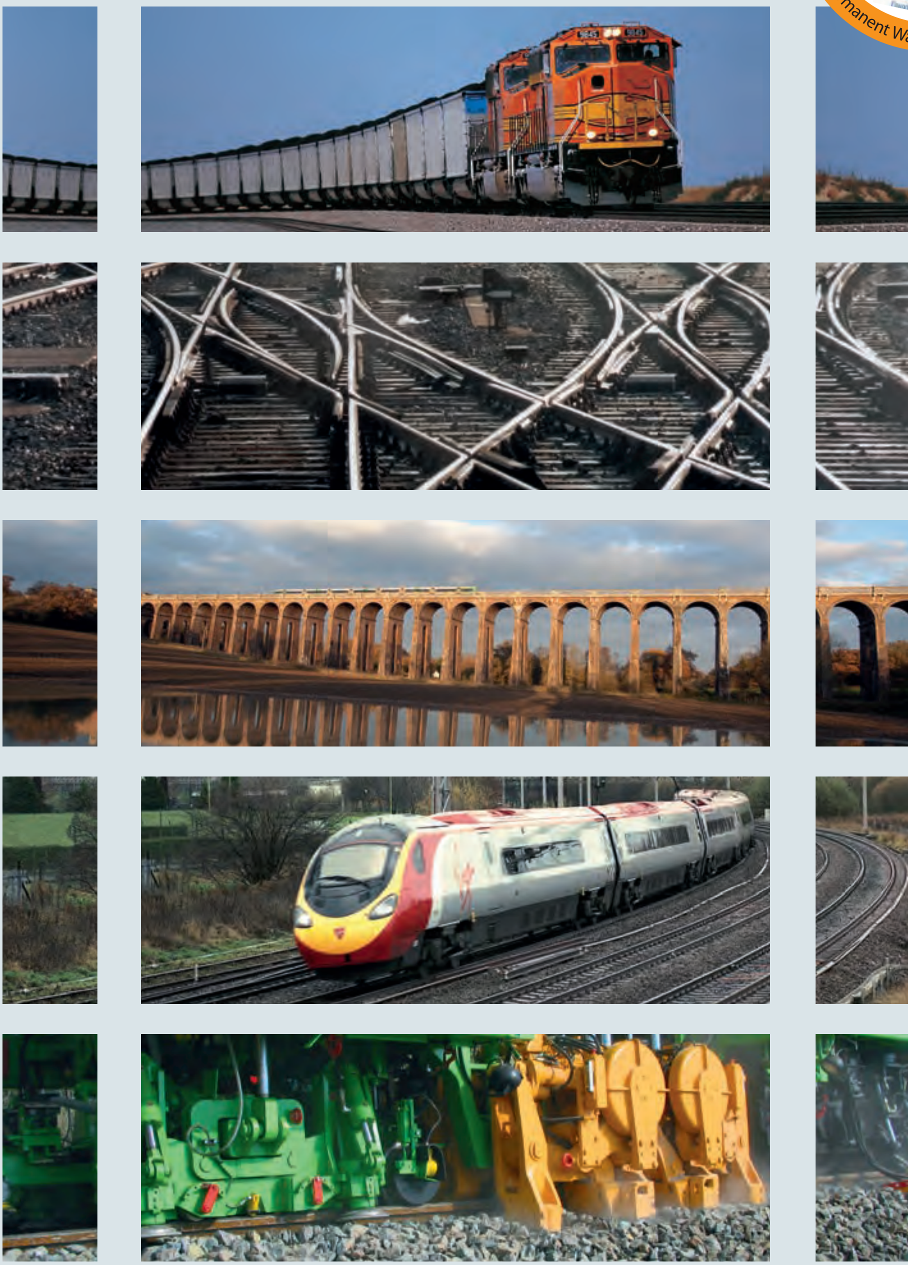
Track Compendium

Track System · Substructure · Maintenance · Economics

endorsed by PWI
– Permanent Way Institution –



Bernhard Lichtberger

New, completely revised version

Eurail press

Bibliographic information published by the Deutsche Nationalbibliothek:
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie, detailed bibliographic data are available in the Internet at http://d-nb.de

Publishing house:	DVV Media Group GmbH I Eurailpress Postbox 10 16 09, D-20010 Hamburg Nordkanalstraße 36, 20097 Hamburg Telephone: +49 (0)40 - 237 14 02 Telefax: +49 (0)40 - 237 14 236 E-mail: eurailpress@dvvmedia.com Internet: www.eurailpress.de, www.dvvmedia.com
Publishing Director:	Detlev K. Suchanek
Editorial office and production coordination:	Dr. Bettina Guiot (responsible), Ulrike Schüring
Advertising:	Silke Härtel (responsible)
Distribution and book service:	Riccardo di Stefano
Cover design:	Karl-Heinz Westerholt
Printing:	TZ-Verlag & Print GmbH, Rossdorf
Copyright:	© 2011 by DVV Media Group GmbH, Hamburg

2nd edition, completely revised
ISBN 978-3-7771-0421-8

A DVV Media Group publication

DVV Media Group | Eurail press

Acknowledgements and Preface

I want to thank *Roland Hogl* who helped me with the illustrations. My thanks go to *Johann Dumser* – who provided valuable support in the collaboration with the publishing house – *Rainer Wenty*, *Klaus Riessberger* and many others not mentioned here by name, who helped me with their suggestions and the resources provided.

This present voluminous book came into being from my – not quite unselfish – wish to draw up a manual in a condensed form, containing relevant data for the railway engineer concerning track. Many ideas, as well as the basis of my understanding of the laws of physics relevant to track and track maintenance, were acquired from my dear friend *Egon Schubert*, who unfortunately died much too early, and *Josef Theurer*, to whom I am indebted. My work as the head of the research & development department of *Plasser & Theurer* has offered and still offers me the opportunity to deal with research in the field of track behaviour and optimum track maintenance methods. This knowledge and the rich experiences gained in my job over the last twenty years have been incorporated in this book. This new Track Compendium also contains many interesting facts from relevant technical publications. I owe thanks and a debt of gratitude also to the numerous authors of these publications, listed in the literature references.

This book has been translated with great precision by *Ursula Hofer*. I am greatly indebted to her for this exemplary work.

My great thanks also go to *Richard Spoors*, former senior railway civil engineer with Network Rail and President of the Permanent Way Institution who took the time to read through this second edition from the viewpoint of an experienced railway engineer and check the consistency and correctness of the railway terminology used, assisted by *Susan Burton*.

This is the 2^{nd} edition of the English version, now translated from the 3^{rd} edition of the original German book which was published in Spring 2010. The opportunity has been taken to make a number of small amendments and additions where technology has advanced or applications progressed.

I hope that this work will be a help and a useful reference book not only for the present generation of railway engineers, but also for those in the future.

In this way I hope to have made a small contribution to the success of the railways.

Bernhard Lichtberger — Linz, August 2011

Introduction

Welcome to this new English translation of the 3rd edition of Track Compendium. Since it was first published in 2005, I have made a number of changes and additions to reflect new techniques and methods that have been developed in the field of track engineering over the last 5 years.

This 2nd edition contains new material including a chapter about the principles of overhead line, installation and maintenance of overhead line, another additional section about the basic terminology of process control technology and safety technology, the latest findings regarding the occurrence of head checks and the wear resistance of head-hardened rails, plus supplementary information in the section on rail-wheel interaction, on the topic of equivalent conicity and running behaviour as well as contact mechanics and on the theme of cost-efficiency of track maintenance. Also included in the new edition are the latest results from comprehensive studies made by Graz University of Technology and Austrian Federal Railways (ÖBB) concerning the influence of parameters, such as track curve radius, axle load, track material and quality of the formation on the durability of the track geometry. Special attention is given to the occurrence of rail vehicle noise and the causes of noise plus the effect of roughness of rails and wheels on the emitted noises are explained. A new, extensive theory of dynamic track stabilisation which depicts as a formula the influence of the different operating parameters, such as frequency, amplitude, impact force and static load, on the stabilisation and settlement of the track. Other findings concerning the productivity of ballast cleaning machines in relation to conveying capacity, chain wear, throughput, reclaimed material, screen quality, influence of dampness of the material and volume of reclaimed material, have also been included in the new edition. In the chapter covering maintenance, laying and renewal of tracks, the latest track maintenance machines have been included with detailed descriptions of their functions, such as the RM1500 high-capacity ballast cleaning machine, the RU 800S a combination machine for track renewal and ballast bed cleaning and the 09-4X Dynamic Tamping Express a continuous action four-sleeper tamping machine with integrated track stabiliser.

For those of you who may be reading my book for the first time, I hope the following is helpful.

The theory and practice of track engineering changes little between the railways of the world. What does change, most of all, is the natural environment in which railways are built and operate, and the loads and speeds they are designed to carry. There can be no doubt that as we move towards the middle of the 21st century railways are becoming an ever increasing part of our lives as an essential and economic mode of land transportation. High speed rail travel is a growing market and of course much of that technology has been developed here in Europe.

In many of the chapters I have documented and referenced well known and internationally recognised civil and mechanical engineering practice. Generally speaking each railway applies this knowledge in slightly different ways, depending on the environment and technical standards developed and adopted by that railway. In this book I have largely followed the practices and norms of the German and Austrian railway infrastructure organisations, frequently adding references and practices of other railways where relevant. At times, therefore, please do not forget to consider how the engineering principles have been adapted for application by your railway administration, as it may be slightly different to the way I have described it in my book.

I hope you find it useful for many years to come.

Bernhard Lichtberger — Linz, August 2011

Contents

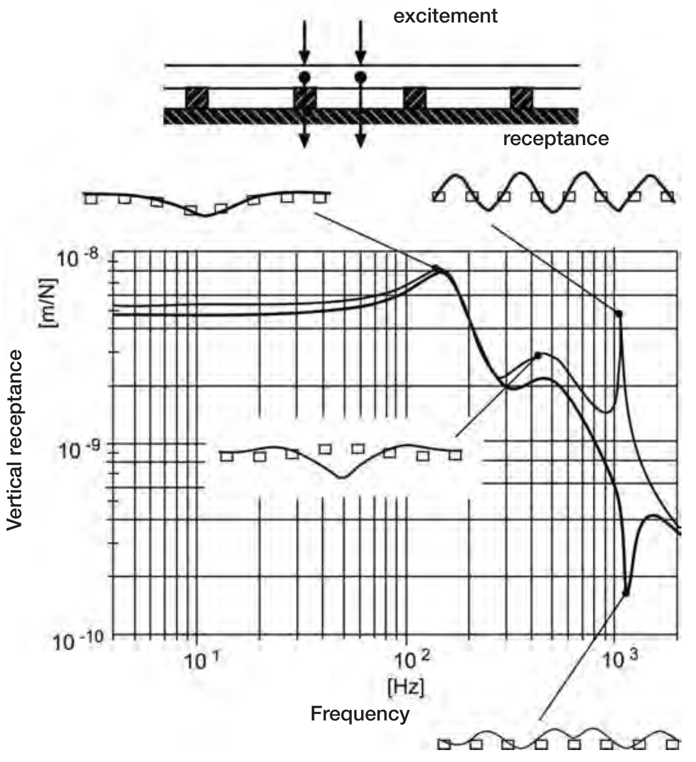


Figure 31: Vertical receptance of rails and sleepers [62]

shows ground waves excited by a vertical vibration source. The slowest and most energy-consuming are surface waves. They are highly damped with increasing depth and horizontal distance and fade away very quickly. Compared to shearing waves they are comparatively harmless to subsoil and formation. As there is much more energy contained in shearing waves than in compression waves, they have an adverse influence on the soil formation.

The amplitude of Rayleigh waves on railway tracks [63] decreases with increasing distance according to the following law:

$$A_2 = A_1 \cdot \left(\frac{R_1}{R_2}\right)^{B - \frac{R_1}{R_2}}$$

A_1, A_2 … amplitudes in the place R1 or R2, respectively
B … fade-away value
R … distance

The following table shows typical values of fade-away values.

Soil type	Fade-away value B
Soft soil (clay, peat)	1.2
Cohesive soil (loam, clay)	1.6
Mixed soil (clay, marl)	2.0
Loose soil (sand, gravel)	2.2

Table 29: Fade-away value B for various soil types

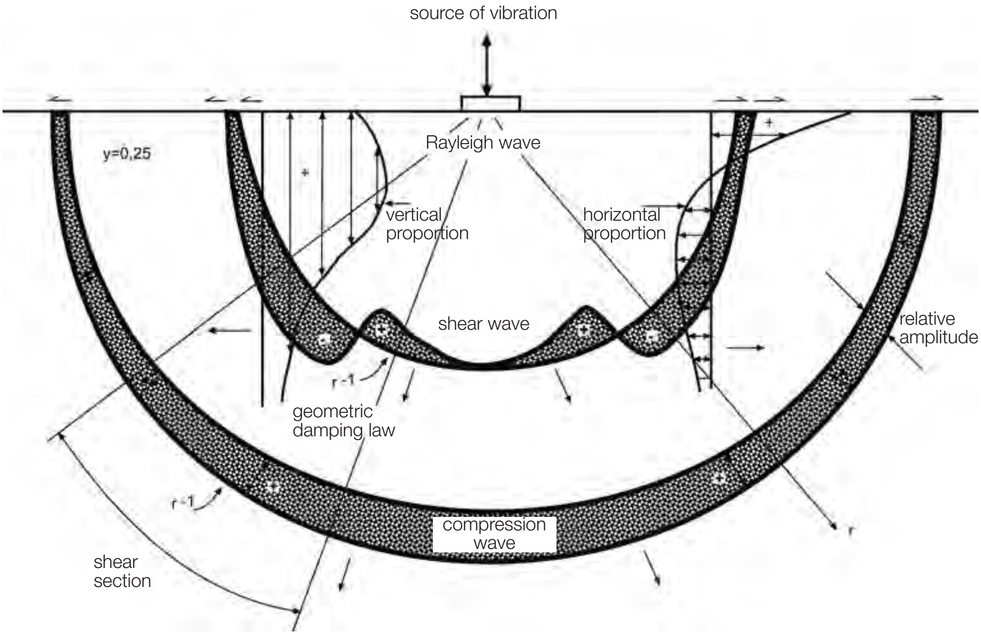


Figure 32: Wave propagation in the elastic half-space [64]

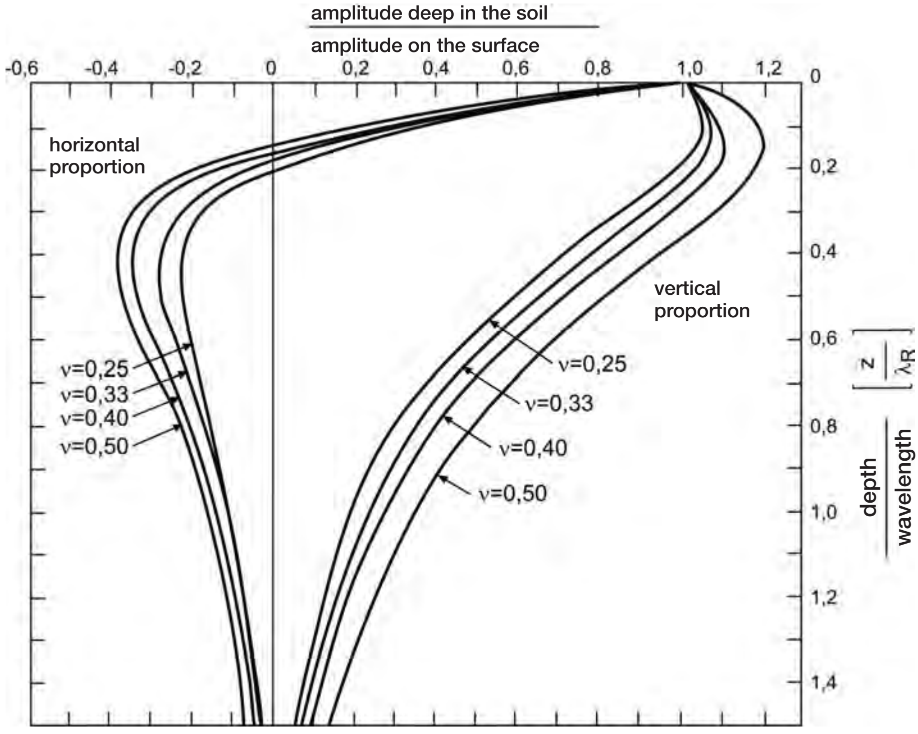


Figure 33: Vibration amplitude versus soil depth, *Rayleigh* waves

9.1.5.4.5 Settlement properties of different ballast materials

The influence of the angularity of ballast on its settlement behaviour is greater than its abrasive properties. Figure 150 shows the settlement behaviour of various ballast materials.

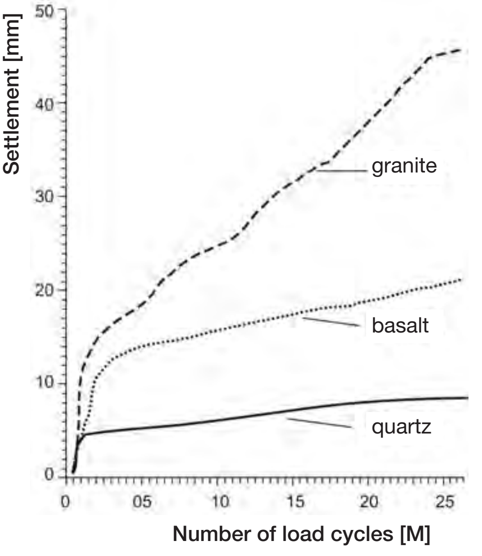


Figure 150: Settlement properties of various ballast materials [305]

The ballast materials have the following properties:

Properties	Granite	Meta-basalt	Quartz
Particle length/width	1.46	1.60	2.30
Particle size	29.2	31.3	39.2
Los Angeles abrasion (adm. ≤ 12–14)	40	11	22
Percentage increase of particle size < 6.7 mm after the experiment	0.35	0.5	0.2
Coefficient of fracture	28	12	19
Coefficient of impact (adm. ≤ 14–18)	33	11	20
Broken particles	85	98	100
Shapelessness (adm. ≤ 5–30)	1	25	14
Surfaces of fractures	5.5	8.1	13.2

Table 78: Mechanical properties of various ballast materials

9.1.5.4.6 Settlement behaviour depending on the contamination of the ballast bed

The track settlement increases progressively with contamination. As defects in longitudinal track level and twist increase proportionally to settlement, track quality decreases faster and tamping has to be carried out earlier and more frequently. Figure 151 shows how settlement depends on the degree of contamination. The contaminating agent in this case was moist silt.

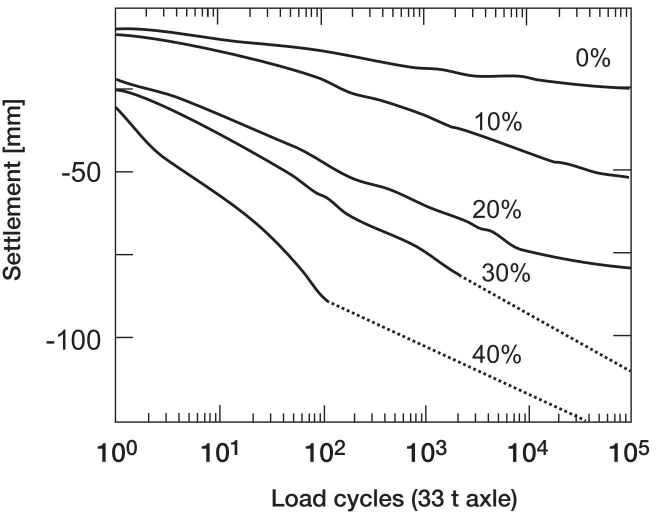


Figure 151: Settlement depending on the percentage of contamination by moist silt [306]

9.1.5.4.7 Settlement after tamping according to Shenton

Shenton [307] developed an empiric formula to forecast settlements which considered various factors. The formula is:

$$e_N = K \cdot \frac{F_e}{10} \cdot \left[\left(0.69 + 0.028 \cdot h \right) \cdot \sqrt[5]{N} + 2.7 \cdot 10^{-6} \cdot N \right]$$

K … factor describing the track structure (type of sleepers, ballast quality, subsoil properties) – a value K = 1.1 is typical for English track

F_e … equivalent wheelset load [t] (considers the fact that high wheelset loads are dominant for settlement)

h … lifting value [mm]

The term proportional to the 5th root of N describes the influence of the tamping machine which is dominant up to an operational load of 1 million tons. The term which is proportional to N describes the settlement of the ballast layer and the subsoil.

The equivalent wheelset load is calculated according to the following formula:

$$F_e = \sqrt[5]{\left(\frac{F_1^5 \cdot N_1 + F_2^5 \cdot N_2 + F_3^5 \cdot N_3 + \ldots}{N_1 + N_2 + N_3 + \ldots} \right)}$$

$F_{1 \ldots n}$ … Axle loads of different train types [t]

$N_{1 \ldots n}$ … Number of cycles of different train types

9.1.6 Critical vibration speed and dynamic settlement behaviour

Rehfeld [308] postulates that the vibration speed is an important factor causing critical dynamic conditions in the ballast bed. Ballast pressure and vibration speeds vary on newly laid tracks from sleeper to sleeper ([309], [310]). On new tracks, vibration speeds of the ballast of 20–26 mm/s were measured. Vibration speeds between 10 and 15 mm/s are considered normal.

In alternating current operated systems the proportion of current returned through the earth can be up to 20–55 % of the traction current. In alternating current installations the current density in the earth decreases exponentially with depth. On direct current railways the proportion of current returned through the earth has to be kept to a minimum because of stray currents and the propensity to initiate corrosion. Current passing through the soil is evenly distributed in the soil.

If the railway current supply is designed for traction currents of more than 1200 A, return cables must be installed [412]. The return cables are usually installed from mast top to mast top. Every 600 m they are connected to the track's earth network. Their advantages are [413]:

– a reduction of the impedance of the overhead line (by 20–30 %),
– a reduction of interference with adjacent telecommunications systems,
– a significant reduction of the magnetic effect of the overhead line network,
– a reduction of the track-earth potential (by up to 55 %),
– the possibility of installing fibre-optic cables for information transfer within the earth cable, and
– a reduction in the required maintenance due to the reduced number of track-to-earth connections.

In order to strengthen the earth contact an additional earth strip is laid parallel to the track which is connected to the rail (earth bar) at regular intervals. This helps to reduce the track-to-earth voltage to approximately 3–4 V/100 A.

13.9 Permissible contact voltage

The track is the preferred choice of medium to protect persons or animals from indirect contact with the power supply. This protection is achieved by connecting all conductive materials to the running rails. We distinguish between immediate and open connection to earth. Immediate railway earth contact means that all conductive materials are connected to the return line. Open railway earth contact means that the conductive elements are connected to the railway earth via voltage limitation devices. In case a failure occurs and the triggering voltage is exceeded, an electrical connection is established. Figure 244 shows that the permissible contact voltage depends on the duration of the voltage occurrence in the event of failure.

Assuming a failure duration of more than 5 seconds, the admissible contact voltage in an alternating current system is 75 V and in a direct current system approximately 180 V. A dangerous situation in the railway area can only occur if the proportion of the track-to-earth potential which can be tapped exceeds the permissible contact voltage.

The improved isolation of modern track structures, such as the Wk track system or slab track, require protective measures against electric shock from the potential in the rail.

Earth connections (non-insulating conductors or conductive elements) in the railway area can be the following:

– foundations of catenary masts,
– earth strips laid parallel to the track (typical parameters: 1 m depth, about 50 % decrease of the track-to-earth potential), and
– natural earth connections, like metal piping, cable sheaths, structural steel elements, foundations of buildings and earth connections of substations.

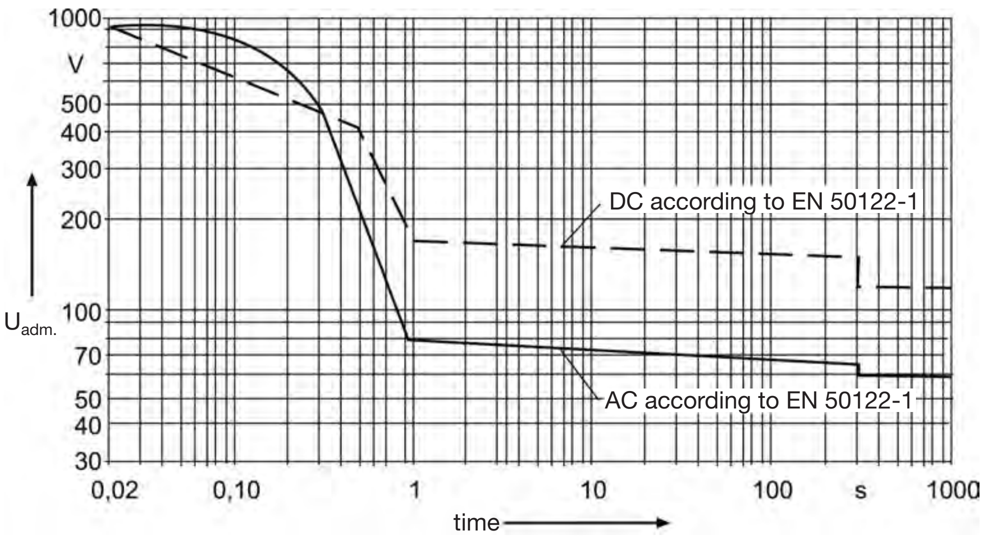


Figure 244: Admissible contact voltages depending on the duration of current flow

The running rails of a track without track circuits must be connected at distances not exceeding 150 m. For urban railways and high-capacity lines the maximum permissible distance is reduced to 75 m.

the rolling stock, and cause the track geometry to deteriorate from the dynamic interaction between the wheel and the rail defects [493].

Figure 333 shows the GWM 550 rail grinding machine for plain line and turnouts.

Figure 333: GWM 550 Grinding Machine

This machine uses oscillating grindstones, as opposed to the rail grinding trains with their rotating grinding wheels. The machine is equipped with five grinding units (see Figure 334). Each grinding unit carries six grindstones. Grinding is performed by the oscillating movement of the grinding units combined with the continuous forward movement of the machine. The vertical static load can be adjusted hydraulically. These components together achieve a high grinding performance and an excellent quality of the rail surface which is why this method is frequently used also for “acoustic” grinding. At forward speeds of 1200 m/h the material removed amounts to 0.05 – 0.07 mm per machine pass. The abrasion mainly depends on the grinding speed, the pressure and the quality of the grindstones, the amplitude of the defects and the hardness of the rail surface.

As the grindstones are arranged to act in a rigid line 2 metres long, they can reliably remove corrugation, as well as long-wave rail defects. A water spray arrangement ensures a grinding procedure free of sparks and dust. The higher the surface quality after grinding, the later corrugation will recur [494]. This is also the reason why preventive grinding of newly laid rails is so economically effective. The graph in Figure 335 (measurement using the roughness measurement device *RMT 1200 E)* shows the roughness profile before and after oscillating grinding of the left hand rail (place of measurement: Bienenbüttel, Celle-Lüneburg track, 23/2/1992; *Schweerbau* company). The roughness amplitude before grinding amounted to about $\pm 20\ \mu m$. It could be reduced by grinding to about $\pm 3\ \mu m$. The graph in Figure 336 gives the third-spectra of roughness at the measurement place mentioned above (roughness level $L = 20 \cdot \log (r/r_0)$; $r_0 = 1\ \mu m$, r = measured and averaged amplitude) before and after grinding.

Figure 334: Grinding unit

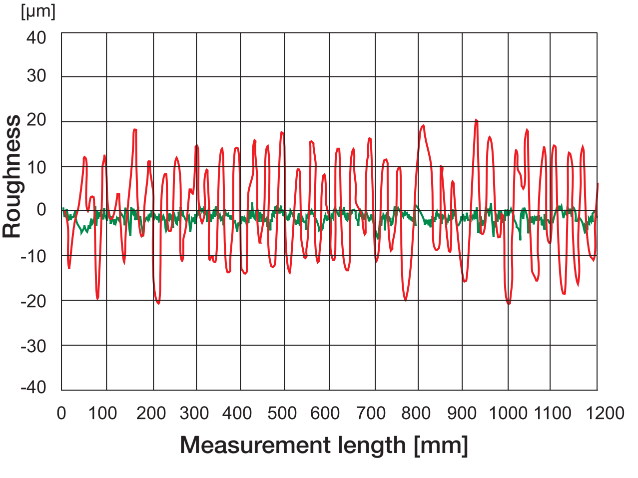


Figure 335: Roughness profile before and after oscillating grinding

Figure 336 shows that for a wavelength of 3 cm the critical peak was reduced from about 15 dB before to –10 dB after grinding. On the basis of these excellent results it can be predicted that the recurrence of corrugation will be significantly delayed and that the noise caused by corrugation will be avoided. In view of the existing trend to further reduce the limits for acceptable noise levels, and due to the fact that flying sparks are avoided, the method

As a standard reference book for railway track engineers and practitioners, **Track Compendium** describes clearly and compactly the physical properties of individual track components and their interrelationships.

Compared to the first English edition, this second edition contains several additional sections on the following topics:

- Equivalent conicity
- Interaction of the vehicle with track geometry faults
- Durability of wooden sleepers
- Ballast bed cleaning and ballast properties

There are also further additions in other chapters.

The author's wealth of knowledge and experience over more than 20 years of research in the field of track behaviour and the optimum methods of track maintenance should serve the railway engineers now and in the future as a practical aid and a useful reference book in their daily work.

ISBN 978-3-7771-0421-8

9 783777 104218