

Determining the deformation and strength characteristics of soil by the plate loading test

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In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

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Translation by DIN-Sprachendienst.

In case of doubt, the German-language original should be consulted as the authoritative text.

Foreword

This standard has been prepared by Technical Committee 05.03.00 *Baugrund, Versuche und Versuchsgeräte* of the *Normenausschuss Bauwesen* (Building and Civil Engineering Standards Committee).

Amendments

This standard differs from the January 1993 edition as follows:

- a) The total thickness of loading plates of 600 mm and 762 mm in diameter including stiffeners has been reduced from 110 mm to 80 mm (cf. subclause 5.3 and figure 2).
- b) More detailed requirements for the measuring devices have been specified (cf. subclauses 5.5 and 5.6).
- c) Specifications for calibration of the plate loading apparatus have been included (cf. Annex A).

Previous editions

DIN 18134: 1976-07, 1990-06, 1993-01.

All dimensions are in millimetres.

1 Scope

This standard is intended for use in earthworks and foundation engineering, as well as in road construction. It specifies a method ('plate loading test', for short) which 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 and to determine the strain modulus and the modulus of subgrade reaction.

2 Normative references

This standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the titles of the publications are listed below. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

DIN 861-1	Gauge blocks – Concepts, requirements and testing
DIN 863-1	Micrometers – Standard design external micrometers – Concepts, requirements and testing
DIN 4018	Calculation of bearing pressure distribution under shallow foundations
DIN EN 10002-3	Metallic materials – Tensile testing – Part 3: Calibration of force-proving instruments used for the verification of uniaxial testing machines
DIN EN 10025	Hot rolled unalloyed structural steel products – Technical delivery conditions (includes Amendment A1 : 1993)
DIN EN ISO 7500-1	Verification of static uniaxial testing machines – Part 1: Tension/compression testing machines – Verification and calibration of the force-measuring system (ISO 7500-1 : 1999)
ISO 2768-1 : 1989	General tolerances – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications
ISO 2768-2 : 1989	General tolerances – Part 2: Geometrical tolerances for features without individual tolerance indications

3 Concepts

3.1 Plate loading test

Test in which a load is applied in increments to a soil sample using a circular loading plate and a loading device, released in decrements, and the entire process is repeated. The average normal stress below the plate, σ_0 , is plotted against the settlement, s , for each load increment so as to obtain a load-settlement curve.

3.2 Strain modulus

The strain modulus, E_V , is a parameter expressing the deformation characteristics of a soil, and is calculated taking values from the load-settlement curve obtained from the first and second loading cycle, from the gradient of the secant between points $0,3 \cdot \sigma_{0\max}$ and $0,7 \cdot \sigma_{0\max}$ (cf. subclause 8.2).

3.3 Modulus of subgrade reaction

The modulus of subgrade reaction, k_{s1} , is a parameter expressing the elastic reaction of a soil under a surface load. It is determined on the basis of the load-settlement curve obtained from the first loading cycle (cf. subclause 8.3).

4 Designation

Designation of a plate loading test using a loading plate with a diameter of 300 mm:

Test DIN 18134 – 300

5 Apparatus

5.1 General

The following equipment is required.

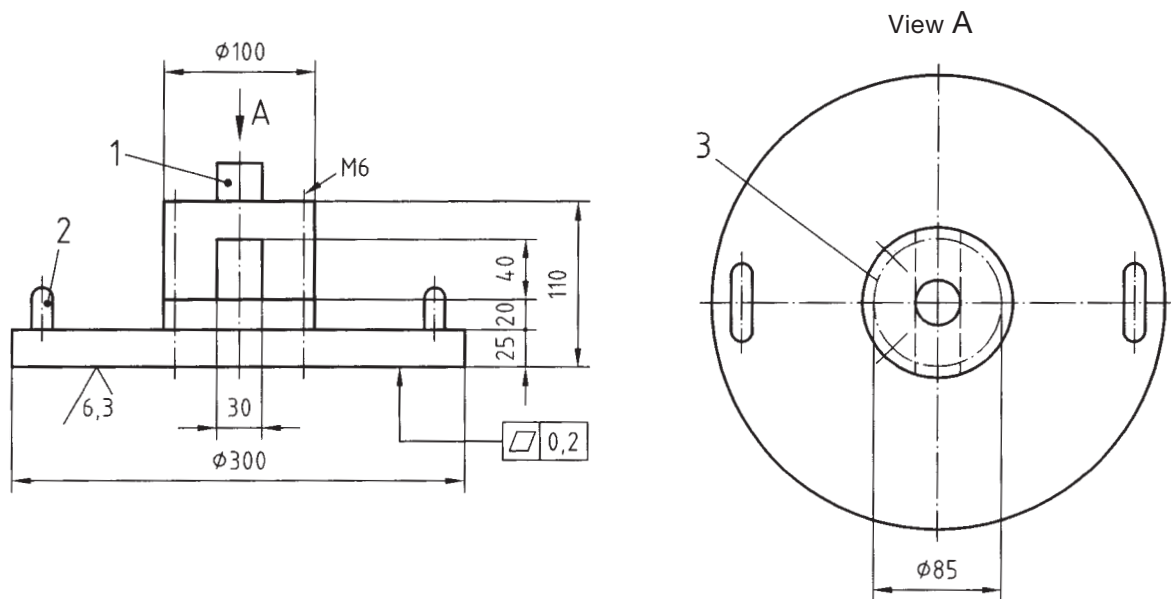
- a) **Reaction loading system.**
- b) **Plate loading apparatus**, consisting of a loading plate, an adjustable spirit level, and a loading system with hydraulic pump, hydraulic jack assembly and high-pressure hose.
- c) **Devices for measuring the load applied** and the settlement of the loading plate at right angles to the loaded surface.
- d) **Programmable pocket calculator**, suitable for calculating quadratic equations.

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, and may be a loaded truck or trailer or any other object of sufficient mass.

5.3 Loading plates

Loading plates shall be made of grade S355J0 steel (cf. DIN EN 10025) and have two handles. They shall be machined to class mk tolerances as in ISO 2768-2 and to the flatness tolerances specified in figures 1 and 2. Loading plates with a diameter of 300 mm shall have a minimum thickness of 25 mm. They shall have an opening of rectangular form to receive the stylus of the settlement-measuring device.



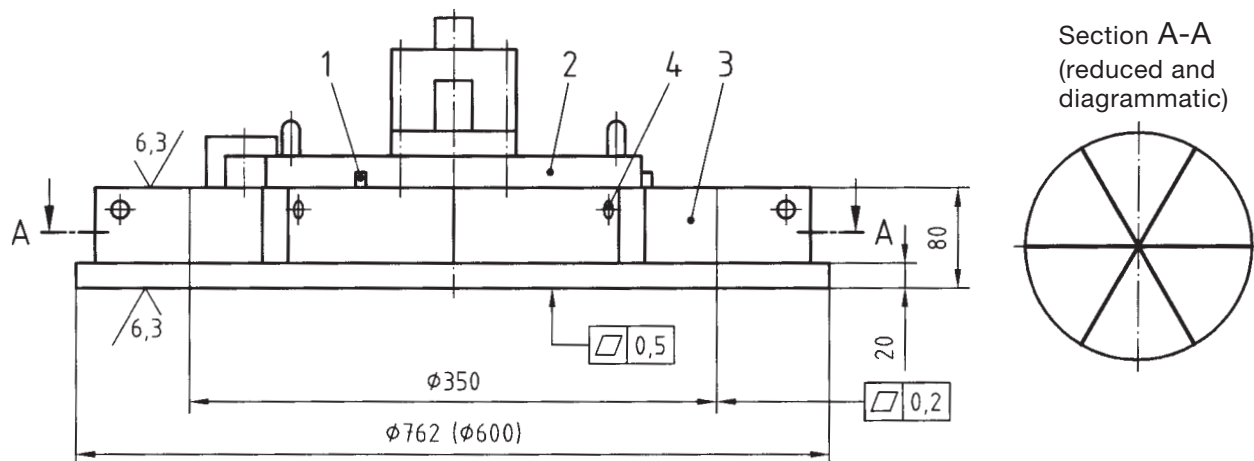
Key to figure

- 1 Centring pin to hold the strain gauge
- 2 Handle
- 3 Hole circle

Figure 1: 300 mm loading plate

Loading plates with diameters of 600 mm and 762 mm shall have a minimum thickness of 20 mm and be provided with equally spaced stiffeners, each 20 mm wide, 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 clamps, if necessary, shall be provided to hold the upper plate in position (cf. figure 2).

The plate diameter shall be subject to a tolerance of 0,5 mm and the plate thickness to a tolerance of 0,2 mm.



Key to figure

- 1 Centring pin
- 2 300 mm loading plate
- 3 Stiffener
- 4 Attachment hole for handle

Figure 2: 600 mm or 762 mm loading plate

5.4 Loading system

The loading system shall consist 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 tipping. The pressure piston shall act through at least 150 mm.

The height of the jack during operation shall 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 pressure piston to be increased to at least 1 000 mm. Suitable means shall be provided to prevent buckling of these elements.

5.5 Load-measuring device

The load on the plate is best measured by means of a strain gauge with a limit of error of 1 %, which shall be fitted between loading plate and piston.

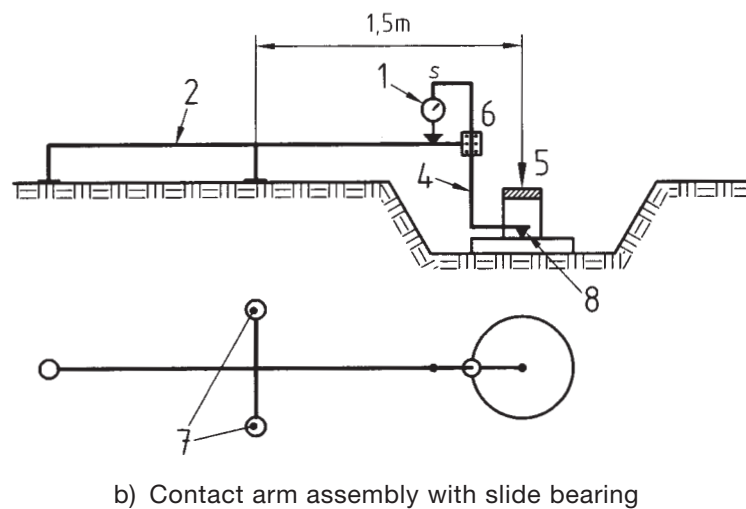
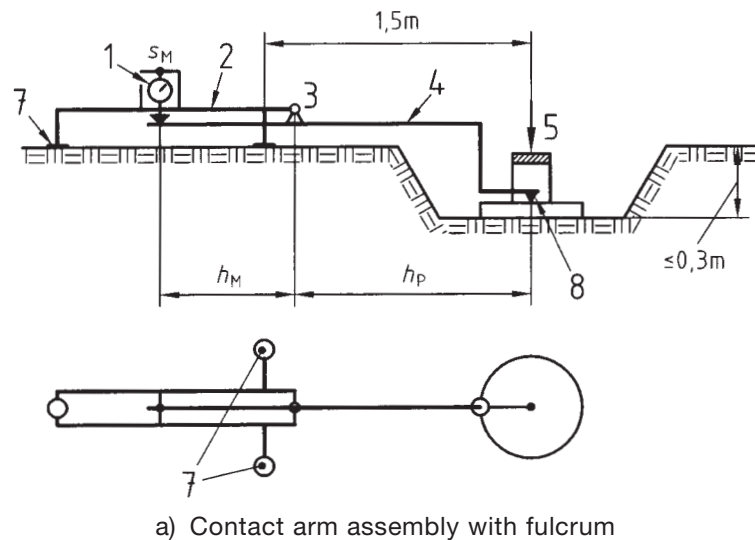
The resolution of the gauge shall be at least 0,001 MN/m² for 300 mm loading plates and at least 0,000 1 MN/m² for 600 mm and 762 mm loading plates.

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

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

5.6 Settlement-measuring device

For measuring the settlement of the loading plate, a contact arm assembly as shown in figure 3 shall be used. This consists of a frame supported at three points, a vertically adjustable, torsion-proof, rigid contact arm, and a displacement transducer or dial gauge. The contact arm is connected to the frame via a fulcrum (cf. figure 3 a)) or a linear bearing (cf. figure 3 b)). The minimum distance between the supports and the centre of the loading plate shall be $(1\ 500 \pm 5)$ mm. The h_p/h_M ratio (cf. figure 3 a)) shall not exceed 2. The assembly shall be capable of being set so that the h_p/h_m ratio does not change during measurement.



Key to figures

- | | |
|---|-----------------|
| 1 Dial gauge or displacement transducer | 5 Load |
| 2 Supporting frame | 6 Slide bearing |
| 3 Fulcrum | 7 Support |
| 4 Contact arm | 8 Stylus |

s_M, s Settlement reading

Figure 3: Assemblies for settlement measurement (examples)

The contact arm assembly with fulcrum is only suitable for settlement measurements in depths up to 0,3 m. The dial gauge or displacement transducer shall be capable of measuring to an accuracy of 0,04 mm for settlement values up to 10 mm and when using a 300 mm or 600 mm loading plate, and for values up to 15 mm when using a 762 mm loading plate. It shall have a resolution of at least 0,01 mm. The above requirements shall apply for temperatures from 0 °C to 40 °C.

5.7 Ancillary equipment

The following ancillary equipment is required.

- Spade.**
- Steel straightedges**, 400 mm, 700 mm and 850 mm long.
- Hand brush.**
- Trowel, spatula, set square, plumb line, folding rule, dry medium sand, gypsum plaster, oil.**
- Tarpaulins** or similar means of protection against sun and wind.

5.8 Calibration of plate loading apparatus

Calibration of the plate loading apparatus shall be carried out as specified in Annex A. It is required before delivery and after repair and shall be repeated once a year.

6 General test conditions

The plate loading 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 on particles larger than approximately 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, the plate loading test shall be conducted with the disturbed soil being removed. The density of the soil under test shall, as far as possible, be uniform throughout.

For fine-grained soil (e.g. silt, clay), the plate loading 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 equal to the diameter of loading plate, d , below ground level.

7 Procedure

7.1 Test area preparation

A test 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 in full contact with the test surface. If necessary, a thin bed of dry medium-grained sand or gypsum plaster paste shall be prepared to obtain a level surface on which the plate is to be bedded 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.

A spirit level shall be fitted to the upper face of the plate and, when the test area is inclined, adjusted accordingly.

The piston of the hydraulic jack shall be placed centrally on, and at right angles to, the loading plate beneath the reaction loading system and secured against tipping. 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.

7.3 Arrangement of settlement-measuring device

The contact arm assembly shall be positioned so that its supports are located 1,5 m from the centre of the loading plate. The dial gauge or displacement transducer shall be set up vertically (cf. figures 3 a) and 3 b)).

When placing the loading plate, care shall be taken to ensure that the stylus of the contact arm can be passed into the rectangular opening without hindrance 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 strain gauge and the dial gauge or displacement transducer shall be set to zero and the plate preloaded for about 30 seconds. The load applied shall correspond to a normal stress of 0,01 MN/m² when using a 300 mm or a 600 mm plate and to a normal stress of 0,005 MN/m² when using a 762 mm plate.

The reading of the gauge or transducer at this load shall be taken as zero reading.

7.5 Loading and unloading

7.5.1 General

The maximum load required or the maximum settlement is governed by the objectives of the test, as well as by the expected strength and deformation characteristics of the soil and the size of the loading plate.

7.5.2 Determining the strain modulus

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 normal stress is reached. Each increase in load (from stage to stage) shall be completed within one minute. The load shall be released in stages, to 50 % and 25 % of the maximum

load and then to the load corresponding to the zero reading. Following that, a further (2nd) loading cycle shall be carried out, in which the load is to be increased only to the penultimate stage of the first cycle.

When testing soil, the time interval between the application of each load increment shall be two minutes, the load being held constant during this period. For subbase testing, one minute is sufficient. The gauge reading shall be recorded at the termination of each loading stage (cf. subclause 9.1 and tables 1 and 2).

To determine the strain modulus for design calculations in road construction, a 300 mm loading plate shall be used and the load increased until a settlement of 5 mm or a normal stress below the plate of 0,5 MN/m² is reached. If the required settlement is reached first, the normal stress measured at this stage shall be taken as maximum stress.

For a 600 mm loading plate, a settlement of 8 mm or a normal stress of 0,25 MN/m², and for a 762 mm loading plate, 13 mm or 0,2 MN/m² shall be reached.

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 stones are encountered, or if the soil is of less than stiff consistency, this shall be recorded.

For soils of low particle strength (e.g. volcanic scoria) and where a rapid deformation of the soil as the loading increases indicates imminent failure, testing shall be terminated at lower settlement or 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 records.

NOTE: In order to check the results obtained from the second loading cycle, a third cycle may be carried out to the same maximum load, this being applied immediately after the second loading stage, without any further intermediate stages.

7.5.3 Determining the modulus of subgrade reaction

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 stress of 0,005 MN/m² 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/m², 0,08 MN/m², 0,14 MN/m², and 0,2 MN/m², with the load being maintained at each stage 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 0,08 MN/m².

NOTE: It should be taken into account that the modulus of subgrade reaction for use in the design of foundations on an elastic base is a function of the loaded area (cf. DIN 4018).

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 (cf. clause 9). For the assembly shown in figure 3 b), M shall be taken as the settlement, s , at the centre 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 factor h_P/h_M , in accordance with equation (1):

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

The stress shall be plotted against the settlement, as shown in figure 4. A smooth curve shall be drawn through the measuring points for each cycle, the loading and unloading cycles being identified by directional arrows.

The test report shall include the following information:

- a) location of test site;
- b) diameter of loading plate;
- c) type of settlement-measuring device used, including h_P/h_M ratio, if relevant;
- d) type of soil;
- e) type of bedding material below the plate;
- f) weather conditions;
- g) time and date of measurements;
- h) time of start and completion of test;
- i) any unusual observations made during the test;
- j) dial gauge readings and corresponding normal stresses;
- k) load-settlement curves;
- l) description of the soil conditions below the plate after testing.

8.2 Calculation of strain modulus

Calculation of the strain moduli of the first and the second loading cycle shall be based on smooth load-settlement curves. These shall be expressed by calculating the settlement, s , at the centre of the loading plate using 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/m²;

a_0, a_1, a_2 are factors, in mm/MN²/m⁴.

For determining the factors, a value of s equal to zero shall be ignored.

For calculating the factors from the results obtained in the loading mode, the normal equations given in Annex B shall be used.

If a computer programme is used, it shall be checked using the calculation examples given in subclause 9.1.

The strain modulus, E_V , in MN/m², shall be calculated using the following equation:

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

where

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

$\sigma_{0\max}$ is the maximum average normal stress, in MN/m².

The subscript 1 shall be used to denote the first loading cycle, and the subscript 2 to denote the second loading cycle (cf. subclause 9.1).

8.3 Calculation of modulus of subgrade reaction

The modulus of subgrade reaction, k_s , in MN/m³, shall be calculated using the following equation:

$$k_s = \frac{\sigma_0}{s} = \frac{\sigma_0}{0,00125} \quad (4)$$

where

σ_0 is the average normal stress, in MN/m²;

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

The modulus of subgrade reaction for use in the design of road and airfield pavements shall be calculated from the normal stress, σ_0 , corresponding to an average settlement of 1,25 mm (cf. figure 5).

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 settlement axis at 0*, as shown in figure 5.

9 Examples

9.1 Determination of strain modulus

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Settlement-measuring device used: contact arm assembly with fulcrum (cf. figure 3 a))

($h_P = 1,26$ m; $h_M = 0,945$ m).

$$h_P/h_M \text{ ratio: } \frac{h_P}{h_M} = \frac{1,26}{0,945} = 1,333.$$

See tables 1 to 3, and figure 4.

Table 1: Measured values for first loading cycle and unloading cycle

Loading stage no.	Load, F , in kN	Normal stress, σ_0 , in MN/m ²	Settlement reading, s_M , in mm	Settlement, s , of loading plate, in mm
0	0	0	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	3,95
8	8,84	0,125	2,78	3,70
9	0	0	1,94	2,59

Table 2: Measured values for second loading cycle

Loading stage no.	Load, F , in kN	Normal stress, σ_0 , in MN/m ²	Settlement reading, s_M , in mm	Settlement, s , of loading plate, in mm
10	0	0	1,94	2,59
11	5,65	0,080	2,42	3,22
12	11,31	0,160	2,65	3,53
13	17,67	0,250	2,84	3,78
14	23,33	0,330	2,99	3,98
15	29,69	0,420	3,10	4,13

Table 3: Results of loading test

Parameter	1 st loading cycle	2 nd loading cycle
τ_{0max} (MN/m ²)	0,50	0,420
a_0 (mm)	0,285	2,646
a_1 (mm/(MN/m ²))	12,270	6,637
a_2 (mm/(MN ² /m ⁴))	- 9,034	- 7,574
$E_V = \frac{1,5 \cdot r}{(a_1 + a_2 \cdot \sigma_{0max})}$ (MN/m ²)	29,0	78,9
$\frac{E_{V2}}{E_{V1}}$	2,72	

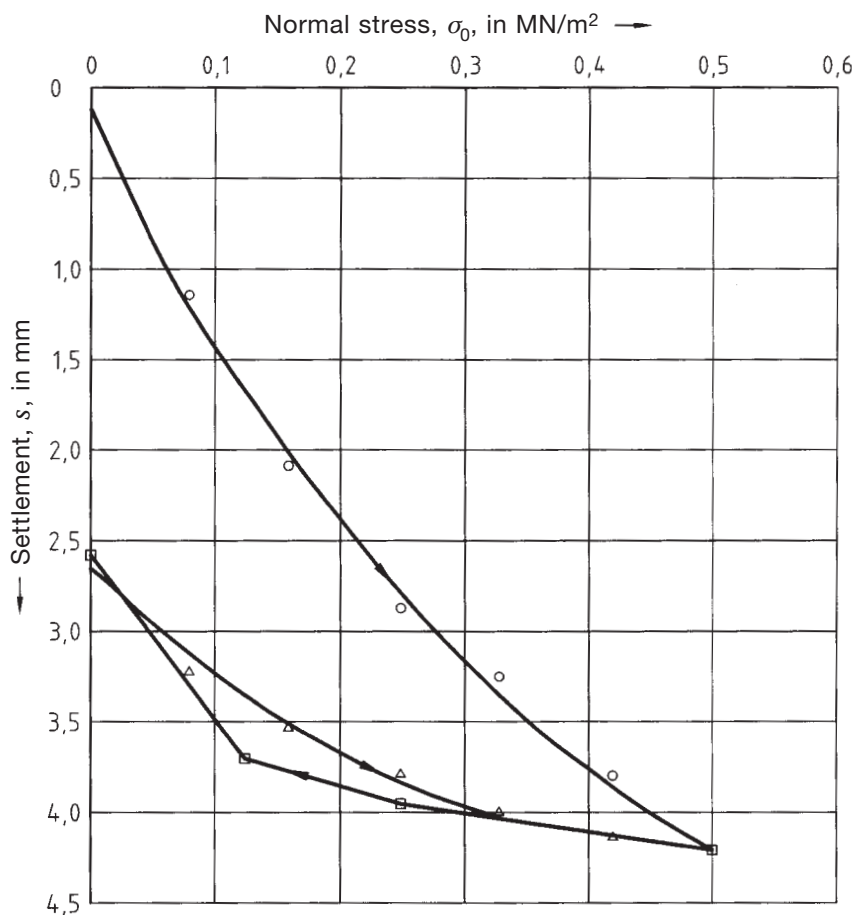


Figure 4: Load-settlement curve for determining the strain modulus

9.2 Determination of modulus of subgrade reaction

Test DIN 18134 – 762

Settlement-measuring device used: contact arm assembly with slide bearing (cf. figure 3 b)).

See table 4 and figure 5.

Table 4: Measured values, in accordance with figure 5

Loading stage no.	Load, F , in kN	Normal stress, σ_0 , in MN/m ²	Settlement, s , of loading plate, in 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	1,53
5	36,48	0,080	1,16
6	0,00	0,000	0,57

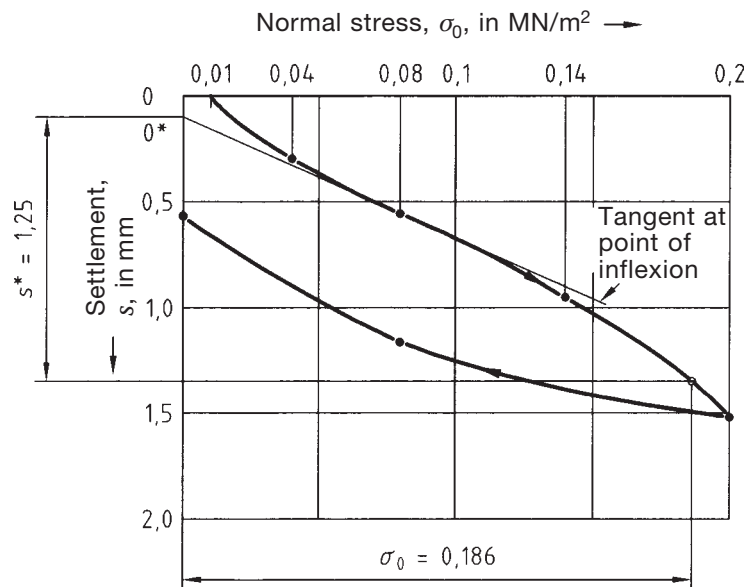


Figure 5: Load-settlement curve for determining the modulus of subgrade reaction

Result obtained with corrected origin:

$$k_s = \frac{\sigma_0}{s^*} = \frac{0,186 \text{ MN/m}^2}{0,00125 \text{ m}} = 148,8 \text{ MN/m}^3$$

Annex A

Calibration of plate loading apparatus

A.1 General

Calibration serves to verify the proper functioning of the plate loading apparatus and to ensure compliance of the measuring devices with requirements. It shall be carried out by a body that uses instruments with certified traceability to the international system of units and repeated at regular intervals to ensure performance of the loading test in accordance with this standard.

Prior to 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 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 apparatus for compliance with requirements

Before calibrating the measuring devices, it shall be checked whether the plate loading apparatus fulfills the requirements regarding

- dimensions of loading plate (cf. subclause 5.3);
- limit of error and resolution of the force-measuring system (cf. subclause 5.5);
- limit of error and resolution of the settlement-measuring device (cf. subclause 5.6);
- distance between supports of contact arm assembly and centre of loading plate (cf. subclause 7.3).
- h_p/h_M ratio of contact arm assembly.

A.3 Apparatus

A.3.1 Force-measuring system

In addition to the equipment described in subclauses 5.3, 5.4, and 5.5, the following is required.

- Frame**, for mounting force-measuring system and reference gauge.
- Class 2 reference gauge** as in DIN EN 10002-3, with transducer.

A.3.2 Settlement-measuring device

In addition to the equipment described in subclause 5.6, the following is required.

- a) **Micrometer** as in DIN 863-2 or DIN 861 **gauge blocks** of grade 2 with nominal lengths from 1 mm to 15 mm.
- b) **Surface**, suitable to receive calibration equipment.

A.4 Procedure

A.4.1 Force-measuring system

The force-measuring system of the plate loading apparatus and the reference gauge shall be mounted centrally in the frame and subjected to a preload corresponding to a normal stress below the plate of 0,01 MN/m², the load being applied using the loading system of the apparatus.

For calibrating the strain gauge and verifying the loading system, two loading cycles and one unloading cycle shall be carried out, with the load increments selected as a function of the plate diameter (cf. 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; cf. table A.1). When both loading and 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 at the force-measuring system and the reference gauge reading recorded.

Calibration shall be carried out at an ambient temperature between 10 °C and 35 °C (cf. DIN EN ISO 7500-1). The relative accuracy error, q , as a percentage, is given by:

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

where

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

F is the force indicated by the reference gauge, in kN;

F_{\max} is the maximum load required for the test, in kN (loading stage no. 8; cf. table A.1).

The limit of error of the force-measuring system shall be as specified in subclause 5.5.

Table A.1: Load increments as a function of plate diameter

Loading stage no.	Diameter of loading plate, in mm					
	300		600		762	
	Load, F , in kN	Normal stress, σ_0 , in MN/m ²	Load, F , in kN	Normal stress, σ_0 , in MN/m ²	Load, F , in kN	Normal stress, σ_0 , in MN/m ²
1.	0,00	0,000	0,00	0,000 0	0,00	0,000 0
2.	5,65	0,080	5,65	0,020 0	4,56	0,010 0
3.	11,31	0,160	11,31	0,040 0	9,12	0,020 0
4.	16,96	0,240	22,62	0,080 0	18,24	0,040 0
5.	22,62	0,320	33,93	0,120 0	36,48	0,080 0
6.	28,27	0,400	45,24	0,160 0	54,72	0,120 0
7.	31,81	0,450	56,55	0,200 0	72,96	0,160 0
8.	35,34	0,500	70,69	0,250 0	91,21	0,200 0

If the difference between the forces indicated by the force-measuring system and the reference gauge, F_i and F , exceeds F_{\max} by more than 1 % for the loading cycles and by more than 2 % for the unloading cycle, the strain gauge 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 shall be placed on a solid, plane surface and the dial gauge or displacement transducer mounted to the contact arm.

For calibration, three zero settings shall be carried out and one series of measurements taken for each zero setting. Each series shall comprise at least five measurements taken at approximately equal intervals along the measuring range of the instrument to be calibrated. Measurements shall start at the maximum calibration range and include the ranges up to 10 mm and up to 15 mm.

The readings of the dial gauge or displacement transducer for the three measurement series shall be recorded. Calibration shall be carried out at an ambient temperature between 10 °C and 35 °C (cf. DIN EN ISO 7500-1). The temperature at which the calibration is carried out shall be recorded.

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

A.5 Calibration report

The calibration report shall include the following information.

- a) name and address of client;
- b) details of the apparatus calibrated (manufacturer, type, identification number, year of manufacture);
- c) calibration temperature;
- d) date of calibration;
- e) name of calibration body and person responsible for calibration;
- f) calibration certificate number of reference instruments used;
- g) general condition of apparatus before calibration;
- h) deviations of loading plate and contact arm assembly dimensions from specified dimensions;
- i) h_P/h_M ratio of contact arm assembly;
- j) accuracy error of force-measuring system, as a percentage;
- k) accuracy error of settlement-measuring device, in mm;
- l) calibration results.

Annex B

Normal equations for determining the factors to be used in settlement calculations

For calculating the factors for equation (2) from the results obtained in the loading mode, the following normal equations shall be used:

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

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

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