April 2012

DIN 18134

ICS 93.020

Supersedes
DIN 18134:2001-09

Soil –
Testing procedures and testing equipment –
Plate load test,
English translation of DIN 18134:2012-04

Baugrund –
Versuche und Versuchsgeräte –
Plattendruckversuch,
Englische Übersetzung von DIN 18134:2012-04

Sol –
Méthodes et appareils d'essais –
Essai de charge à plaque,
Traduction anglaise de DIN 18134:2012-04

Document comprises 25 pages

Translation by DIN-Sprachendienst.
In case of doubt, the German-language original shall be considered authoritative.

A comma is used as the decimal marker.

Contents

Figures

Tables

Foreword

This document has been prepared by Working Committee NA 005-05-03 AA *Baugrund, Laborversuche* (*SpA zu CEN/TC 341/WG 6*) of the *Normenausschuss Bauwesen* (Building and Civil Engineering Standards Committee).

Attention is drawn to the possibility that some elements of this document may be the subject of patent rights. DIN [and/or DKE] shall not be held responsible for identifying any or all such patent rights.

Amendments

This standard differs from DIN 18134:2001-09 as follows:

a) in the settlement-measuring device, the distance of the centre of the loading plate to the centreline of the support has been changed to a minimum of 1,50 m, and alternative measuring devices are now permitted;

b) the description of the test procedure has been modified;

c) in Equation (3), σ_{0max} has been explained in more detail;

d) the examples have been reworked;

e) the standard has been editorially revised.

Previous editions

DIN 18134: 1976-07, 1990-06, 1993-01, 2001-09

1 Scope

This standard is intended for use in earthworks and foundation engineering, as well as in road construction.

The plate load test permits the relationship between load and settlement (load-settlement curve) to be determined, the aim being to assess the deformation and strength characteristics of soil, using the load-settlement curves to determine the strain modulus E_V and the modulus of subgrade reaction k_s.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

DIN 863-2, *Verification of geometrical parameters — Micrometers — Part 2: Micrometer callipers heads, depth micrometer — Concepts, requirements, testing*

DIN 1319-1:1995-01, *Fundamentals of metrology — Part 1: Basic terminology*

DIN EN 10025-1, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

DIN EN ISO 376, *Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines*

DIN EN ISO 3650, *Geometrical product specifications (GPS) — Length standards — Gauge blocks*

DIN EN ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

DIN ISO 2768-1, *General tolerances — Tolerances for linear and angular dimensions without individual tolerance indications*

DIN ISO 2768-2, *General tolerances — Geometrical tolerances for features without individual tolerances indications*

3 Terms and definitions

For the purposes of this standard, the terms and definitions in DIN 1319-1 and the following apply.

3.1
plate load test
test in which a load is repeatedly applied and released in increments using a circular loading plate aided by a loading device, with the settlement of the loading plate being measured

3.2
strain modulus
E_V
parameter expressing the deformation characteristics of a soil, calculated from the secants of the load-settlement curves obtained from the first or repeat loading cycle between points $0{,}3 \cdot \sigma_{0max}$ and $0{,}7 \cdot \sigma_{0max}$

NOTE The calculation of the strain modulus is based on 8.2 and is explained in Annex B.

3.3
modulus of subgrade reaction
k_s
ratio of the normal stress σ_0 under an area load to the associated settlement s

NOTE For the purposes of this standard, the modulus of subgrade reaction is calculated from the load-settlement curve obtained from the first loading cycle of the soil according to 8.3.

3.4
maximum permissible errors
maximum permitted limits of error of a measuring instrument

[DIN 1319-1:1995-01, 5.12]

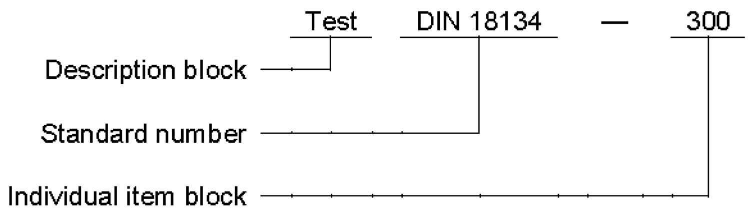
4 Designation

The designation according to this standard comprises the following elements.

Table 1 — Elements of the standard designation

Element of standard designation	Information given in this standard
Description block	Test
Identity block	
Standard number	DIN 18134
Individual items	Possible loading plate diameter *d* in mm: 300 600 762

EXAMPLE Designation of a plate load test according to DIN 18134 using a loading plate with a diameter of 300 mm:



5 Apparatus

5.1 General

The following equipment is required for carrying out the plate load test:

a) reaction loading system;

b) plate loading apparatus, consisting of a loading plate, an adjustable spirit level (30’ level), and a loading system with hydraulic pump, hydraulic jack assembly and high-pressure hose;

c) devices for measuring the load applied and the settlement of the loading plate at right angles to the loaded surface;

d) means of calculating the strain modulus.

5.2 Reaction loading system

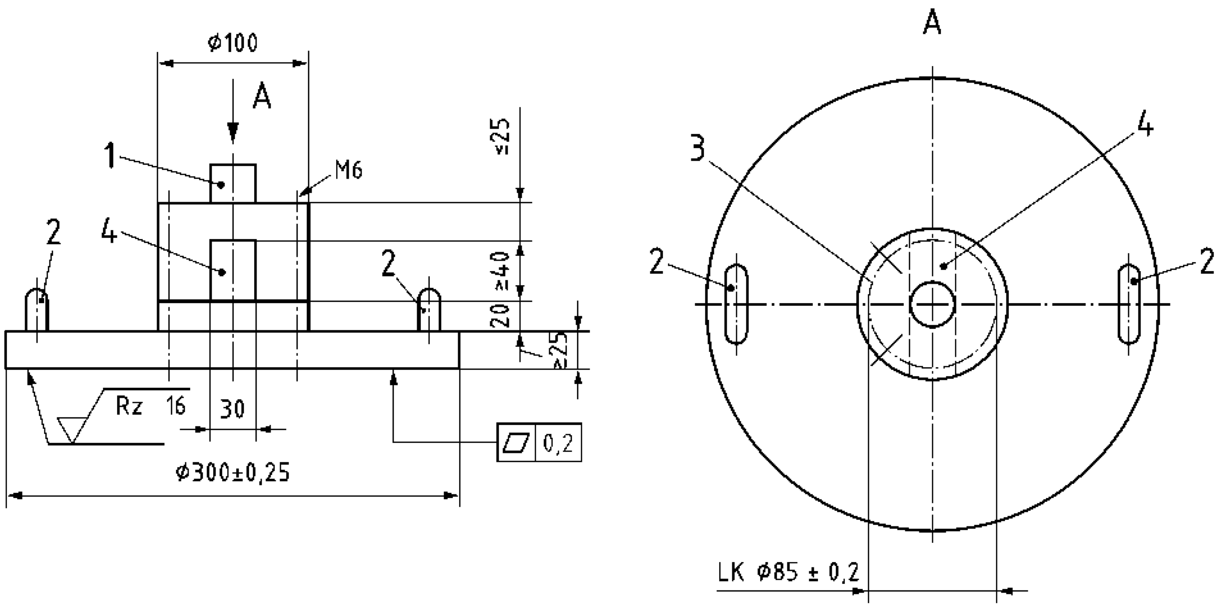
The reaction loading system shall produce a reaction load which is at least 10 kN greater than the maximum test load required. It may be a loaded truck or roller or any other object of sufficient mass.

5.3 Loading plates

Loading plates shall be made of grade S355 J0 steel to DIN EN 10025-1. They shall be machined so as to have the flatness and roughness tolerances in accordance with Figures 1 and 2. The loading plate shall have two handles (see Figure 1).

Dimensions in millimetres

General tolerances: ISO 2768 – mL



Key

1 Centring pin to hold the force transducer with articulated top
2 Handle
3 Hole circle (e.g. 85 mm with three M6 bolts (distributed equally on hole circle))
4 Measuring tunnel

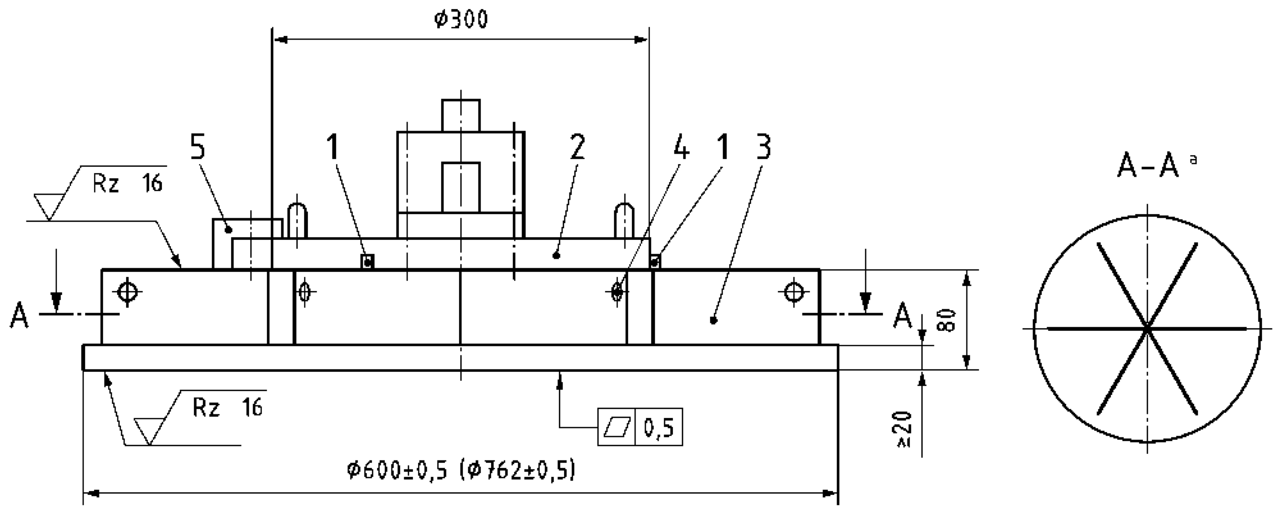
Figure 1 — 300 mm loading plate with measuring tunnel

Loading plates with a diameter of 300 mm shall have a minimum thickness of 25 mm.

Loading plates with a diameter of 600 mm or 762 mm shall have a minimum thickness of 20 mm and be provided with equally spaced stiffeners with even upper faces parallel to the plate bottom face to allow the 300 mm plate to be placed on top of it. Centring pins, and also clamps, if necessary, shall be provided to hold the upper plate in position (see Figure 2).

Dimensions in millimetres

General tolerances: ISO 2768 – mL



Key

1 Centring pins for 300 mm loading plate
2 300 mm loading plate
3 Stiffeners (t = 20 mm)
4 Attachment hole for handle
5 Three clamps
a Arrangement of stiffeners reduced in scale and shown schematically

Figure 2 — Loading plate 600 mm or 762 mm in diameter with equally distributed stiffeners

5.4 Loading system

The loading system consists of a hydraulic pump connected to a hydraulic jack via a high-pressure hose with a minimum length of 2 m. The system shall be capable of applying and releasing the load in stages.

For the pressure to be properly applied, the hydraulic jack shall be hinged on both sides and secured against tilting. The pressure piston shall act through at least 150 mm.

The height of the plate loading apparatus during operation should not exceed 600 mm. In order to compensate for differences in the heights of the vehicles used as reaction loads, elements shall be provided that allow the initial length of the hydraulic jack to be increased to at least 1 000 mm. Suitable means shall be provided to prevent buckling of these elements.

5.5 Force-measuring apparatus

A mechanical or electrical force transducer shall be fitted between the loading plate and the hydraulic jack. It shall measure the load on the plate with a maximum permissible error of 1 % of the maximum test load.

The stress shall be indicated at a resolution of at least 0,001 MN/m^2 for a 300 mm loading plate and at least 0,000 1 MN/m^2 for 600 mm and 762 mm loading plates.

The resolution of the force-measuring system shall be equivalent to that of the force transducer.

The above requirements apply for temperatures from 0 °C to 40 °C.

5.6 Settlement-measuring device

The arrangement in Figure 3 shows a settlement-measuring device with a rotatable contact arm (see Figure 3 a)) and one with a contact arm capable of being moved horizontally in axial direction (i.e. with a slide bearing, see Figure 3 b)).

The measuring device with a rotatable contact arm is only suitable for tests in excavations up to 0,3 m deep. The measuring device with a contact arm capable of being moved horizontally in axial direction can also be used in deeper excavations.

The settlement-measuring device consists of

— a frame supported at three points (see “2” in Figure 3),

— a vertically adjustable, torsion-proof, rigid contact arm (see “4” in Figure 3),

— a displacement transducer or dial gauge (see “1” in Figure 3).

The distance from the centre of the loading plate to the centreline of the support shall be at least 1,5 m and shall not be greater than 1,6 m (see Figure 3).

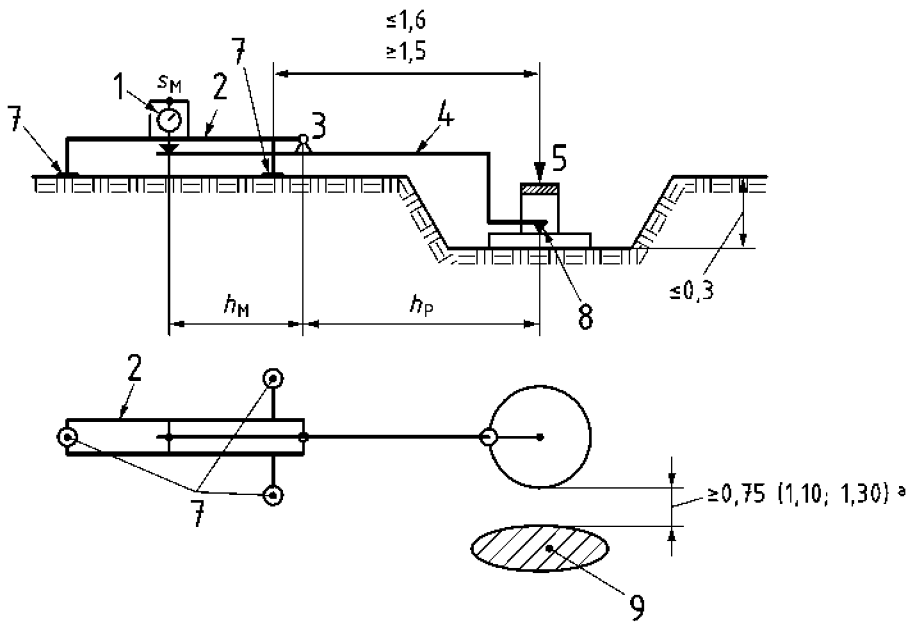
The $h_P : h_M$ ratio (see Figure 3 a)) shall not exceed 2,0. The setting of the assembly shall be capable of being locked so that the h_P / h_M ratio does not change during measurement.

The settlement-measuring device shall be capable of measuring the settlement of the loading plate with a maximum permissible error of 0,04 mm in the measuring range up to 10 mm when using a 300 mm or 600 mm loading plate, and in the measuring range up to 15 mm when using a 762 mm loading plate.

The indication shall have a resolution of at least 0,01 mm.

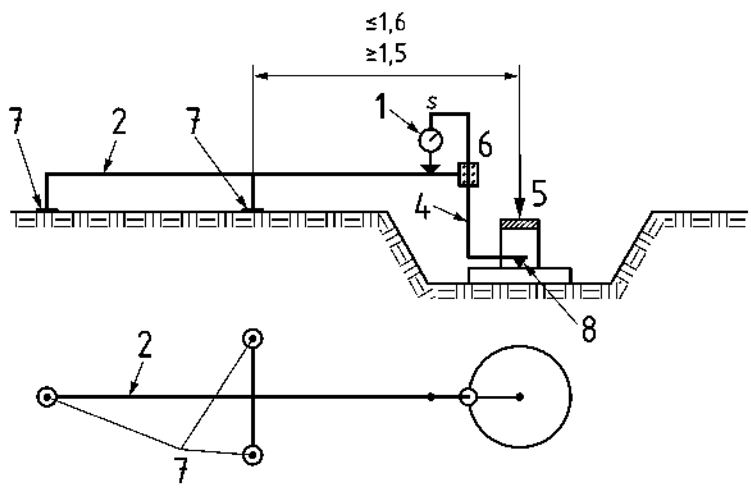
The above requirements apply for temperatures from 0 °C to 40 °C.

Dimensions in metres



a) Rotatable contact arm according to the “weighbeam principle”; measurement of settlement taking into account the lever ratio $h_P : h_M$

Dimensions in metres



b) Contact arm with slide bearing; measurement of settlement in the lever ratio 1:1

Key

1 Dial gauge or displacement transducer
2 Supporting frame
3 Fulcrum
4 Contact arm
5 Load
6 Slide bearing
7 Support
8 Stylus
9 Area taken up by reaction load system

s_M, s Settlement reading on dial gauge or displacement transducer

a For distance see 7.2

Figure 3 — Settlement-measuring device (Examples)

Measurement of settlement with alternative measuring devices is permitted if these have at least the same resolution and measure to the same accuracy and are recognized as remaining unaffected by soil deformation occurring as a result of testing. Such measuring devices shall be calibrated according to A.4.2.

5.7 Ancillary equipment

5.7.1 Spade

5.7.2 Steel straightedges, 400 mm, 700 mm and 850 mm long

5.7.3 Hand brush

5.7.4 Trowel, spatula, set square, plumb line, folding rule, dry medium sand, gypsum plaster, oil

5.7.5 Tarpaulins or similar means of protection against sun and wind

5.8 Calibration of plate loading apparatus and functional testing

Calibration of the plate loading apparatus and functional testing shall be carried out as specified in Annex A.

The plate loading apparatus shall be calibrated before delivery and after repair. Calibration shall be repeated once a year.

6 Test conditions

The plate load test may be carried out on coarse-grained and composite soils as well as on stiff to firm fine-grained soils. Care shall be taken to ensure that the loading plate is not placed directly on particles larger than one-quarter of its diameter.

In the case of rapidly drying, equigranular sand, or soil which has formed a surface crust, has been softened or has been otherwise disturbed in its upper zone, this disturbed soil shall be removed before the plate load test is carried out. The density of the soil under test shall remain as unchanged as possible.

For fine-grained soil (e.g. silt, clay), the plate load test can only be carried out and evaluated satisfactorily if the soil is stiff to firm in consistency. In case of doubt, the consistency of the soil under test shall be determined at various depths up to a depth, d, below ground level (d = diameter of loading plate).

7 Procedure for plate load test

7.1 Test area preparation

An area sufficiently large to receive the loading plate shall be levelled using suitable tools (e.g. steel straightedge or trowel) or by turning or working the loading plate back and forth. Any loose material shall be removed.

7.2 Setting up the plate loading apparatus

The loading plate shall lie on, and be in full contact with, the test surface. If necessary, a thin bed (i.e. only a few millimetres in thickness) of dry medium-grained sand or gypsum plaster paste shall be prepared to obtain a level surface. The plate shall be bedded on this surface by turning and slightly tapping on its upper face. When using gypsum plaster as bedding material, the plate shall be greased on its underside. Any excess plaster shall be removed with the spatula before it sets. Testing shall not begin until the plaster has set.

The hydraulic jack shall be placed onto the middle of, and at right angles to, the loading plate beneath the reaction loading system and secured against tilting. The minimum clearance between loading plate and contact area of the reaction load shall be 0,75 m for a 300 mm plate, 1,10 m for a 600 mm plate, and 1,30 m for a 762 mm plate. The reaction load shall be secured against displacement at right angles to the direction of loading.

Care shall be taken to ensure that the loading system remains stable throughout the test.

These requirements also apply to inclined test surfaces.

7.3 Arrangement of settlement-measuring device

Measurement of settlement shall be carried out using a dial gauge, a displacement transducer or an alternative measuring system (see 5.6).

In order to measure settlement, the stylus (see Figure 3) shall be placed in the centre of the loading plate. The distance between the support for the supporting frame and the area taken up by the reaction load shall be at least 1,25 m. The dial gauge or transducer shall be set up so as to be vertical (see Figure 3 a) and Figure 3 b)).

When placing the loading plate, care shall be taken to ensure that the stylus of the contact arm can be passed without hindrance into the measuring tunnel in the plinth of the loading plate and positioned centrally on the plate.

The settlement-measuring device shall be protected from sunlight and wind. Care shall be taken to ensure that the device and the reaction loading system are not subjected to vibration during the test.

7.4 Preloading

Prior to starting the test, the force transducer and dial gauge or displacement transducer shall be set to zero, after which a load shall be applied corresponding to a stress of 0,01 MN/m^2 when using a 300 mm or a 600 mm plate and to a stress of 0,005 MN/m^2 when using a 762 mm plate.

The reading of the gauge or transducer shall not be reset to zero until at least 30 s after the preload has been applied.

7.5 Loading and unloading

7.5.1 General

The maximum load and/or the maximum settlement required are governed by the objectives of the test, as well as by the properties of the soil and the size of the loading plate.

7.5.2 Determining the strain modulus, E_V

To determine the strain modulus, E_V, the load shall be applied in not less than six stages, in approximately equal increments, until the required maximum stress is reached. Each change in load (from stage to stage) shall be completed within one minute. The load shall be released in 3 stages, to 50 %, 25 % and approximately 2 % of the maximum load. Following unloading, a further (2nd) loading cycle shall be carried out, in which, however, the load is to be increased only to the penultimate stage of the first cycle (so that the full load is not reached).

When increasing and decreasing the load, 120 s after the previous loading stage has been reached shall elapse before beginning the next stage. For roadbase testing, 60 s are sufficient. The load shall be held constant during this period. The reading shall be recorded at the termination of each loading stage (see Tables 1 and 2).

To determine the strain modulus for road construction purposes, a 300 mm loading plate shall be used and the load increased until a normal stress below the plate of 0,5 MN/m^2 is reached. If a settlement of 5 mm is reached first, the normal stress measured at this stage shall be taken as the maximum stress.

For a 600 mm loading plate, the limit values are 0,25 MN/m^2 (for normal stress) and 8 mm (for settlement), and for a 762 mm loading plate, 0,2 MN/m^2 and 13 mm.

If a test proceeds in an unexpected manner (e.g. if the loading plate tips or sinks rapidly), the soil at the test site shall be dug up to a depth equal to the plate diameter. If any local inhomogeneity is encountered (e.g. stones, or soil of varying consistency), this shall be recorded.

For soils of low particle strength (e.g. volcanic scoria), or where rapid deformation of the soil as the loading increases indicates imminent failure, the plate load test shall be terminated at lower normal stress values.

If, during the loading cycle, a higher load than intended is inadvertently applied, this load shall be maintained and a note made in the test report.

NOTE In order to check the results obtained from the second loading cycle, once unloading in stages has been completed a third cycle may be carried out to the same maximum load. However this shall be applied immediately after the second loading stage, without any further intermediate stages.

7.5.3 Determining the modulus of subgrade reaction, k_s

In order to determine the modulus of subgrade reaction, k_s, for use in the design of road and airfield pavements, a 762 mm loading plate shall be used. A preload of 0,005 MN/m^2 shall be maintained until the rate of settlement of the plate is less than 0,02 mm/min. The load shall then be applied in increments producing normal stresses of 0,04 MN/m^2, 0,08 MN/m^2, 0,14 MN/m^2, and 0,2 MN/m^2. At each stage the load shall be maintained until the rate of settlement of the plate becomes less than 0,02 mm/min. The load may be released with one intermediate stage at a normal stress of 0,08 MN/m^2.

8 Evaluation and representation of results

8.1 Load-settlement curve

For each load increment, the average normal stress, σ_0, and the associated settlement reading, M, shall be recorded on the dial gauge or displacement transducer (see Clause 9). For the assembly shown in Figure 3 b), M shall be taken as the settlement, s, of the plate. For the assembly shown in Figure 3 a), s is to be obtained by multiplying the settlement reading, s_M, by the lever ratio $h_P : h_M$, in accordance with Equation (1):

$$s = s_M \cdot \frac{h_P}{h_M} \qquad (1)$$

The normal stresses shall be plotted against the settlement as shown in 9.1, Figure 4. A load-settlement fitting curve shall be drawn through the measuring points of the first loading cycle and repeat loading cycle. The measuring points from the unloading cycle shall be joined in a straight line. The loading and unloading cycles shall be identified by directional arrows.

The test report shall include the following information:

- location of test site;
- diameter of loading plate;
- type of settlement-measuring device used, including lever ratio, if relevant;
- type of soil;
- type of bedding material below the plate;
- weather conditions, including the temperature;

- time and date of measurements;
- the person carrying out the test;
- any observations made during the test;
- settlement readings and corresponding normal stresses;
- load-settlement curves;
- an evaluation of the test;
- where appropriate, a description of the soil conditions below the plate after testing.

8.2 Calculation of strain modulus, E_V

Calculation of the strain modulus, E_V, from the first and of the second loading cycle shall be based on load-settlement fitting curves. These shall be calculated by means of a second-degree polynomial according to Equation (2):

$$s = a_0 + a_1 \cdot \sigma_0 + a_2 \cdot \sigma_0^2 \quad (2)$$

where

σ_0 is the average normal stress below the plate, in MN/m^2,

s is the settlement of the loading plate, in mm,

a_0 are the constants of the second-degree polynomial, in mm,

a_1 are the constants of the second-degree polynomial, in mm/(MN/m^2),

a_2 are the constants of the second-degree polynomial, in mm/(MN^2/m^4).

In order to determine the constants of the first loading cycle, the first stage of the first loading cycle (loading stage 0 in Table 2) shall be neglected.

In order to determine the constants of the second loading cycle, the first stage of the second loading cycle (loading stage 9 in Table 3) shall be taken into account.

In order to calculate the constants of the polynomial from the measuring values from the first and second loading cycles, normal equations (B.1), (B.2) and (B.3) in Annex B shall be evaluated. A computational aid programmed to deal with these equations shall be used.

If a computer programme is used to determine the strain modulus, the programme shall be checked using the calculation example given in 9.1.

The strain modulus, E_V, in MN/m^2, shall be calculated using Equation (3):

$$E_V = 1{,}5 \cdot r \cdot \frac{1}{a_1 + a_2 \cdot \sigma_{0\,max}} \quad (3)$$

where

E_V is the strain modulus, in MN/m^2,

r is the radius of the loading plate, in mm,

σ_{0max} is the maximum average normal stress below the loading plate in the first loading cycle, in MN/m^2.

The subscript 1 shall be used after E_V to denote the first loading cycle, and the subscript 2 to denote the second loading cycle (see 9.1). σ_{0max} from the first loading cycle shall also be used to determine the parameters of the second loading cycle.

8.3 Calculation of modulus of subgrade reaction, k_s

The modulus of subgrade reaction, k_s, in MN/m^3, shall be calculated using Equation (4):

$$k_s = \frac{\sigma_0}{s*} = \frac{\sigma_0}{0{,}001\,25} \quad (4)$$

where

k_s is the modulus of subgrade reaction, in MN/m^3,

σ_0 is the average normal stress, in MN/m^2,

$s*$ is the settlement of the loading plate, in m.

In road and airfield construction, the normal stress, σ_0, corresponding to a settlement $s*$ of the loading plate of 1,25 mm (see Figure 5), shall be measured using a 762 mm loading plate .

When the shape of the load-settlement curve requires a correction of the origin, a tangent shall be drawn at the point of inflexion so as to intersect the axis of settlement $s*$ at 0* (see example in 9.2).

9 Examples of application

9.1 Determination of strain modulus, E_V

Test DIN 18134 — 300

Arrangement of settlement-measuring apparatus as in Figure 3 a) (h_P =1,260 m; h_M = 0,945 m).

Lever ratio:

$$\frac{h_P}{h_M} = \frac{1{,}260}{0{,}945} = 1{,}333 \quad (5)$$

Strain modulus E_{V1} and strain modulus E_{V2} shall be calculated from the values in Tables 2 and 3.

The load-settlement curves are shown in Figure 4. A compilation of results is given in Table 3.

Table 2 — Measured values for first loading cycle and unloading cycle

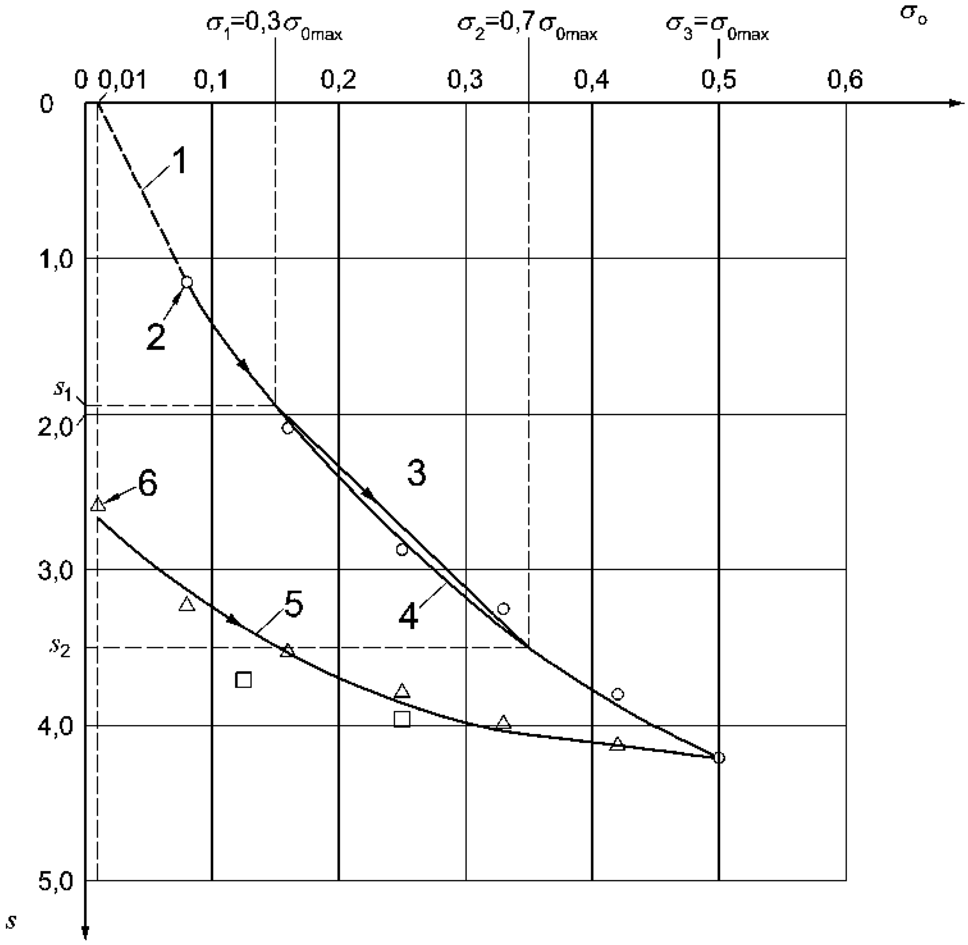
Loading stage no.	Load F kN	Normal stress σ_0 MN/m^2	Dial gauge reading s_M mm	Settlement of loading plate s mm
0	0,71	0,01	0	0
1	5,65	0,080	0,86	1,15
2	11,31	0,160	1,57	2,09
3	17,67	0,250	2,15	2,87
4	23,33	0,330	2,44	3,25
5	29,69	0,420	2,85	3,80
6	35,34	0,500	3,16	4,21
7	17,67	0,250	2,97	3,96
8	8,84	0,125	2,78	3,71
9	0,71	0,01	1,94	2,59

Table 3 — Measured values for second loading test

Loading stage no.	Load F kN	Normal stress σ_0 MN/m^2	Dial gauge reading s_M mm	Settlement of loading plate s mm
9	0,71	0,01	1,94	2,59
10	5,65	0,080	2,42	3,23
11	11,31	0,160	2,65	3,53
12	17,67	0,250	2,84	3,79
13	23,33	0,330	2,99	3,99
14	29,69	0,420	3,10	4,13

Table 4 — Compilation of results

Parameters		1st loading cycle	2nd loading cycle
σ_{0max}	MN/m²	0,500	0,500
a_0	mm	0,285	2,595
a_1	mm/(MN/m²)	12,270	7,120
a_2	mm/(MN²/m⁴)	–9,034	–8,451
$E_V = \frac{1{,}5 \cdot r}{(a_1 + a_2 \cdot \sigma_{0max})}$	MN/m²	29,0	77,7
$\frac{E_{V2}}{E_{V1}}$		2,68	



Key

○ Measurement points from the first loading cycle
□ Measurement points from the unloading cycle
△ Measurement points from the second loading cycle
1 Line connecting point (0,01 MN/m^2; 0 mm) and the first point from the first loading cycle
2 First point from the first loading cycle
3 Secant between 0,3 · σ_{0max} and 0,7 · σ_{0max}
4 Quadratic parabola between the first and the last point from the first loading cycle
5 Quadratic parabola between the first and the last point from the second loading cycle
6 First point from the second loading cycle
s Settlement in mm
σ_0 Normal stress in MN/m^2

Figure 4 — Load-settlement curve, fitting curves according to Table 2 and Table 3 for the first and second loading cycles

9.2 Determination of modulus of subgrade reaction, k_s

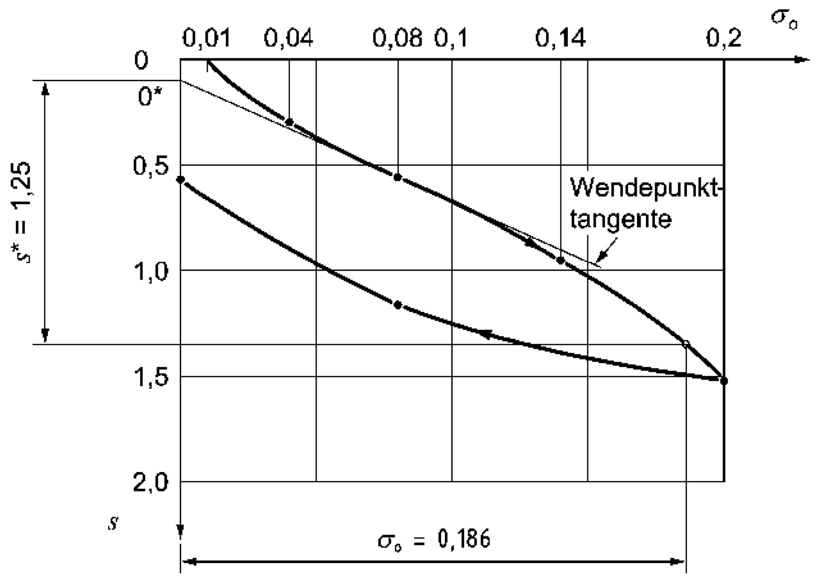
Test DIN 18134 – 762

Arrangement of settlement-measuring apparatus as in Figure 3 b).

The modulus of subgrade reaction k_s shall be calculated from the values in Table 5. The load-settlement curves are shown in Figure 5.

Table 5 — Measured values

Loading stage no.	Load F kN	Normal stress σ_0 MN/m^2	Settlement of loading plate s mm
0	4,56	0,010	0
1	18,24	0,040	0,31
2	36,48	0,080	0,56
3	63,85	0,140	0,97
4	91,21	0,200	2,53
5	36,48	0,080	1,16
6	0,00	0,000	0,57



Key

s Settlement in mm

σ_0 Normal stress in MN/m^2

Wendepunkttangente = Tangent at point of inflection

Figure 5 — Load-settlement curve for determining the modulus of subgrade reaction, k_s

Result obtained by evaluation using the corrected origin 0* and corrected settlement s*:

$$k_s = \frac{\sigma_0}{s^*} = \frac{0{,}186\ \text{MN/m}^2}{0{,}001\,25\ \text{m}} = 148{,}8\ \text{MN/m}^3 \qquad (6)$$

Annex A
(normative)

Calibration of plate loading apparatus

A.1 General

The plate loading apparatus is calibrated to verify its proper functioning and to ensure compliance of the loading- and settlement-measuring devices with requirements.

Calibration shall be carried out by a body that uses instruments with certified traceability.

Calibration of the plate loading apparatus shall be repeated at regular intervals to ensure performance of the loading test in accordance with this standard.

Prior to each calibration, the apparatus shall be checked for mechanical damage and proper functioning of all components. The results shall be stated in the calibration report.

Calibrated loading- and settlement-measuring devices shall be durably marked with labels giving the name and address of the calibration body and the validity of calibration.

A.2 Check of plate loading apparatus for compliance with requirements

It shall be checked whether the plate loading apparatus fulfills the requirements regarding:

a) dimensions of loading plate (see 5.3);

b) indication (limit of error) and resolution of the force-measuring system (see 5.5);

c) indication (limit of error) and resolution of the settlement-measuring device (see 5.6);

d) distance between centre of loading plate and centreline of support of contact arm assembly (see 5.6);

e) lever ratio of settlement-measuring device (see 5.6).

A.3 Apparatus and equipment used for calibration and functional testing

A.3.1 Force-measuring system

The following is required for calibration of the force-measuring system:

a) frame, for mounting the force-measuring system of the plate loading apparatus;

b) class 2 reference compressive force transducer as in DIN EN ISO 376, including a measurement amplifier;

c) apparatus as in 5.3, 5.4 and 5.5.

A.3.2 Settlement-measuring device

The following is required for calibration of the settlement-measuring device:

a) micrometer as in DIN 863-2 or gauge blocks according to DIN EN ISO 3650 of grade 2 with nominal lengths from 1 mm to 15 mm;

b) surface suitable to receive calibration equipment;

c) the complete settlement-measuring device as in 5.6.

A.4 Calibration and functional test

A.4.1 Force-measuring system

The force-measuring system of the plate loading apparatus and reference compressive force transducer for calibration purposes shall be mounted centrally in the frame and subjected to a preload corresponding to a normal stress below the plate of 0,01 MN/m^2 or 0,001 MN/m^2 (first loading stage, Table A.1). The load shall be applied using the loading system of the plate loading apparatus requiring calibration.

For calibrating the force-measuring system and checking the correct functioning of the loading system, two loading cycles and one unloading cycle shall be carried out. The load increments shall be selected as a function of the plate diameter (see Table A.1). Each increase/decrease in load from stage to stage shall be completed within one minute. The load shall be released in four stages (nos. 6, 4, 2, 1 according to Table A.1). Whether loading or unloading, the interval between the end of one stage and the start of the next shall be two minutes, during which time the load shall be maintained. Each load shall be set on the force-measuring system, read on the reference compressive force transducer, and recorded in the calibration report.

Table A.1 — Loading stages as a function of the loading plate diameter

Loading stage no.	Diameters of loading plates					
	300 mm		600 mm		762 mm	
	Load F kN	Normal stress σ_0 MN/m²	Load F kN	Normal stress σ_0 MN/m²	Load F kN	Normal stress σ_0 MN/m²
1	0,71	0,010	0,28	0,001	0,46	0,001
2	5,65	0,080	5,65	0,020	4,56	0,010
3	11,31	0,160	11,31	0,040	9,12	0,020
4	16,96	0,240	22,62	0,080	18,24	0,040
5	22,62	0,320	33,93	0,120	36,48	0,080
6	28,27	0,400	45,24	0,160	54,72	0,120
7	31,81	0,450	56,55	0,200	72,96	0,160
8	35,34	0,500	70,69	0,250	91,21	0,200

Calibration shall be carried out at an ambient temperature between 10 °C and 35 °C (see DIN EN ISO 7500-1).

The error of measurement in the indication, q, in %, is calculated as in Equation (A.1) in relation to F_{max}:

$$q = \frac{F_i - F}{F_{max}} \cdot 100 \qquad \text{(A.1)}$$

where

F_i is the force indicated on the force-measuring system, in kN;

F is the force indicated on the reference compressive force transducer, in kN;

F_{max} is the maximum load required for the plate-loading test, in kN (loading stage no. 8 according to Table A.1).

The limit of error of the force-measuring system (i.e. 1 % of the maximum load in the plate load test in accordance with 5.5) shall not be exceeded.

If the difference between the reading on the force-measuring system, F_i and the reading on the reference gauge, F, exceeds F_{max} by more than 1 % for the loading cycles and by more than 2 % for the unloading cycle in the plate-loading test, the force-measuring system of the plate loading apparatus shall be adjusted in accordance with the manufacturer's instructions and the calibration repeated.

The zero error shall not exceed 0,2 % of F_{max} one minute after the load has been completely removed.

A.4.2 Settlement-measuring device

The contact arm assembly of the plate loading device shall be placed on a firm, even, horizontal surface and the dial gauge or displacement transducer mounted into the contact arm.

For calibration, three different zero settings of the settlement-measuring device shall be carried out, and one series of measurements shall be taken for each zero setting. Each series shall comprise at least five measurements (beginning at the maximum calibration range). They shall be taken at approximately equal intervals along the measuring range of the settlement-measuring device and cover the ranges up to 10 mm and up to 15 mm.

The travelling distance for the calibration of the sensing device shall be 0,5 mm.

The readings of the settlement-measuring device for each of the three measurement series shall be recorded in the calibration report.

Calibration shall be carried out at an ambient temperature between 10 °C and 35 °C (see DIN EN ISO 7500-1). The ambient temperature at which the calibration is carried out shall be recorded.

If one of the values indicated by the settlement-measuring device differs from the micrometer reading or the nominal value of the gauge block by more than 0,04 mm, the settlement-measuring device of the plate loading apparatus shall be adjusted in accordance with the manufacturer's instructions and the calibration repeated.

When using plate loading apparatus with a settlement-measuring device based on the "weighbeam principle", the lever ratio $h_P : h_M$ shall be taken into account.

A.5 Calibration report

The calibration report shall include the following information.

a) applicant;

b) manufacturer of apparatus;

c) type of apparatus;

d) apparatus identification number;

e) year of manufacture;

f) ambient temperature during calibration;

g) date of calibration;

h) name of calibration body and person(s) responsible for calibration;

i) reference instruments used, with traceability certificates;

j) general condition of plate loading apparatus on delivery;

k) deviations of loading plate and contact arm dimensions from specified dimensions;

l) information on the lever ratio of the settlement-measuring device;

m) deviations of the actual readings on the force-measuring device from the target values, in %;

n) deviations of the actual readings on the settlement-measuring device from the target values, in mm;

o) calibration result (test result).

Annex B
(informative)

Principles underlying the normal equations for calculation of the constants of the second degree polynomial for the load settlement curve and for calculation of the strain modulus, E_V

The normal equations for calculation of the parameters for the following equation

$$s = a_0 + a_1 \cdot \sigma_0 + a_2 \cdot \sigma_0^2$$

from the test results (σ_{01} ; s_1), (σ_{02} ; s_2) ... (σ_{0n} ; s_n) are as follows:

$$a_0 \cdot n + a_1 \sum_{i=1}^{n} \sigma_{0i} + a_2 \sum_{i=1}^{n} \sigma_{0i}^2 = \sum_{i=1}^{n} s_i \quad \text{(B.1)}$$

$$a_0 \sum_{i=1}^{n} \sigma_{0i} + a_1 \sum_{i=1}^{n} \sigma_{0i}^2 + a_2 \sum_{i=1}^{n} \sigma_{0i}^3 = \sum_{i=1}^{n} s_i \cdot \sigma_{0i} \quad \text{(B.2)}$$

$$a_0 \sum_{i=1}^{n} \sigma_{0i}^2 + a_1 \sum_{i=1}^{n} \sigma_{0i}^3 + a_2 \sum_{i=1}^{n} \sigma_{0i}^4 = \sum_{i=1}^{n} s_i \cdot \sigma_{0i}^2 \quad \text{(B.3)}$$

Hence parameters $a_{0,}$ a_1 and a_2 are known.

The strain modulus E_{V1} can be calculated as a secant modulus according to elastic isotropic half-space theory. The secant is determined by the following points on the quadratic parabola (see Figure 4):

P_1 (0,3 σ_{0max} ; s_1) ; P_2 (0,7 σ_{0max} ; s_2)

The strain modulus E_{V1} can thus be calculated as follows:

$$E_{V1} = 1{,}5 \cdot r \cdot \frac{\Delta\sigma}{\Delta s} = 1{,}5 \cdot r \cdot \frac{\sigma_2 - \sigma_1}{s_2 - s_1}$$

$$= 1{,}5 \cdot r \cdot \frac{0{,}7 \cdot \sigma_{0max} - 0{,}3 \cdot \sigma_{0max}}{\left[a_0 + a_1 \cdot 0{,}7 \cdot \sigma_{0max} + a_2 \cdot (0{,}7 \cdot \sigma_{0max})^2\right] - \left[a_0 + a_1 \cdot 0{,}3 \cdot \sigma_{0max} + a_2 \cdot (0{,}3 \cdot \sigma_{0max})^2\right]}$$

$$= 1{,}5 \cdot r \cdot \frac{0{,}4 \cdot \sigma_{0max}}{0{,}4 \cdot a_1 \cdot \sigma_{0max} + \left(0{,}7^2 \cdot a_2 - 0{,}3^2 \cdot a_2\right)\sigma_{0max}{}^2}$$

$$= 1{,}5 \cdot r \cdot \frac{1}{a_1 + a_2 \cdot \sigma_{0max}}$$

The strain modulus E_{V2} can also be calculated from the curve of the second loading cycle using σ_{0max} from the first loading cycle.

Bibliography

DIN 863-1, *Verification of geometrical parameters — Micrometers — Part 1: Standard design micrometer callipers for external measurement — Concepts, requirements, testing*

DIN 4018, *Subsoil — Calculation of the bearing pressure distribution under spread foundations*