Historic data on track geometry in relation to maintenance

The programme of work of the ORE Committee D 161 was initiated to determine how the dynamic interaction between vehicle and track influences track deterioration and the subsequent need for track maintenance and renewal. This paper examines the basic concepts of this work based on the analysis of historic track data and reports the most important conclusions to date.

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The track maintenance engineer is faced with the problem of keeping the geometry and mechanical strength parameters within limits dictated by operational considerations whilst minimizing maintenance costs [1]. Three fundamental points of view have to be taken into account:

— *safety,* for which maintenance must be preventive;
— *comfort,* for which one may accept if necessary only corrective maintenance;
— *economy,* for which the maintenance costs must be minimized, but not forgetting to preserve a suitable margin of safety and to limit the rate of irreversible deterioration.

The essential qualities of a ballasted track, in comparison with other constructions, are the low cost of substructure materials, the ease of construction and the adaptability to differing loads and environment. The consequence is that there are many more interventions for track geometry than for maintenance of track components, in a ratio of about one to ten.

In order to avoid reaching an irreversible deterioration level, the maintenance operations may be organized according to two basic methods:

— Routine maintenance in accordance with fixed cycles. This ancient method is not very economical. The advantage of this method is that it requires neither prior inspection nor decision making, it is not applied by modern railways.
— Maintenance based on the results of inspection, taking appropriate action as and only when required. This is the most economical method, but it requires specific methods for inspection and a decision making process, which involves human responsibilities or the implementation of a very reliable decision algorithm.

This second method is nowadays spreading into more and more networks. The study of historic data for track geometry appeared with the development of track quality monitoring systems. It begins to find applications not only in the field of research about the influence of various parameters on geometry deterioration [4], but also in the most recent maintenance decision making processes [1], [2].

Inspecting track geometry

When looking at track irregularities different wave bands can be considered. Faults in the band 0-3 m are mainly due to the rail shape and welds, whereas the longer waves originate from ballast and subsoil. Therefore it is not possible to represent properly track quality by one simple figure. Figure 1 represents the different wave bands in the vertical geometry which are significant for the maintenance of rail and track quality. This information is nowadays commonly measured by recording cars.

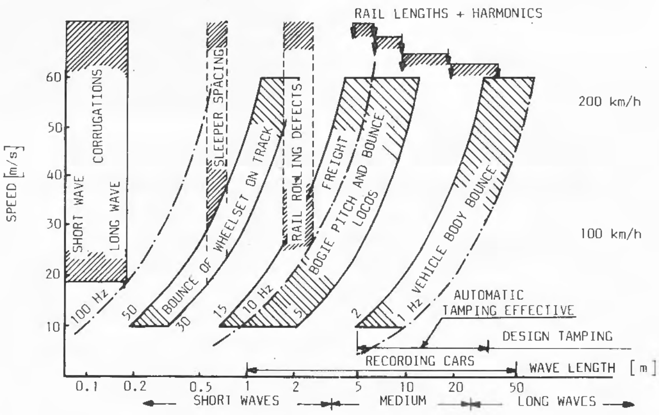

Fig. 1: Relevant wavelengths in vertical geometry

The measuring bandwidth of these recording cars is generally restricted to wavelengths from a few metres to 20 or 30 metres. This information is represented by the transfer function. Figure 2 shows some examples of transfer functions for recording systems used in Europe.

It is important to note that the effectiveness of the modern tamping machines is restricted to the same wave band (fig. 3).

Complementary measuring methods were developed for collecting short wave information on rail geometry:

— trolleys or straight edges with a short reference base for measuring rail rolling defects or corrugations and weld geometry;
— vertical axle-box accelerations, often measured, as for example described in [3] and [8], on geometry inspection cars, and filtered in such a way that the signals produced are speed independent as much as possible.

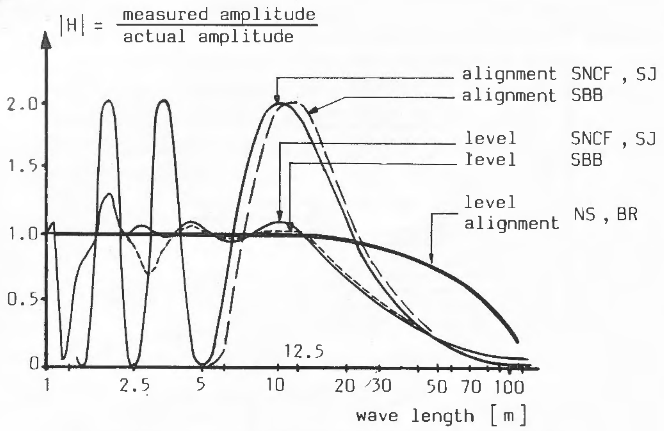

Fig. 2: Transfer functions of various recording cars

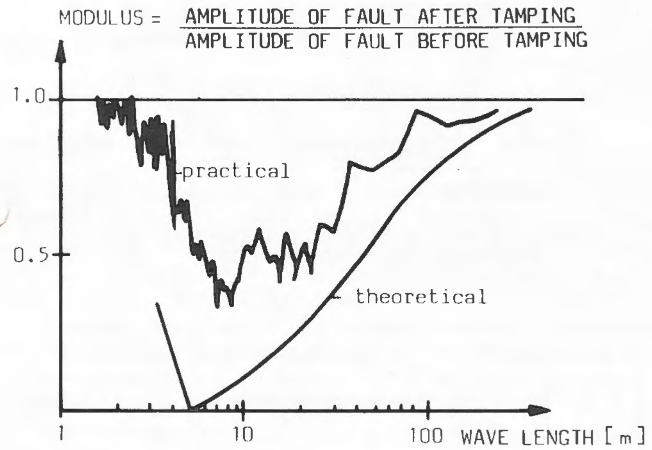

Fig. 3: Transfer function for levelling by a PLASSER 07-16 tamping machine

In order to quantify track quality with a reasonable accuracy the measuring systems are required to have an overall measuring accuracy depending on the spectral content:

Waveband	**0-5 m**	**5-10 m**	**10-20 m**	**20-40 m filtered**
Typical spectral content [mm²] (variance)	0.05 to 0.20	0.30 to 1.20	0.4 to 1.6	0.3 to 1.0
Required measuring accuracy [mm] (±2.5 deviation)	±0.05	±0.1	±0.2	±0.3

Assessment of track quality

In order to make decisions for geometry maintenance, it is necessary to have available the representation along the line of the important characteristic parameters. This must be more simple than using spectra or defect distributions.

The geometrical track quality can be assessed in various ways. Firstly, by counting the defects exceeding a given amplitude level. With this method the quality index gives importance to the maximum defect values for each parameter. For instance the P-value used on the Shinkansen network is the ratio of the track defects exceeding 3 mm to the total number of defects [5]. A total index can also be obtained by combining the various values from several geometrical parameters, e.g. the DB-method [6]. The advantage of this method lies in making the large local track defects more noticeable.

Secondly, there are systems which compute standard deviations, for instance BR and NS. In this case the quality index represents directly the total energy of the measured geometrical parameter. Alternatively the mean 'absolute' deviation, which is proportional to the standard deviation, can be very easily calculated by analogue filtering of the signal [1]. These indices do not give information about the shape of the defects, but one very well suited to continuous maintenance decision making.

Historic data on track geometry

The production of track quality indices allows the study of the evolvement of quality as a function of time or traffic.

Indeed with methods for longitudinal location one can calculate quality indices for long distances, and also for short elementary zones. For instance the SNCF produces digital indices for each track kilometre [1]. The NS compute per section of 200 m the standard deviations of the geometrical irregularities. For decision making this information is further condensed by calculating the quality indices for "maintenance sections" which have lengths of 5 to 10 km [2].

It is also possible to study the deterioration of track quality for a given track zone. Figure 4 is the time history of the vertical profile (level) index for a 200 m long section of a BR line. This example shows three significant aspects of track geometry development:

1. the large and quite constant improvement due to successive tamping operations;
2. the linear trend of quality deterioration over the period between the tamping operations;
3. the tamping operations do not affect the rate of deterioration.

These characteristics of the track geometry history can be used for the optimization of maintenance operations and for the general study of factors influencing the changes in the track geometry.

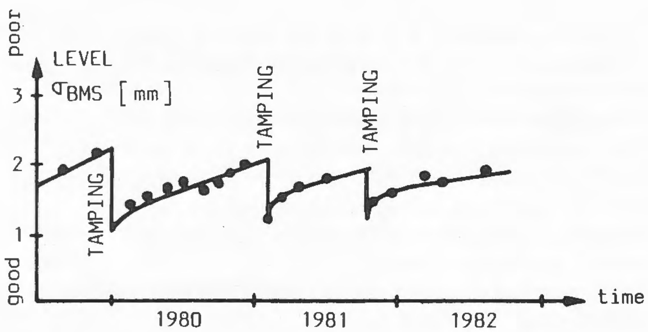

Fig. 4: Historic data for track quality on a BR test section

Use of historic data for maintenance decision-making

Historic data of track geometry are not, as yet, in general use by the engineers in charge of maintenance.

The calculation of track quality indices for each maintenance section (or each elementary zone) is normally used for the comparison, at a given time, of the quality of each section with the whole of a line or a network, in order to share out the resources of the maintenance services.

After each track inspection the programme of work of the tamping machines can be determined until the next inspection. This method is applied for instance by the NS, as described in [2].

It is also possible to calculate the deterioration trends for the mean quality indices of maintenance sections (MAINS). The distribution of the deterioration rates for the 600 MAINS of NS (3500 km of track) is represented in figure 5.

On the SNCF the optimization of tamping operations is not only based on the track quality at a given time, but also on the assessment of the change in quality until the next inspection of geometry [1], [7].

As there is a very large amount of data to be considered (one index value for each geometrical parameter, for each elementary zone, and for each inspection), the utilization of time histories for maintenance plans requires the development of computational means for the engineer.

Study of factors influencing track geometry development on the basis of historic data

From an international point of view, the study of track geometry deterioration was part of the work of two previous ORE committees:

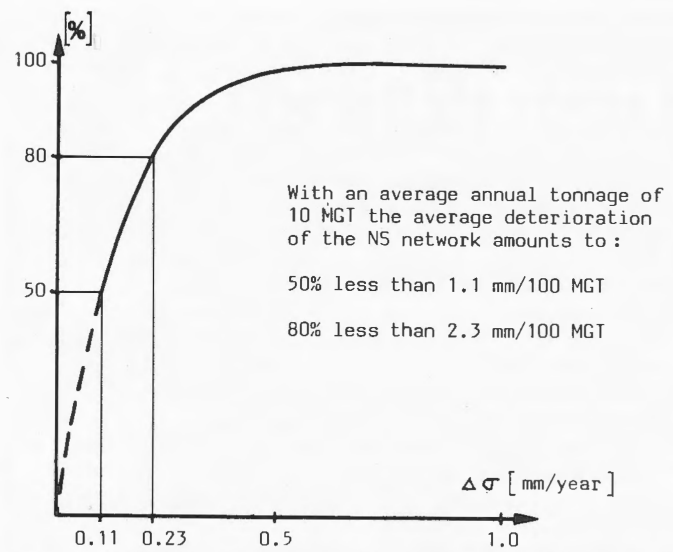

Fig. 5: Distribution of track deterioration on NS for 600 MAINS. (3500 km of track)

— D 117: "Optimum adaptation of conventional track to future traffic".

— D 141: "Effect on the track of raising the axleload from 20 to 22 t".

This object became a part of the question ORE D 161: "Dynamic vehicle/track interaction phenomena, from the point of view of track maintenance".

The report RP1 D 161 summarizes the work of D 117 and D141 committees, and the further work done by BR, CFF, SJ and SNCF networks on the basis of track geometry historic data.

General conditions of study

Only tracks using continuous welded rail were examined. The length of individual zones varied from 200 to 1000 m according to the railway.

The parameters adopted as geometry quality indices were the standard deviations of defects in longitudinal level and in alignment as measured by the track recording cars of each railway. For the SNCF the mean absolute value of the deviations was adopted, this always stays in a constant ratio with the standard deviations.

The basic presentation of data is a time history showing the development of the index as a function of traffic or time, with indications about maintenance operations.

One can then study not only the statistical distribution of the quality indices, but also their mean deterioration rate between inspections or maintenance operations and the improvement obtained by these operations.

Figure 6 shows the distribution of the standard deviations evaluated by the BMS system of the NS on several lines of various European networks. Equivalent standard deviation values with respect to the BMS system of NS, produced by the recording cars of various administrations, are as follows:

Network	NS	DB	CFF	SNCF/ SJ	CSD	BR	FS	CFR	PKP
Longitudinal level	1	1,24	0,91	0,91	1,52	1,14	1,33	1,40	0,73
Alignment	1	1,41	1,44	1,47	1,77	1,20	1,72	1,95	—

Deterioration rates of geometry

The deterioration rates of quality indices are calculated as a function of traffic in mm/100 MGT or of time in mm/year. Without including the quick settlement and rapid deterioration of track immediately after tamping, the deterioration rate has generally a linear trend between two maintenance operations.

BR established, that the average quality over several maintenance cycles remains stable in 65% of the cases, but tends to slowly increase in 33% of the cases (figure 7a) and marginally improve for the remaining 2% (fig. 7b).

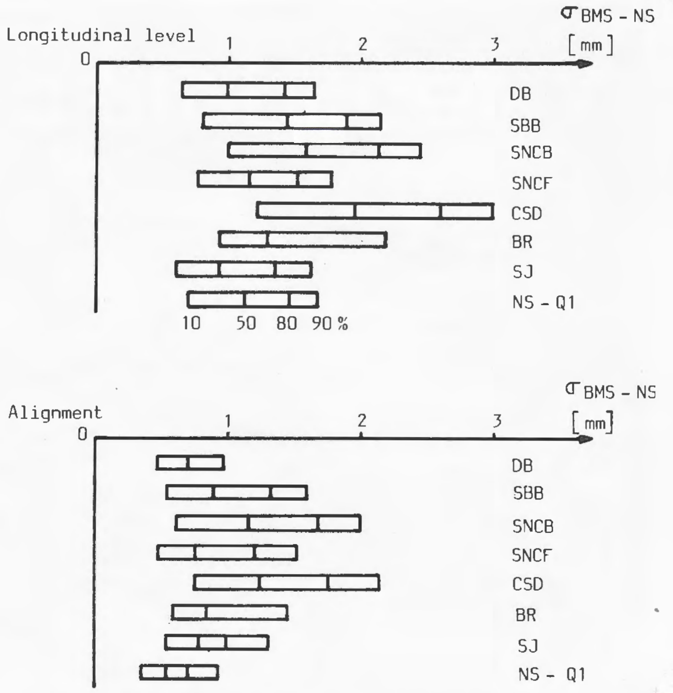

Fig. 6: Standard deviation distributions of level and alignment measured by BMS on several European networks

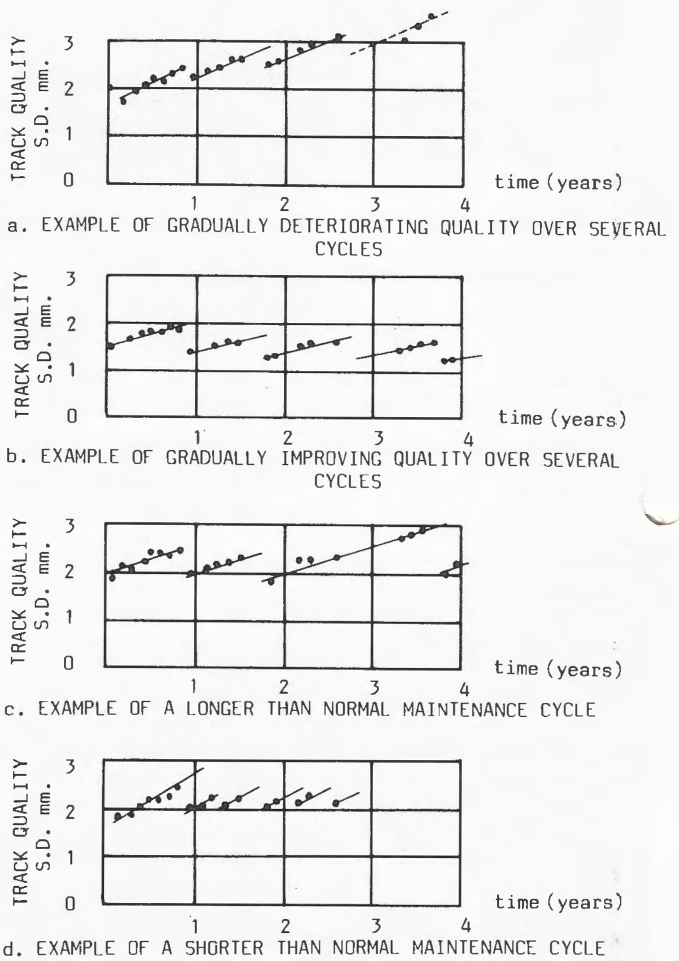

Fig. 7: Various trends of track deterioration observed on BR test sections

The following table gives the mean rates of deterioration observed on various networks (standard deviation as measured by NS car in mm/100 MGT).

	BR	SBB	SJ	SNCF	NS
Longitudinal level	2,0	1,1	1,6	0,7-1,4	1,1
Alignment	—	0,3	0,6	—	—

The scatter in deterioration rate values is very large: for longitudinal level the maxima are about 10 mm/100 MGT, with current mean values from 1 to 2 mm/100 MGT, for alignment the maxima are only about 2 mm/100 MGT. For this reason the longitudinal level indices, which vary more quickly, are preferred for decision-making of levelling/lining works to the alignment indice.

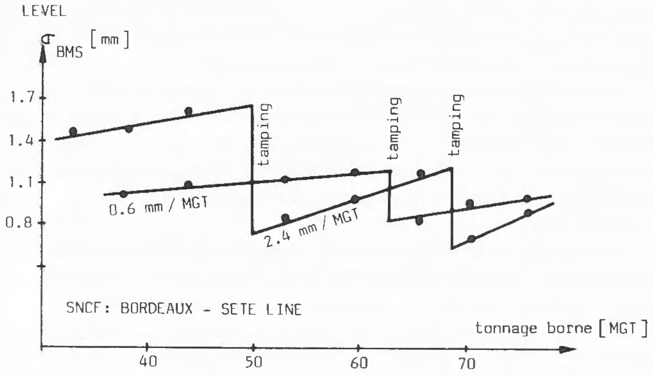

Fig. 8: Deterioration scatter between two close track sections

The scatter is also very large between short zones very close together. Figure 8 shows two zones of the same line, being of the same age, with the same construction, carrying the same traffic, a 0,7 mm/100 MGT slope in the first case, and a 2,9 mm/100 MGT slope in the second.

Attempts were made to study factors which could influence the variations of the deterioration rate under different track and traffic conditions for the longitudinal level by multiple linear regressions but these were unsuccessful.

The parameters used for the regression calculations were the radius of curves, the age of the track since the last renewal, the types of rail and sleepers, the daily or yearly traffic, the percentage of passenger traffic, the maximum speed and the mean value (or maximal value before tamping) of the standard (or mean) deviation of longitudinal level.

One can partly explain the bad correlations obtained by the lack of detail of the parameters used (especially for the traffic) and by the absence of some very significant parameters, e.g. vertical track and subsoil stiffness and the longitudinal railhead quality for short defects wavelength.

Effects of tamping

With regard to the improvement of track quality due to a maintenance operation, one can note that in many cases the tamping machines reduce the track geometry to a relatively constant level, both for the longitudinal level and for the alignment. Figure 9 represents the improvement in longitudinal level due to tamping over two groups of tests sections on the SJ, where different methods are adopted i.e. with and without consolidation, and the change in level and alignment on sections of the SBB.

The level obtained depends on the working capability of the tamping machines in the defect wavelength band corresponding to that for the quality index, and on the condition of the ballast bed under the sleepers.

Future work

As described in this article, the development of systematic track geometry inspection by modern accurate recording cars allows the local track quality to be quantified at regular intervals.

Some networks now use these data in order to optimize maintenance works, especially for tamping machines [1, 2].

The ORE committee D 161 analysed historic data from BR, CFF, SJ and SNCF [4] and the results showed clearly that:

- the track geometry deterioration can be considered as a linear function of the tonnage carried;
- for the majority of the track sections observed, the deterioration rates are not influenced by consecutive tamping operations;
- the scatter of the deterioration rates is very large, in ratio from 1 to 10 even for sections with comparable structure or traffic.

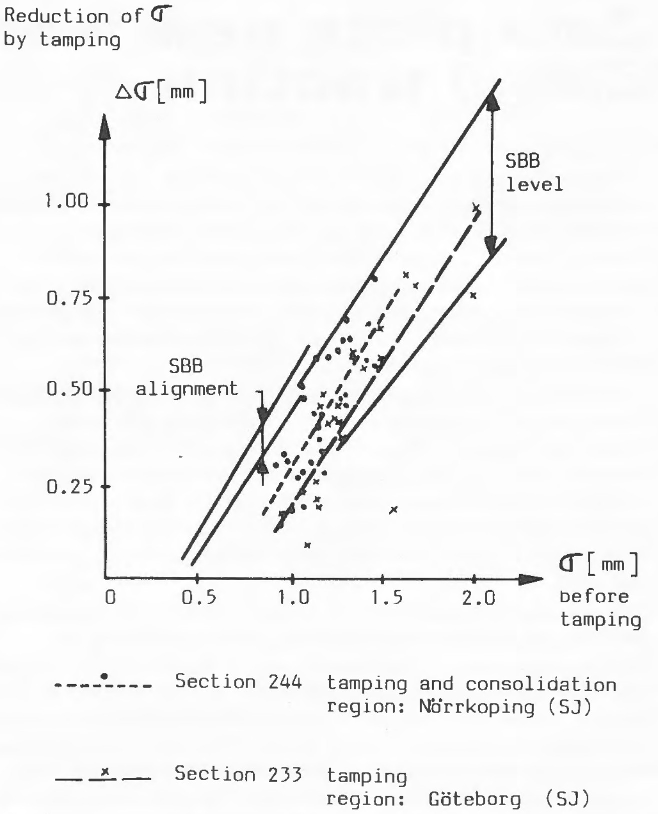

Fig. 9: Improvement of level (SBB and SJ) and alignment (SBB) due to tamping

The initial results obtained by ORE D 161 do not suggest that the types of traffic or track structure have any marked effects on the change in track geometry.

In order to establish more accurately the laws of track deterioration, the D 161 committee undertook new specific track tests, which should allow to measure separately the influences of traffic, construction of track and various modern maintenance methods. The study of the development of geometry is carried out in both older and recently renewed sections of various railways. New results are awaited in 1988 and will be presented in a future article.

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