Road and Transportation Research Association

Working Group Earthworks and Foundations

FGSV

R 1

Technical testing regulations for soil and rock in road construction

TP BF-StB

Part B 8.3

Dynamic Plate Load Testing with the Light Drop-Weight Tester

Edition 2012
Translation 2018

ISBN 978-3-86446-036-4

Road and Transportation Research Association

Working Group Earthworks and Foundations

FGSV

R 1

Technical testing regulations for soil and rock in road construction

TP BF-StB

Part B 8.3

Dynamic Plate Load Testing with the Light Drop-Weight Tester

Edition 2012
Translation 2018

Working Group Earthworks and Foundations
Committee: Testing Equipment

Director:

Prof. Dr.-Ing. Wolfram Kudla, Freiberg

Members:

Dipl.-Geophys. Berno Bumiller, Munich
Dipl.-Ing. Alexander Cejka, Hamburg
Dipl.-Math. Dr. rer. nat. Tilmann Deutler, Lampertheim
Dipl.-Ing. Ulrich Diehl, Herdecke
Dipl.-Ing. Karl-Heinz Franzen, Münster
Dr.-Ing. Dirk Jansen, Bergisch Gladbach
Prof. Dr.-Ing. Kurt Kliesch, Frankfurt/Main
Dipl.-Ing. Hans-Josef Kloubert, Boppard
Dipl.-Ing. Bernd Kratzer, Berlin
Dipl.-Ing. Hermann Lammen, Münster
Dipl.-Ing. Werner Lange, Cologne
Dipl.-Ing. Marcel Neuhaus, Münster
Dipl.-Phys. Reinhardt Nickol, Halberstadt
ORBR Dipl.-Ing. André Paulsen, Kiel
Dipl.-Ing. Franz Schlögl, Munich
Ltd. Akad. Dir. a. D. Dipl.-Ing. Paul von Soos, Munich
Dipl.-Ing. (FH) Dieter Straußberger, Nuremberg
Prof. Dr.-Ing. Wolfgang Weingart, Barleben

Preliminary remark:

The present part B 8.3 „Dynamic Plate Load Testing with the Light Drop-Weight Tester" of the Technical testing regulations for soil and rock in road construction („TP BF-StB") was drafted by the Committee „Testing Equipment". This part is included in the compilation „Technical testing regulations for soil and rock in road construction". It replaces the corresponding part of the edition from 2003.

Table of Content

Preface

Dynamic test procedures have been developed in various countries to enable fast testing of constructed layers of earth under load conditions approximating those imposed by road traffic.

The in the following described dynamic plate load test differs from the static plate load test (according to DIN 18 134) in that the load is generated by a damped impact. The impact activates forces of inertia in the soil and in the tester, and these have an effect on the movements which have been generated.

In analogy to the static plate load test, also for the dynamic plate load test, a load plate with a 300 mm diameter is used.

The dynamic plate load test is authorized in the ZTV E-StB 09 as an indirect testing method.

The specification of permitted values and instructions for the performance of comparison tests with other testing methods are not subject of these technical testing regulations.

The Light Drop-Weight Tester must be calibrated yearly by a calibration agency accredited by the German Federal Highway Research Institute (BASt) (TP BF-StB, Part B 8.4, „Calibration Rules for the Light and Medium Drop-Weight Tester“).

1. Field of Application and Purpose

The dynamic plate-load test by means of the LDWT is suitable to determine the bearing capacity and the reached compaction quality of soils in underground/ substructure in earthwork and road construction.

The test does not require much time. Thus, it is possible to evaluate quickly the degree of uniformity of the test area. An advantage, compared to the static plate load test acc. to DIN 18 134 is the possibility to make tests in confined location (e.g. utility trenches, building backfills).

The test procedure is suited, in particular, for coarse-grained and mixed-grain soils up to a maximum grain size of 63 mm and can be also applied to determine the dynamic modulus of deformation E_{vd} in the range from 15 to 70 MN/m^2. The application of the dynamic plate load test is not permitted for the dynamic modulus of deformation E_{vd} above 70 MN/m^2, because in this range the LDWT can not be calibrated sufficiently.

2. Terminology

2.1. Dynamic Plate Load Test

The dynamic plate load test performed by means of the Light Drop-Weight Tester is a test procedure, in which the soil receives an impact of maximum force F_{max} transmitted through the fall of a drop-weight onto a circular load plate of radius r which is assumed to be rigid.

When the device is getting calibrated, this force is selected so that the maximum normal stress σ_{max} under the load plate is 0.1 MN/m^2 during the test. The working depth during the testing with the Light Drop-Weight Tester is about one plate diameter.

2.2. Dynamic Modulus of Deformation

Dynamic modulus of deformation E_{vd} is a parameter for the deformability of soil under a defined, vertical impact load with the impact duration t_{max} (see figure 1). Its value is being calculated with the maximum settlement s_{max} of the load plate as follows according to the formula:

$$E_{vd,L} = 1.5 \cdot r \cdot \frac{\sigma_{max}}{s_{max}} \qquad (1)$$

with

s_{max} = average value of the settlements s_{max1}, s_{max2}, s_{max3} out of 3 measuring impacts (after 3 preloading impacts)

r = radius of the load plate

σ_{max} = normal stress under the load plate (0.1 MN/m^2).

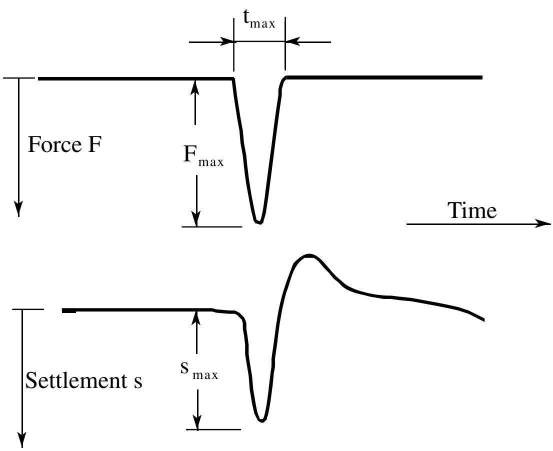

Figure 1: Schematic diagram regarding chronological sequence of force & settlement during impact loading by means of the Light Drop-Weight Tester

Note: Furthermore the deformation speed v_{max} should be registered as an average value from the deformation speeds v_{max1}, v_{max2} and v_{max3} determined at the 3 measuring impacts.

3. Equipment

3.1. General

To perform dynamic plate load tests a Light Drop-Weight Tester as shown in figure 2 according to the schematic diagram is required.

It consists of:

- load plate (1) and handles (2)
- sensor (3) placed in the centre of the load plate vertically to the loaded surface of the settlement measuring instrument (4)
- loading mechanism consists of drop-weight (5), spring assembly (6), tilt compensator (9), guide rod (7) with a release device (8) and circular level (10).

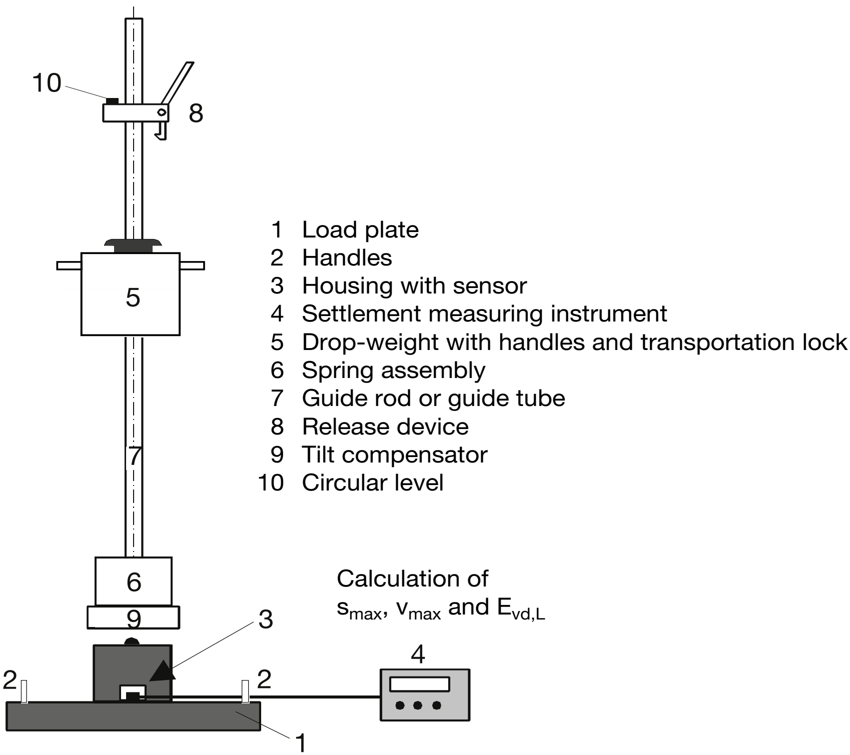

Figure 2: Schematic diagram of the Light Drop-Weight Tester

The load plate, the loading mechanism and the settlement measuring instrument may only be used together. Therefore the load plate, the loading mechanism and the settlement measuring instrument have to be marked by stickers, so that the togetherness of these three parts is easily recognizable. They may not be exchanged by means of parts from other Light Drop-Weight Tester.

3.2. Load Plate

The dimensions of the load plate are as follows:
diameter: 300 mm ± 0.5 mm
plate thickness: 20 mm ± 0.2 mm.

The material for the load plate must be steel of at least grade S355JO. The underside must be even, i.e., it must have an average roughness of 6.3 µm. The load plate must have two handles. The sensor for settling measurements must be attached to the centre of the load plate. The mass of the load plate is: 15kg ± 0.25 kg. This includes the two handles, the housing with sensor, and all the parts of the settling measuring device which are attached to the load plate.

3.3. Loading Mechanism

The loading mechanism consists of drop-weight, spring assembly, guide tube and release device at the top end of the guide rod. As spring assembly a pre-stressed disk spring package (17 disk springs $D_e \cdot D_i \cdot t$ = 63 mm · 31 mm · 2.5 mm according to DIN 2093) has to be used. The Light Drop-Weight Tester has two additional extremely useful components: a tilt compensator at the bottom end of the guide rod, and a transportation lock which immobilizes the drop-weight. To the total mass of the guide rod belong the masses of the spring assembly, tilt compensator and the release device.

The following technical data have to be observed:

mass of the drop-weight:	10 kg ± 0.1 kg
total mass of the guide rod:	5 kg ± 0.1 kg
maximum impact force F_{max}:	7.07 kN (required value)
duration of impact t_{max}:	17 ms ± 1.5 ms.

The spring assembly and the drop-weight have to be defined by calibration, so that the max. impact force is on average 7.07 kN. The compliance with the required impact duration t_{max} is also being checked during calibration.

The drop-weight must be made of steel of at least grade S355JO, and the guide rod must be of hard-chrome plated steel. The drop-weight must be shaped in such a way that it can be caught after the first impact on the load plate. In addition, appropriate design and maintenance measures should be taken to ensure that friction between the drop-weight and the guide rod is minimal at all times.

These requirements are valid for a temperature range between 0 °C and 40 °C.

3.4. Settlement Measuring Instrument

The settlement measuring instrument consists of a sensor (e.g. acceleration sensor) and the settlement measuring instrument. The settlement measuring instrument uses the signal from the sensor to determine the settling s_{max}. Then, the dynamic modulus of deformation E_{vd} is calculated by using equation (1). The settlement measuring instrument must also display and store the maximum settling of each measuring impact and the modulus of deformation E_{vd}. Moreover, the settlement measuring instrument should also display and store the maximum speed v_{max} during impact load. Such settlement measuring instruments are permitted which measure settlements in a range from 0.3 mm to 1.5 mm in a frequency range of at least 8 Hz to 100 Hz and in an air temperature range of 0 °C to 40 °C. In addition, the settlement measuring instrument must fulfil the requirements of TP BF-StB, Part B 8.4.

3.5. Auxiliary Equipment

The following auxiliary equipment might be necessary when making the test:

- spade
- steel rule
- hair broom
- trowel, fillers, right-angle, perpendicular, folding yardstick
- dry middle sand (grain size 0.2 mm to 0.6 mm).

4. Test Conditions

The dynamic plate-load test can be conducted on coarse-grained and mixed-grain soils as well as on stiff or solid fine-grained soils (according to DIN 18196) or on comparable building materials. Individual grains bigger than 63 mm may not be directly below the load plate.

If the test is to be conducted on fast-drying, even-grained sands, on crusted soils, or on soils with sodden surfaces or whose upper layer has been disturbed in some other way, the disturbed zone must in all cases be removed before testing begins. The density of the soil being tested ought to remain largely unchanged.

Test results for fine-grained soils (silts, clays) can only be satisfactorily obtained and evaluated when these soils are stiff to slid in their consistency. In case of doubt the consistency of the soil has to be tested in different depths until the depth d (d = load plate diameter) below the surface of the measuring point.

The incline of the test area must not exceed 6 %.

Performing the dynamic plate load test is only possible within an air temperature range from 0 °C to 40 °C. A test on frozen soil is not permitted.

5. Performing the Test

5.1. Preparation of the Test Area

To place the load plate, a correspondingly large area has to be prepared at the appropriate place. Within the contact space the soil surface has to be made as even as possible by shifting the load plate and or by means of appropriate tools (steel rule, brick trowel). Loose particles of the soil should be removed.

The entire undersurface of the load plate must be in contact with the test area. For compensating any unevenness, if necessary, a few millimetre thick “layer” of central sand can be applied, whereby the sand may only compensate the unevenness directly below the load plate. Afterwards the load plate has to be put on and the thickness of the sand layer minimized by shifting.

These requirements are also valid for inclined test areas.

5.2. Procedure and evaluation of the measurement

After preparing the test surface and positioning the load plate, the loading mechanism has to be placed centrically on the load plate, and the device for measuring the settlement has to be made ready for testing. The guide rod has to be kept vertically, even when the test surface is not horizontal.

The test area has to be preloaded by means of three impacts. Therefore the drop-weight has to be loosened from the release device and held after each impact.

Afterwards after switching on the settlement measuring instrument, three measuring impacts have to be performed. Therefore the drop-weight has to be loosened from the release device and held after each impact. Here the drop height has to comply with the drop height, determined by the calibration.

The dynamic modulus of deformation $E_{vd,L}$ in MN/m^2 is calculated by using equation (1) under due consideration of the maximum normal stress under the load plate $\sigma_{max} = 0.1\ MN/m^2$, the load plate diameter $2 \cdot r = 300$ mm and the average value s_{max} of the three measured settlements as follows:

$$E_{vd,L} = 1.5 \cdot r \cdot \frac{\sigma_{max}}{s_{max}} = 1.5 \cdot 0.15\ m \cdot \frac{0,1\ MN/m^2}{s_{max}} = \frac{22,5}{s_{max}} \qquad (2)$$

The dynamic modulus of deformation $E_{vd,L}$ is indicated in MN/m^2 without decimal places (e.g. 41 MN/m^2).

For verification purposes on a statistical basis acc. to TP BF-StB, Part E 1, the dynamic modulus of deformation $E_{vd,L}$ (used as a calculation input value) has to be indicated with one decimal place (e.g. 41.3 MN/m^2) (see TP BF-StB, Part A 3).

The test result should not be used if there is a lateral movement of the load plate during time of the impact load (e.g. at inclined test areas).

5.3. Digging Up the Test Point

If the measurement results obtained are unusual, the soil underneath the test point until the depth, which complies with the load plate diameter, has to be dug up or the test has to be repeated at a different test point. If there occur any local inhomogeneities during digging up, e.g. soil with different consistency or stones, this has to be indicated on the test protocol.

Unusual test results can occur e.g. because of strong canting of the load plate or because of big differences of the settlement measuring values between the three measuring impacts.

For fine-grained soils within each inspection lot the compliance with the consistency (at least "stiff") according to the stated requirements indicated in section 4 must be proven by digging up at least one testing point to a depth of 30 cm.

6. Test Protocol and Evaluation

The test protocol should include the following data:

- project
- manufacturer/ serial number
- date of test
- inspection personnel
- location of test area
- soil type/ soil group
- weather (including temperature and time, if necessary)
- remarks, e.g. concerning unusual occurrences
- results of diggings, if necessary, consistency
- settlements s_{max1}, s_{max2}, s_{max3} measured at each test location
- the dynamic modulus of deformation $E_{vd,L}$ calculated in terms from the average value s_{max} of the settlements.

Furthermore can be indicated the ratio $\frac{s_{max}}{v_{max}}$

with

v_{max} = maximum deformation speed.

The following form template can be used as a test protocol to determine the modulus of deformation $E_{vd,L}$.

Determine of the dynamic modulus of deformation by means of the Light Drop-Weight Tester acc. to TP BF-StB, Part B 8.3

Manufacturer: Serial number:	Date of last calibration: Drop height as per calibration label:

Test protocol number: ....
Project: ....
Soil type according to DIN EN ISO 14688: ....
Soil group according to DIN 18196: ....
Weather/temperature: ....
Test date and time: ....
Carried out by: ....
Comments: ....

<table>
<tr><th>Test point no.</th><th>Measuring impact no.</th><th>v_{max} [mm/s]</th><th>s_{max} [mm/s]</th><th>Comments (location of test point; where appropriate result of excavation)</th></tr>
<tr><td rowspan="7">1</td><td colspan="3">3 Preloading impacts</td><td rowspan="7"></td></tr>
<tr><td>1</td><td>v_{max1} =</td><td>s_{max1} =</td></tr>
<tr><td>2</td><td>v_{max2} =</td><td>s_{max2} =</td></tr>
<tr><td>3</td><td>v_{max3} =</td><td>s_{max3} =</td></tr>
<tr><td>Average values</td><td>v_{max} =</td><td>s_{max} =</td></tr>
<tr><td colspan="3">$t_v \text{ [ms]} = \frac{s_{max} \text{ [mm]}}{v_{max} \text{ [mm/s]}} \cdot 1000 =$</td></tr>
<tr><td colspan="3">$E_{vd,L} \text{ [MN/m}^2\text{]} = \frac{22.5}{s_{max} \text{ [mm]}} =$</td></tr>
<tr><td rowspan="7">2</td><td colspan="3">3 Preloading impacts</td><td rowspan="7"></td></tr>
<tr><td>1</td><td>v_{max1} =</td><td>s_{max1} =</td></tr>
<tr><td>2</td><td>v_{max2} =</td><td>s_{max2} =</td></tr>
<tr><td>3</td><td>v_{max3} =</td><td>s_{max3} =</td></tr>
<tr><td>Average values</td><td>v_{max} =</td><td>s_{max} =</td></tr>
<tr><td colspan="3">$t_v \text{ [ms]} = \frac{s_{max} \text{ [mm]}}{v_{max} \text{ [mm/s]}} \cdot 1000 =$</td></tr>
<tr><td colspan="3">$E_{vd,L} \text{ [MN/m}^2\text{]} = \frac{22.5}{s_{max} \text{ [mm]}} =$</td></tr>
<tr><td rowspan="7">3</td><td colspan="3">3 Preloading impacts</td><td rowspan="7"></td></tr>
<tr><td>1</td><td>v_{max1} =</td><td>s_{max1} =</td></tr>
<tr><td>2</td><td>v_{max2} =</td><td>s_{max2} =</td></tr>
<tr><td>3</td><td>v_{max3} =</td><td>s_{max3} =</td></tr>
<tr><td>Average values</td><td>v_{max} =</td><td>s_{max} =</td></tr>
<tr><td colspan="3">$t_v \text{ [ms]} = \frac{s_{max} \text{ [mm]}}{v_{max} \text{ [mm/s]}} \cdot 1000 =$</td></tr>
<tr><td colspan="3">$E_{vd,L} \text{ [MN/m}^2\text{]} = \frac{22.5}{s_{max} \text{ [mm]}} =$</td></tr>
</table>

7. Regulations and Literature References

7.1. Technical Regulations

DIN	DIN 18134	Building ground; tests and test equipment – Plate load test	1)
	DIN 18196	Earthworks and foundation engineering – soil classification for construction purposes	1)
	DIN 2093	Disc springs – Quality requirements – Dimensions	1)
	DIN EN ISO 14688	Geotechnical exploration and surveying – Designation, description and classification of soils	1)
FGSV	ZTV E-StB	Supplementary technical contract provisions and guidelines for earthworks and road construction (FGSV 599)	2)
		Information sheet on the statistical evaluation of test results	
		Part 1: The fundamental principles of precision in test methods (FGSV 926/1)	2)
		Part 2: Identifying and dealing with outliers (FGSV 926/2)	2)

Reference sources

1) **Beuth Verlag GmbH**
Postal address: Burggrafenstraße 6, 10787 Berlin, Germany
Tel.: +49 30/26 01-22 60, Fax: +49 30/26 01-12 60,
E-mail: info@beuth.de, Internet: www. beuth.de

2) **FGSV Verlag GmbH**
Postal address: Wesselinger Straße 17, 50999 Köln, Germany
Tel.: +49 22 36/38 46 30, Fax: +49 22 36/38 46 40,
E-mail: info@fgsv-verlag.de, Internet: www.fgsv-verlag.de

7.2. Literature References

Bohn, A.: Tragfähigkeitsmessungen mittels Fallgerät, Straße und Autobahn, Volume 1/1968

Weingart, W.: Probleme der dynamischen Tragfähigkeitsprüfung mit Fallgeräten, Die Straße, Volume 11/1981

Behr, H.: Entwicklung eines Schnellprüfverfahrens zur Bestimmung des Verformungsmoduls von Böden, 26. Erfahrungsaustausch über Erdarbeiten im Straßenbau, Bundesanstalt für Straßenwesen (German Federal Highway Research Institute), 1986

Final report on research project FA 5.087 commissioned by the German Federal Ministry of Transport; Trialling of the dynamic drop plate test as a quick testing method for quality assurance in earthworks and for unbound road-bearing layers, Test Centre for Foundation Engineering, Soil Mechanics and Rock Mechanics of the Technical University of Munich, 1990

Kudla, W.; Floss, R.; Trautmann, Ch.: Dynamischer Plattendruckversuch – Schnellprüfverfahren für die Qualitätssicherung von ungebundenen Schichten, Straße und Autobahn, Volume 2/1991

Schwab, E.; Szabo, S.; Tykal, I.: Tragfähigkeits – und Dichteprüfung mittels dynamischer Lastplatte, Straßenbauforschung, Volume 394, Federal Ministry of Economic Affairs, Vienna, 1991

Final report on research project FA 5.114 commissioned by the German Federal Ministry of Transport; Compilation of requirement values for the dynamic modulus of deformation, Test Centre for Foundation Engineering, Soil Mechanics and Rock Mechanics of the Technical University of Munich, 2000

Final report on research project FGSV 3/00 commissioned by the German Road and Transport Research Association; Evaluation of the ring test for calibration of the Light Drop-Weight Tester, Department of Earthworks and Civil Engineering, Technical University of Freiberg, 2000

8. List of Abbreviations

$E_{vd,L}$	Dynamic modulus of deformation (MN/m^2) measured with the Light Drop-Weight Tester
r	Radius of the load plate (r = 15 cm)
s	Settlement
$s_{max1, 2, 3}$	Maximum settlement of the load plate under impact load
s_{max}	Average value of the settlements out of 3 measuring impacts
$v_{max1, 2, 3}$	Maximum deformation speed of the load plate under impact load
v_{max}	Average value of the deformation speeds in 3 measuring impacts
σ	Stress under the load plate
σ_{max}	Maximum stress under the load plate (0.1 MN/m^2)

Remarks on the system of technical publications of the FGSV

R stands for regulations:

These publications either specify the technical design or realization (R1) or give recommendations on the technical design or realization (R2).

W stands for information documents:

These publications represent the current state-of-the-art knowledge and define how a technical issue shall be practicably dealt with or has already been successfully dealt with.

Category R1 indicates 1st category regulations:

R1-publications contain the contractual basis (Additional Technical Conditions of Contract and Guidelines, Technical Conditions of Delivery and Technical Test Specifications) as well as guidelines. They are always coordinated within the FGSV. R1-publications – in particular if agreed on as integral part of the contract – have a high binding force.

Category R2 indicates 2nd category regulations:

R2-publications contain information sheets and recommendations. They are always coordinated within the FGSV. Their application as state-of-the-art technology is recommended by the FGSV.

Category W1 indicates 1st category documents of knowledge:

W1-publications contain references. They are always coordinated within the FGSV but not with external parties. They represent current state-of-the-art knowledge within the respective responsible boards of the FGSV.

Category W2 indicates 2nd category documents of knowledge:

W2-publications contain working papers. These may include preliminary results, supplementary information and guidance. They are not coordinated within the FGSV and represent the conception of an individual board of the FGSV.

FGSV 591/B 8.3 E

Production and sales:

FGSV Verlag GmbH

Wesselinger Straße 15-17, 50999 Köln, Germany
Tel: 0 22 36 / 38 46 30 · Fax: 0 22 36 / 38 46 40
Internet: www.fgsv-verlag.de
ISBN 978-3-86446-036-4

R 1

591/B 8.3/05/18