 09-32 4S Dynamic universal tamping machine

Fig. 11: Track stabiliser with attached tamping section in North America

$$S = (4.2*\ln(h)-4)*(0.037*f-0.14)*(0.002*Fv+0.52)*(-0.07*\ln(v)+1.03)*(0.007*me+0.4)$$
$$QVW[\%] = 13*\ln(s)+10$$

5.2 New opportunities

5.2.1 Parameters affecting track stabilisation

According to Lichtberger [31], the following parameters affect track stabilisation:

- the stabilisation frequency,
- the vertical load which is applied by the hydraulic cylinders to the stabilising units,
- the working speed and
- the dynamic impact force.

While the first three parameters vary during machine work, the impact force is determined by the eccentric mass. In the standard DTS 62 N, the total dynamic impact force at 30 Hz is ± 200 kN. The vertical load varies between 0 and 240 kN (sum of all units).
The effectiveness of the individual parameters – assuming that they are not coupled to each other – can be represented by the empirical equation above.

S = calculated settlement due to DTS [mm]
h = lift [mm]
l = frequency [Hz]
Fv = vertical load [kN]
v = working speed [km/h]
me = total eccentric mass [kg]

While the eccentric mass is, as a rule, fixed, the vertical load is controlled by the levelling system which thus controls the level. The frequency is usually adapted to the track condition; to be able to avoid resonance, there are often special instructions for working on solid structures. The working speed affects the result only to a small degree; therefore it is adjusted to the preceding machine.

5.2.2 Adjustable unbalance

It can be seen from the equation that settling is affected most strongly by the eccentric mass. It is, therefore, possible to install adjustable unbalanced masses in the DTS and thus control the track settlement (and thus the track level) by adjusting the unbalance. This is of particular interest where control by means of the vertical load is not sufficient.

5.2.3 QVW measurement with the stabiliser

The DTS introduces frictional energy into the track. The greater the lateral resistance, the more energy must be introduced. It is, therefore, permissible to conclude that it is possible to measure the resistance to lateral displacement with the DTS if the energy introduced is recorded. Such a recording facility is offered for the DTS. As the users expect comparability with existing measurement methods, a corresponding validation is required. Van den Bosch of AET Netherlands has been able to develop a conversion algorithm on tracks with UIC 60 rails and monobloc concrete sleepers in a series of tests [32].

5.3 Latest developments

The standard design of the track stabiliser continues to be the four-axle self-propelled DTS 62 N machine (Fig. 7). However, with the development of the continuously working tamping machine in 1983, new possibilities arose: the stabiliser which only works well in continuous working mode can now be combined with tamping machines (Fig. 10). These machines are designated "09-Dynamic". Major versions are:

- Continuously working plain line tamping machines as one-, two-, three- or four-sleeper tamping machines.
- Continuously working universal tamping machines for tracks and points as one- or two-sleeper tamping machines.
- Type Dyna-C.A.T. was designed as a compact solution for North America (Fig. 11). In this case, the tamping machine is an add-on to the DTS.

Another option is the combination with a continuously working ballast regulator; this version is the standard design in Japan (Fig. 8). In Europe, such combinations are also used, for example in France.
The advantage of the combination machine is the savings in operating staff and, in particular, the correct work method which automatically results from this.

5.3.1 Stabilising in points

Track stabilisation is also possible at points. Only the side rollers must be folded up so that no parts of the point are damaged. The vibrations of the unit are nonetheless transferred to the track via the vertical load (Fig. 12). The advantage of stabilising points is above all the improvement of vertical stability and also the fact that the ballast bed of the point and its rails is homogenised.
At ÖBB, for example, the following rules – in brief – apply to the use of the DTS at points:

- "Worksite":
  The DTS is always used at every run of the tamping machine (see also 4.2 – Lichtberger).
- Maintenance tamping:
  V <= 100 km/h – DTS is recommended at points (not mandatory).
  100 < V <=160 km/h – for tamping inside a profile the DTS is not required; however, it is required in all other cases (in this case V max = 90 km/h for 48 hours applies if the DTS is not used).
  V >160 km/h – the DTS is to be used in all cases (otherwise V max = 90 km/h for 48 hours, after that V=160 km/h until DTS is deployed).

6. Summary

"Dynamic track stabilisation" is a technology which has been contributing to better track work for 40 years. Homogenisation of the ballast bed leads to an effective embedding of the track panel into the ballast bed, combined with stability values which ensure a safe geometry even immediately after track maintenance. However, the advantage of extending maintenance intervals could be exploited much more yet. The policy of track maintenance strictly dependent on the condition, as it is practised today by Europe's railways, is the ideal condition for this.
The combination with other machines, as offered nowadays, enables the cost-effective operation of this technology.

Fig. 11: Stabilising at points

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