Designation: D1196/D1196M – 24

Standard Test Method for Nonrepetitive Static Plate Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements[1]

This standard is issued under the fixed designation D1196/D1196M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the apparatus and procedure for making nonrepetitive static plate load tests on subgrade soils and compacted pavement components, in either the compacted condition or the natural state, and is to provide data for use in the evaluation and design of rigid and flexible-type airport and highway pavements.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A572/A572M Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

2.2 *AASHTO Standard:*[3]

T 222 Standard Method of Test for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements

2.3 *German Standard:*[4]

DIN 18134 Soil—Testing Procedures and Testing Equipment—Plate Load Test

2.4 *U.S. Army Corps of Engineers:*

CRD-C 655-95 Standard Test Method for Determining the Modulus of Soil Reaction

3. Terminology

3.1 *Definitions:*

3.1.1 *deflection, n*—the amount of downward vertical movement of a surface due to the application of a load to the surface.

3.1.2 *modulus of subgrade reaction (k_s), n*—the ratio of the normal stress σ_0 under an area load to the associated settlements "s."

3.1.3 *plate load test, n*—a 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.

3.1.4 *rebound deflection, n*—the amount of vertical rebound of a surface that occurs when a load is removed from the surface.

3.1.5 *residual deflection, n*—the difference between original and final elevations of a surface resulting from the application and removal of one or more loads to and from the surface.

3.1.6 *strain modulus (E_v), n*—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 $0.3 - \sigma_{0max}$ and $0.7 - \sigma_{0max}$.

[1] This test method is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.41 on Pavement Testing and Evaluation.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

[4] Available from Deutsches Institut für Normung e.V.(DIN), Am DIN-Platz, Burggrafenstrasse 6, 10787 Berlin, Germany, http://www.din.de.

4. Summary of Test Method

4.1 This test method covers the apparatus and procedure for making nonrepetitive static plate load tests on subgrade soils and compacted pavement components, in either the compacted condition or the natural state, and is to provide data for use in the evaluation and design of rigid and flexible-type airport and highway pavements.

5. Significance and Use

5.1 Field, in-place nonrepetitive static plate load tests are used for the evaluation and design of pavement structures. Nonrepetitive static plate load tests are performed on soils and unbound base and subbase materials to determine the modulus of subgrade reaction or a measure of the shear strength of pavement components.

6. Apparatus

6.1 Presented below are analog and digital configurations with manual and electronic data collection methods. It is intended that either apparatus configuration is suitable for performing all of the test methods presented in Section 11.

6.1.1 Care should be exercised in comparing results from historical tests to current tests due to variations in operator, apparatus, weather conditions, loading device, and changes to the material being tested.

6.1.2 Users of this standard should specify whether the analog or digital apparatus presented below is required. It is critical for evaluating results that they were produced with the same apparatus regardless of which technology was specified to eliminate variability between apparatuses.

6.1.3 This test method requires the use of a 762 mm [30 in.] diameter load plate to obtain a valid test result.

6.2 The following apparatus describes the analog or dial gauge system that requires the data to be collected manually.

6.2.1 *Loading Device*—A truck or trailer or a combination of both a tractor-trailer, an anchored frame, or other structure loaded with sufficient weight to produce the desired reaction on the surface under test. The supporting points (wheels in the case of a truck or trailer) shall be at least 2.4 m [8 ft] from the circumference of the largest diameter bearing plate being used. The mass shall be at least 5675 kg [25 000 lb].

6.2.2 *Hydraulic Jack Assembly,* with a spherical bearing attachment, capable of applying and releasing the load in increments. The jack shall have sufficient capacity for applying the maximum load required, and shall be equipped with an accurately calibrated gauge or proving ring that will indicate the magnitude of the applied load.

6.2.3 *Bearing Plates*—A set of circular steel bearing plates not less than 25.4 mm [1 in.] in thickness, machined so that they can be arranged in a pyramid fashion to ensure rigidity, and having diameters of 457 mm [18 in.], 610 mm [24 in.], and 762 mm [30 in.]. The diameters of adjacent plates in the pyramid arrangement shall not differ by more than 152 mm [6 in.]. Aluminum alloy No. 24ST plates 38 mm [1.5 in.] thick may be used in lieu of steel plates (AASHTO T 222 and CRD-C 655-95).

6.2.4 *Dial Gauges,* three or more, graduated in units of 0.01 mm [0.001 in.] and capable of recording a maximum deflection of 25.4 mm [1 in.], or other equivalent deflection-measuring devices.

6.2.5 *Deflection Beam*—A beam upon which the dial gauges shall be mounted. The beam shall be a 64 mm [2½ in.] standard black pipe or a 76 by 76 by 6 mm [3 by 3 by ¼ in.] steel angle, or equivalent. It shall be at least 5.5 m [18 ft] long and shall rest on supports located at least 2.4 m [8 ft] from the circumference of the bearing plate or nearest wheel or supporting leg. The entire deflection-measuring system shall be adequately shaded from direct rays of the sun.

FIG. 1 Analog System Configuration

6.2.6 *Miscellaneous Tools,* including a spirit level, for preparation of the surface to be tested and for operation of the equipment.

6.2.7 Fig. 1 shows a typical analog system configuration with dial gauges and requires manual data collection.

6.3 This subsection describes the digital system using a displacement transducer and load cell to capture the data during the test procedure. The description below is in compliance with DIN 18134. Fig. 2 shows a typical digital system configuration.

6.3.1 *Plate Loading Apparatus,* consisting of a loading plate stack of 300 mm diameter on top of the 762 mm diameter plates (see Fig. 3), an adjustable spirit level, and a loading system with hydraulic pump and jack assembly with high-pressure hose.

6.3.2 Devices for measuring the load applied and the settlement of the loading plate at right angles to the loaded surface; means of calculating the strain modulus.

6.3.3 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.

6.3.4 Loading plates shall be made of Specification A572/A572M Gr. 50 (EN10025 grade S355J0) steel or equivalent material with the same stiffness and hardness. They shall be machined so as to have the flatness and roughness tolerances in accordance with Figs. 4 and 5. The loading plate shall have two handles (see Fig. 4).

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

6.3.6 Loading plates with a diameter of 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. Centering pins, and also clamps, if necessary, shall be provided to hold the upper plate in position (see Figs. 4 and 5).

6.3.7 *Loading System:*

FIG. 3 Assembly of the 300 mm Diameter Load Plate on the 762 mm Diameter Load Plate

6.3.7.1 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.

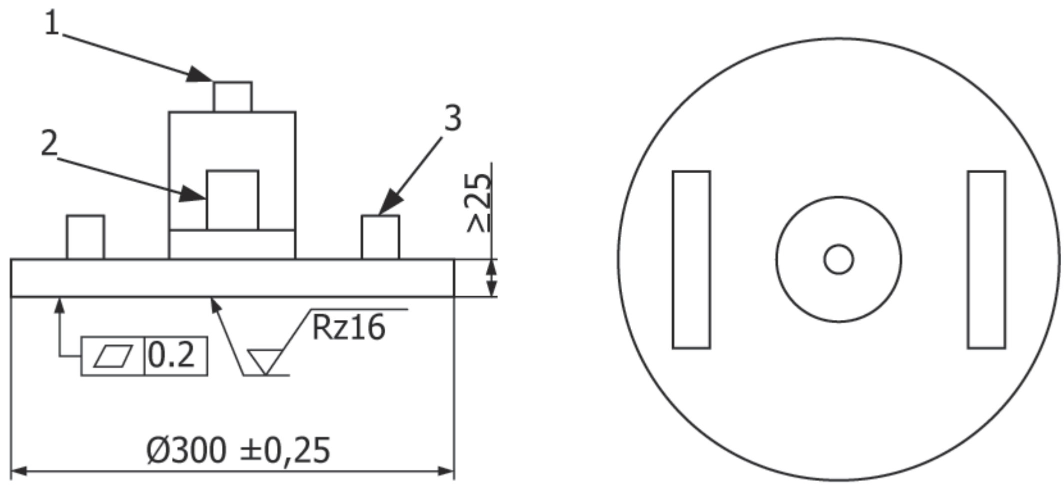
6.3.7.2 For the pressure to be properly applied, the hydraulic jack shall be hinged on both sides and secured against tilting. The pressure piston shall act through at least 150 mm.

6.3.7.3 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.

6.3.8 *Force-Measuring Apparatus:*

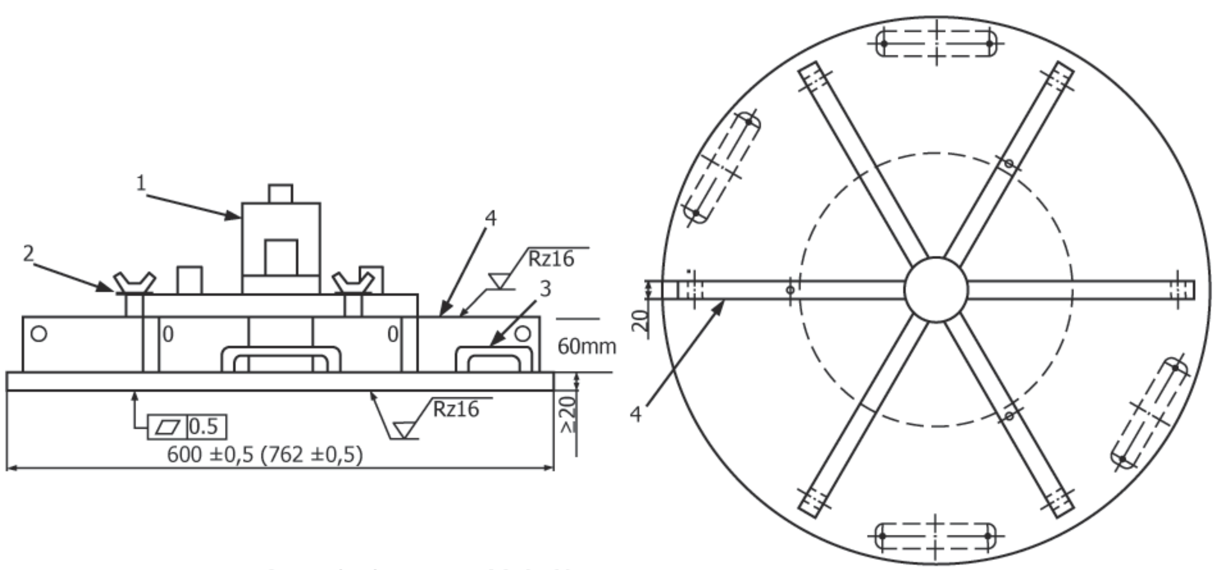
6.3.8.1 A mechanical or electrical force transducer shall be fitted between the loading plate and the hydraulic jack. It shall

FIG. 2 Digital System Configuration



Dimensions in mm, General tolerances: ISO 2769-mL
Key
1 – Centering pin to hold the force transducer
2 – Measuring tunnel
3 – Handles

FIG. 4 300 mm Loading Plate with Measuring Tunnel



Dimensions in mm, General tolerances: ISO 2769-mL
Key
1 – 300 mm loading plate
2 – Centering pins and clamps
3 – Handles
4 – Stiffeners

FIG. 5 Loading Plate 600 mm or 762 mm in Diameter with Equally Distributed Stiffeners

measure the load on the plate with a maximum permissible error of 1 % of the maximum test load.

6.3.8.2 The stress shall be indicated at a resolution of at least 0.0001 MPa 762 mm loading plates.

6.3.8.3 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.

6.3.9 *Settlement-Measuring Device:*

6.3.9.1 The arrangement in Fig. 6 shows a settlement-measuring device with a rotatable contact arm (see Fig. 6(a)) and one with a contact arm capable of being moved horizontally in axial direction (that is, with a slide bearing, see Fig. 6(b)) or direct measurement with gauge (Fig. 6(1b)) in the middle of the plate.

6.3.9.2 The measuring device with a rotatable contact arm is only suitable for tests in excavations up to 0.3 m deep. The

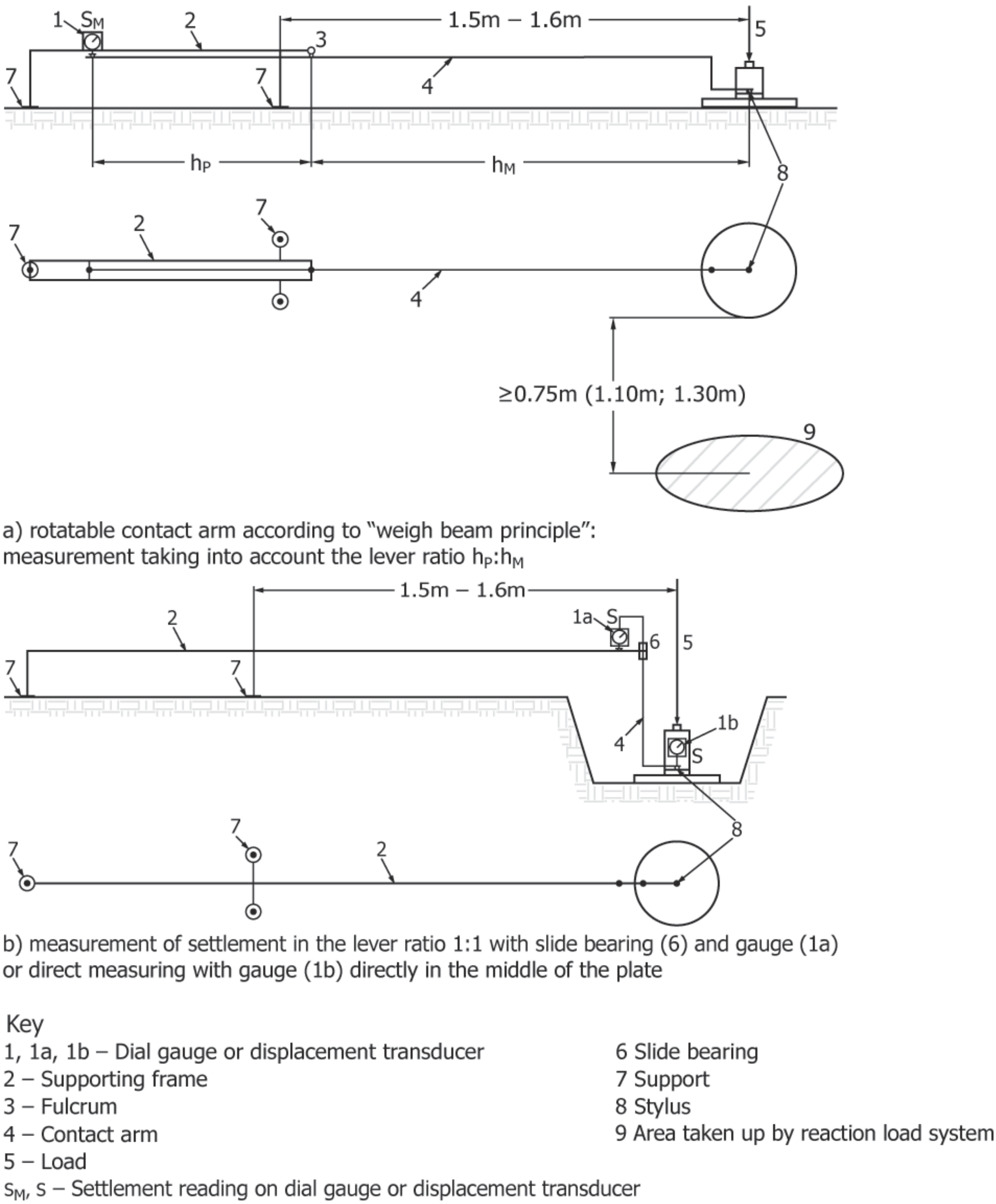


FIG. 6 Examples of Settlement-Measuring Devices (dimensions in meters)

measuring device with a contact arm capable of being moved horizontally in axial direction—or direct measuring—can also be used in deeper excavations.

6.3.10 The settlement-measuring device consists of:

6.3.10.1 A frame supported at three points (see "2" in Fig. 6).

6.3.10.2 A vertically adjustable, torsion-proof, rigid contact arm (see "4" in Fig. 6), a displacement transducer, or dial gauge (see "1," "1a," or "1b" in Fig. 6).

6.3.10.3 The distance from the center of the loading plate to the centerline of the support shall be at least 1.5 m and shall not be greater than 1.6 m (see Fig. 6).

6.3.10.4 The h_p:h_M ratio (see Fig. 6(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.

6.3.10.5 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 loading plate, and in the measuring range up to 15 mm when using a 762 mm loading plate.

6.3.10.6 The indication shall have a resolution of at least 0.01 mm.

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

7. Hazards

7.1 The loading device should be secured to avoid movement during the test.

7.2 Operators should wear head protection when working under and around the loading device during the assembly/disassembly of the apparatus and performing the test.

7.3 The operator should avoid placing their hands between the loading device and the hydraulic jack assembly.

7.4 Use proper lifting techniques when moving base plates and transport cases to avoid back injury.

7.5 De-energize the hydraulic jack and piston prior to disassembling the testing apparatus.

8. Preparation of Apparatus

8.1 The following procedure shall be used to set up the apparatus for manually collecting data while performing the nonrepetitive static plate load test to determine bearing strength. For performing tests related to highway pavements, either the 300 mm or 762 mm diameter loading plates may be used. Only the 762 mm diameter loading plate shall be used for performing airport and airfield pavements tests.

8.1.1 *Preparation of Test Area*—Strip an area of the soil to be tested to the proposed elevation of the subgrade surface. The stripped area should be at least twice the diameter of the plates to eliminate surcharge or confining effects. If the subgrade is to be composed of fill material, construct a test embankment at least 762 mm [30 in.] in height using the proposed fill material compacted to the moisture content and density that will be required during construction. Clear the area to be tested of any loose materials and make it level. Care should be taken not to disturb the soil in the test area, especially in granular material (CRD-C 655-95).

8.1.2 Carefully center a bearing plate of the selected diameter under the jack assembly. Set the remaining plates of smaller diameter concentric with, and on top of, the bearing plate.

8.1.3 The loading plate shall lie on, and be in full contact with, the test surface. If necessary, make a thin bed (that is, only a few millimeters in thickness) of a mixture of sand and gypsum plaster, of gypsum plaster alone, or of fine sand, using the least quantity of materials required for uniform bearing. 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 gypsum plaster shall be removed with the spatula before it sets. Testing shall not begin until the gypsum plaster has set.

8.1.4 To prevent loss of moisture from the subgrade during the load test, cover the exposed subgrade to a distance of 2.0 m [6 ft] (AASHTO T 222) from the circumference of the bearing plate with a tarpaulin or waterproof paper.

8.1.5 Where unconfined load tests are to be made at a depth below the surface, remove the surrounding material to provide a clearance equal to twice (AASHTO T 222 and CRD-C 655-95) the bearing plate diameters from the edge of the bearing plate. For confined tests, the diameter of the excavated circular area shall be just sufficient to accommodate the selected bearing plate.

8.1.6 Use a sufficient number of dial gauges, so located and fixed in position as to indicate the average deflection of the bearing plate. The three gauges shall be set at an angle of 120° from each other, and equidistant from the circumference of the bearing plate, and near each extremity of a diameter of the bearing plate, 25.4 mm [1 in.] from the circumference.

8.2 The following procedure shall be used to set up the apparatus for automatically collecting data while performing the nonrepetitive static plate load test with digital instrumentation to determine bearing strength.

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

8.2.2 The loading plate shall lie on, and be in full contact with, the test surface. If necessary, make a thin bed (that is, only a few millimeters in thickness) of a mixture of sand and gypsum plaster, of gypsum plaster alone, or of fine sand, using the least quantity of materials required for uniform bearing. 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 gypsum plaster shall be removed with the spatula before it sets. Testing shall not begin until the gypsum plaster has set.

8.2.3 To prevent loss of moisture from the subgrade during the load test, cover the exposed subgrade to a distance of 2.0 m [6 ft] (AASHTO T 222) from the circumference of the bearing plate with a tarpaulin or waterproof paper.

8.2.4 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 the loading plate and contact area of the reaction load shall be 0.75 m for a 300 mm plate and 1.30 m for a 762 mm plate (see Fig. 6(a)).

8.2.5 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.

8.2.6 Measurement of settlement shall be carried out using a displacement transducer.

8.2.7 In order to measure settlement, the stylus or displacement transducer (see Fig. 6) shall be placed in the center 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 transducer shall be set up so as to be vertical (see Fig. 6(a) and Fig. 6(b)).

8.2.8 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.

8.2.9 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.

9. Calibration and Standardization

9.1 Load cells, displacement transducers, analog or digital gauges, and pressure gauges that make up the plate loading apparatus shall be calibrated before delivery or after repairs.

9.2 Calibration of the components should be performed once a year.

10. Conditioning

10.1 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.

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

10.3 For fine-grained soil (for example, silt, clay), the plate load test can only be carried out and evaluated satisfactorily if the soil is relatively stiff or firm in consistency. In case of doubt, the consistency of the soil under the test can be checked with a small adjacent test pit at various depths up to a depth, *d*, below ground level (*d* = diameter of loading plate).

11. Procedure

11.1 The following procedure is presented for performing the nonrepetitive static plate load test to determine bearing strength.

11.2 Use one of the following initial procedures:

11.2.1 *Seating Procedure No. 1 (CRD-C 655-95)*—Only use this procedure for airport/airfield pavement tests. Seat the loading system and bearing plate by applying a load of 6.9 kPa [1 psi] when the design thickness of the pavement will be less than 380 mm [15 in.] or a load of 13.8 kPa [2 psi] when the design thickness of the pavement is 380 mm [15 in.] or more. Allow the seating load to remain in place until practically complete deformation has taken place. Then take a reading which will be used as the "zero" reading. The seating load is also considered to be the "zero" load. Cyclic loading under the seating load may be used to ensure good seating of the apparatus and bearing plate.

11.2.2 *Seating Procedure No. 2 (AASHTO T 222)*—Only use this procedure for highway pavement tests. After the equipment has been properly arranged, with all of the dead load (jacks, plates, etc.) acting, seat the bearing plate and assembly by the quick application and release of a load sufficient to produce a deflection of not less than 0.25 mm [0.01 in.] or more than 0.50 mm [0.02 in.]. When the dial needles or transducer come to rest following release of this load, reseat the plate by applying one half of the recorded load producing the 0.25 to 0.50 mm [0.01 to 0.02 in.] deflection. When the dial needles or transducer have then again come to rest, set each dial or transducer accurately at its zero mark.

11.3 Without releasing the seating load, Load Application Procedure No. 1 or 2 shall then be followed:

11.3.1 *Load Application Procedure No. 1 (AASHTO T 222)*—Only use this procedure for highway pavement tests. Apply loads at a moderately rapid rate in uniform increments. The magnitude of each load increment shall be small enough to permit the recording of a sufficient number of load-deflection points to produce an accurate load-deflection curve (not less than six). After each increment of load has been applied, allow its action to continue until a rate of deflection of not more than 0.02 mm/min [0.001 in./min] has been maintained for 3 consecutive min. Record load and deflection readings for each load increment. Continue this procedure until the selected total deflection has been obtained, or until the load capacity of the apparatus has been reached, whichever occurs first. At this point, maintain the load until an increased deflection of not more than 0.02 mm/min [0.001 in./min] for 3 consecutive min occurs. Record the total deflection, after which release the load to that at which the dial gauges were set at zero, and maintain the zero-setting load until the rate of recovery does not exceed 0.02 mm [0.001 in.] for 3 consecutive min. Record the deflection at the zero-setting load. Each individual set of readings shall be averaged, and this value is recorded as the average settlement reading.

11.3.2 *Load Application Procedure No. 2 (CRD-C 655-95)*—Only use this procedure for airport/airfield pavement tests. Apply two load increments of 34.5 kPa [5 psi] each with load increment being held until deformation averages less than 0.02 mm/min [0.001 in./min] for 10 consecutive minutes. Read all three dial gauges at the end of each load increment. Following the completion of the 69.0 kPa [10 psi] load increment, determine the average deflection by averaging the total movement between the "zero" and 69.0 kPa [10 psi] increment.

11.3.3 Compute a value of k'_u (uncorrected modulus of soil reaction) using the following formula:

$$k'_u = \frac{69.0 \text{ kPa } [10 \text{ psi}]}{\text{average deflection}} \quad (1)$$

11.3.4 The k-formula applies to both load application procedures 1 and 2. If the value of k'_u is less than 54.3 kPa/mm [200 psi/in.], typically occurring with non-cohesive material, the test is considered complete and the load may be released. Should the value of k'_u be 54.3 kPa/mm [200 psi/in.] or greater, typically occurring with cohesive material, apply load increments of 34.5 kPa [5 psi] until a total load of 207 kPa [30 psi] is reached, allowing each load increment to remain until the deformation averages less than 0.02 mm/min [0.001 in./min] for 10 consecutive min.

11.4 Obtain an undisturbed sample of the foundation material for laboratory testing to determine the saturation correction to apply to the field test value. The undisturbed sample must be large enough to obtain two consolidometer specimens side by side (that is, at the same elevation). Take the sample in a container suitable for sealing to preserve the moisture content until the laboratory correction tests can be performed. When the plate-bearing test is performed directly on cohesive subgrade material, obtain the undisturbed specimen from the foundation at the same elevation at which the test is performed, but alongside rather than under the plates. When the test is performed on a granular base course material that is underlaid by a cohesive material, and when the base course is less than 1.9 m [75 in.] in thickness, take the undisturbed sample from the cohesive material at the bottom of the base course.

11.5 From a thermometer suspended near the bearing plate, read and record the air temperature at half-hour intervals.

12. Calculation or Interpretation of Results

12.1 When the k'_u value, as computed in 11.3.3, is less than 54.3 kPa/mm [200 psi/in.], load-deformation curves need not be prepared. However, when the k'_u value is 54.3 kPa/mm [200 psi/in.] or greater, it is necessary to plot the load-deformation curve and correct the curve for such things as poor seating of the plates, nonlinear load-deformation relations, or shear failure; the unit load (kPa [lb/in.^{2}]) on the plate is plotted versus the deflection (average deflection if multiple dial gauges are used) for each load increment. The deflection is the readings between the "zero" and the end of each load increment. If averaging dial gauge readings, the data should be carefully examined to ensure that a reasonable average is being computed. If the load-deformation relation does not plot a straight line passing through the origin, the curve is corrected as shown in Fig. 7. Generally, the load-deformation curve will approximate a straight line between the unit loads of 69.0 and 207 kPa [10 and 30 psi]. The correction consists of drawing a straight line, parallel to the straight-line portion of the plotted curve, through the origin. When correcting the load-deformation curve, good engineering judgment will be required. If the curve is nonlinear through its length, the straight-line correction will be based on the average slope of the curve through at least three points in the region of the curve having the least curvature.

12.2 An uncorrected modulus of soil reaction k'_u kN/m^3 [lb/in.^{3}] is computed from the field test data using the formula:

$$k'_u = \frac{69.0\ \text{kPa}\ [10\ \text{psi}]}{\text{average deflection}} \quad (2)$$

12.3 When a load deformation curve is unnecessary, as outlined in 12.1, the deflection (average deflection if multiple dial gauges are used) is recorded between the "zero" and the completion of the load increment. If the load deformation curve is required, the average deflection is read from the corrected curve as a load of 69.0 kPa [10 psi]. The value of k'_u computed from the above formula must then be corrected for bending of the bearing plates and saturation of the soil as follows:

12.3.1 There is a certain amount of bending in the bearing plates, even when a nest of plates is used. If the deflection is measured from the center of the plate with a digital transducer, then no correction is needed for plate bending. The bending results in a greater deflection at the center of the plate than at the rim where the deflections are measured by dial gauges. Because the modulus of soil reaction is actually a measurement of volume displacement under load, the lower deflection measured at the rim results in a value higher than actually exists. The amount of plate bending is related only to the strength of the soil being tested. Hence, for any one k'_u value, the correction to be made is always the same. This correction has been determined by test and is shown by the curve in Fig. 8. The correction of k' is made by entering the plot in Fig. 8 with the computed value of k'_u on the ordinate and projecting horizontally to the intersection of the plotted curve. The corrected value for the modulus of soil reaction (k'_u) is then determined by projecting vertically to the abscissa of the plot and reading the value.

12.3.2 The design of pavement is generally based on the modulus of soil reaction when the soil is saturated. It is not feasible to saturate the soil in the field prior to the field test, and seldom will the soil be in a saturated condition in its natural state. Therefore, the field test value must be corrected to reflect the value that will be obtained when the soil becomes saturated. Saturation correction is not normally required when evaluating pavements older than three years. Cohesionless soils are insensitive to saturation, and when the field test is performed on this type soil, the correction for saturation is not necessary. The most applicable method for correcting for saturation is through an adaption of the consolidation test. The correction test will be made on undisturbed specimens of the soil from the location of the field test. For the case where a field test is performed on the surface of a cohesionless base course material but which is underlain by a cohesive soil, the saturation correction will be determined by tests on the underlying cohesive material.

12.3.2.1 The saturation correction factor is the ratio of the deformation of the consolidation specimen at the natural moisture content to the deformation in a saturated specimen under a 69.0 kPa [10 psi] loading. Two specimens of the undisturbed material are placed in a consolidometer. One specimen will be tested at the *in situ* moisture content, and the other specimen will be saturated after the seating load has been applied. Each specimen is then subjected to the same seating load (6.9 or 13.8 kPa [1 or 2 psi]) that was used for the field test (see 11.2.1 or 11.2.2). The seating load is allowed to remain on the *in situ* moisture content specimen until all deformation occurs, at which time a "zero" reading is taken on the vertical deformation dial. Without releasing the seating load, an additional 69.0 kPa [10 psi] load is applied to the specimen and allowed to remain until all deformation has occurred. A final reading is then taken on the vertical deformation dial.

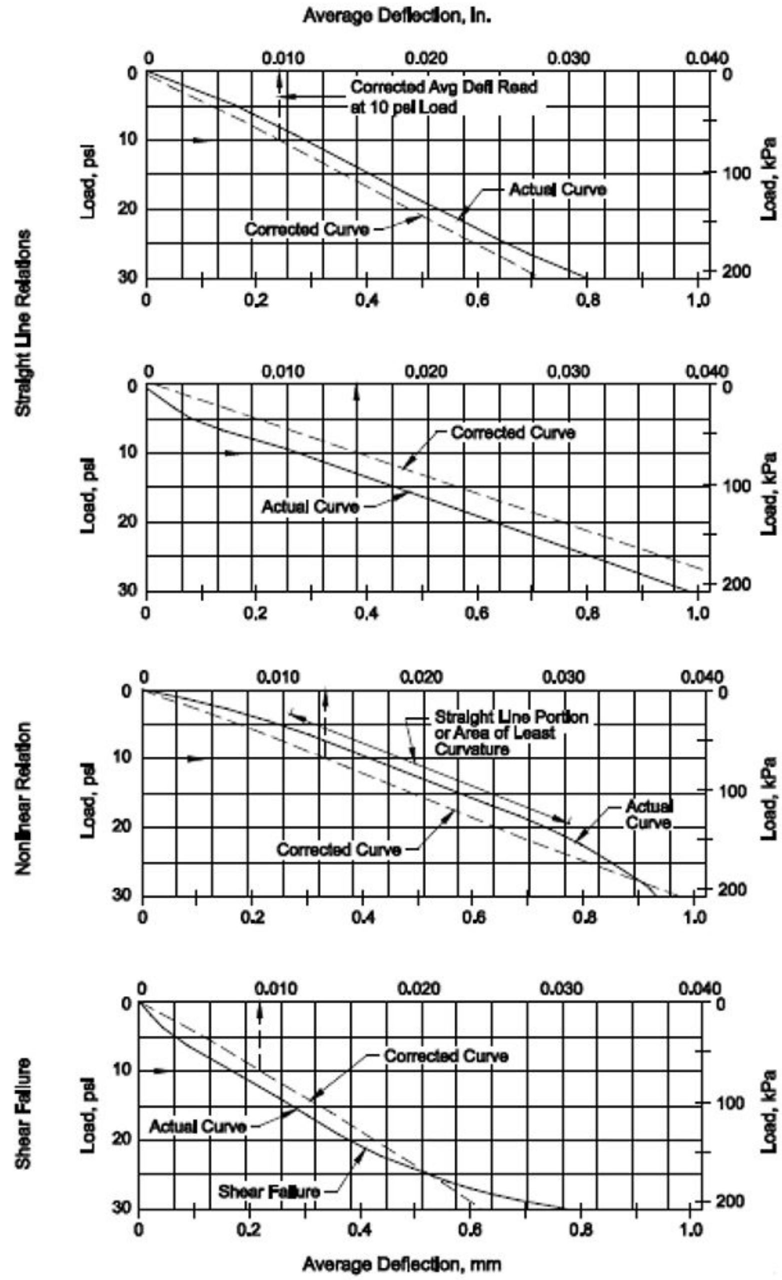


FIG. 7 Correction of Load-Deformation Curve

12.3.2.2 The other specimen is allowed to soak in the consolidometer under the seating load (6.9 or 13.8 kPa [1 or 2 psi]). After the specimen is saturated, a "zero" dial reading is obtained; then, without releasing the seating load, an additional 69.0 kPa [10 psi] load is applied. This load is allowed to remain on the specimen until all vertical deformation has occurred, after which a final reading on the dial is obtained. For soils of certain types, the specimen may swell under the seating load as it becomes saturated. Swelling of the material will result in extrusion of material above the top of the consolidometer ring, so that when the 69.0 kPa [10 psi] load is applied, the material may squeeze out over the ring rather than consolidate, which will lead to erroneous results. To prevent this, when dealing with a swelling-type soil or one that is suspected of being a swelling-type soil, the consolidometer ring will not be completely filled with soil. This can be accomplished by trimming the top of the specimen a sufficient amount, generally 1.6 mm [0.0625 in.], to allow for the swelling. When the specimen for saturation is trimmed to allow for swelling, the specimen to be tested at the *in situ* moisture content will also be trimmed an equal amount so that the heights of the specimens will be equal at the beginning of the test.

12.3.2.3 The correction for saturation will be applied in proportion to the deformation of the two specimens under a unit load of 69.0 kPa [10 psi] as follows:

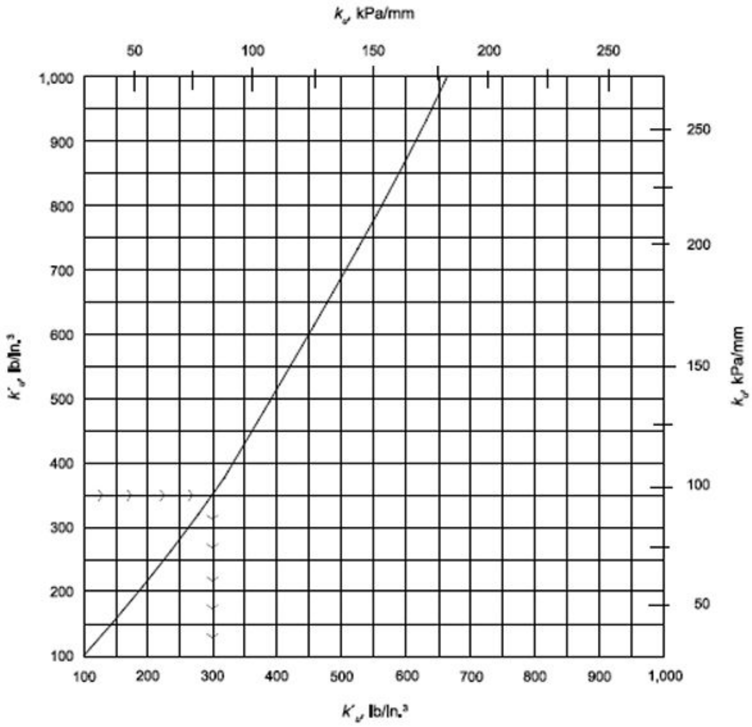


FIG. 8 Correction of k'$_u$ for Bending of the Plate

SI Units:

$$K = k_u\left[\frac{d}{d_s} + \frac{b}{1905}\left(1 - \frac{d}{d_s}\right)\right] \quad (3)$$

U.S. Customary Units:

$$K = k_u\left[\frac{d}{d_s} + \frac{b}{75}\left(1 - \frac{d}{d_s}\right)\right] \quad (4)$$

where:

k = corrected modulus of soil reaction, kPa [psi],
k_u = modulus of soil reaction uncorrected for saturation, kPa [psi],
d = deformation (mm [in.]) of a consolidometer specimen at *in situ* moisture content under a unit load of 69.0 kPa [10 psi],
d_s = deformation (mm [in.]) of saturated consolidometer specimen under a unit load of 69.0 kPa [10 psi], and
b = thickness of base course material (mm [in.]).

13. Report

13.1 In addition to the continuous listing of all load, deflection, and temperature data, a record shall also be made of all associated conditions and observations pertaining to the test including the following:

13.1.1 Date.
13.1.2 Time of beginning and completion of test.
13.1.3 List of personnel.
13.1.4 Weather conditions.
13.1.5 Any irregularity in routine procedure.
13.1.6 Any unusual conditions observed at the test site.
13.1.7 Any unusual observations made during the test.
13.1.8 Location of test site.
13.1.9 Diameter of the loading plates.
13.1.10 Seating procedure (1 or 2).
13.1.11 Loading application procedure (1 or 2).
13.1.12 Type of settlement-measuring device used, including lever ratio, if relevant.
13.1.13 Type of soil.
13.1.14 Type of bedding material below the plate.
13.1.15 Settlement readings and corresponding normal stresses; load-settlement curves.
13.1.16 Description of the soil conditions below the plate after testing.
13.1.17 Uncorrected subgrade modulus (K_u).
13.1.18 Correction factors:
(1) Load deformation.
(2) Plate bending.
(3) Saturation.
13.1.19 Corrected subgrade modulus (K).

14. Precision and Bias

14.1 The precision and bias of this test method for making nonrepetitive static plate load tests on subgrade soils and flexible pavement components has not been determined. Soils and flexible pavement components at the same location may exhibit significantly different load deflection relationships. No method presently exists to evaluate the precision of a group of nonrepetitive plate load tests on soils and flexible pavement components because of the variability of these materials. The subcommittee is seeking pertinent data from users of this test method that may be used to develop meaningful statements of precision and bias.

15. Keywords

15.1 bearing capacity; bearing plate; deflection; pavements; plate load tests

ANNEX

(Mandatory Information)

A1. CALIBRATION OF PLATE LOADING APPARATUS

A1.1 General

A1.1.1 The plate loading apparatus is calibrated to verify its proper functioning and to ensure compliance of the loading and settlement-measuring devices with requirements.

A1.1.2 Calibration shall be carried out by a body that uses instruments with certified traceability.

A1.1.3 Calibration of the plate loading apparatus shall be repeated at regular intervals to ensure performance of the loading test in accordance with this standard.

A1.1.4 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.

A1.1.5 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.

A1.2 Check of Plate Loading Apparatus for Compliance with Requirements

A1.2.1 It shall be checked whether the plate loading apparatus fulfills the requirements regarding:

A1.2.1.1 Dimensions of loading plate (see 6.3.4 – 6.3.6).

A1.2.1.2 Indication (limit of error) and resolution of the force-measuring system (see 6.3.8).

A1.2.1.3 Indication (limit of error) and resolution of the settlement-measuring device (see 6.3.10.5 and 6.3.10.6).

A1.2.1.4 Distance between center of loading plate and centerline of support of contact arm assembly (see 6.3.10.3).

A1.2.1.5 Lever ratio of settlement-measuring device (see 6.3.10.4).

A1.3 Apparatus and Equipment Used for Calibration and Functional Testing

A1.3.1 *Force-Measuring System*—The following is required for calibration of the force-measuring system:

A1.3.1.1 Frame for mounting the force-measuring system of the plate loading apparatus.

A1.3.1.2 Class 2 reference compressive force transducer including a measurement amplifier.

A1.3.1.3 Apparatus as in 6.3.1, 6.3.7, and 6.3.8.

A1.3.2 *Settlement-Measuring Device*—The following is required for calibration of the settlement-measuring device as in 6.3.9:

A1.3.2.1 Micrometer or gauge blocks with nominal lengths from 1 mm to 15 mm.

A1.3.2.2 Surface suitable to receive calibration equipment.

A1.3.2.3 The complete settlement-measuring device.

A1.4 Calibration and Functional Test

A1.4.1 *Force-Measuring System:*

A1.4.1.1 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 MPa or 0.001 MPa (first loading stage, Table A1.1). The load shall be applied using the loading system of the plate loading apparatus requiring calibration.

A1.4.1.2 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 A1.1). Each increase/decrease in load from

TABLE A1.1 Loading Stages as a Function of the Loading Plate Diameter

Loading Stage Number	Diameters of Loading Plates					
	300 mm		600 mm		762 mm	
	Load, *F* kN	Normal Stress, a_0 MPa	Load, *F* kN	Normal Stress, a_0 MPa	Load, *F* kN	Normal Stress, a_0 MPa
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

stage to stage shall be completed within 1 min. The load shall be released in four stages (Nos. 6, 4, 2, and 1 according to Table A1.1). Whether loading or unloading, the interval between the end of one stage and the start of the next shall be 2 min, 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.

A1.4.1.3 Calibration shall be carried out at an ambient temperature between 10 °C and 35 °C. The error of measurement in the indication, q, in %, is calculated as in Eq A1.1 in relation to F_{max}:

$$q = \frac{F_i - F}{F_{max}} \cdot 100 \quad \text{(A1.1)}$$

where:

F_i = force indicated on the force-measuring system, kN,
F = force indicated on the reference compressive force transducer, kN, and
F_{max} = maximum load required for the plate-loading test, kN (Loading Stage No. 8 according to Table A1.1).

A1.4.1.4 The limit of error of the force-measuring system (that is, 1 % of the maximum load in the plate load test in accordance with 6.3.8.1) shall not be exceeded.

A1.4.1.5 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.

A1.4.1.6 The zero error shall not exceed 0.2 % of F_{max} 1 min after the load has been completely removed.

A1.4.2 *Settlement-Measuring Device:*

A1.4.2.1 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.

A1.4.2.2 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.

A1.4.2.3 The travelling distance for the calibration of the sensing device shall be 0.5 mm.

A1.4.2.4 The readings of the settlement-measuring device for each of the three-measurement series shall be recorded in the calibration report.

A1.4.2.5 Calibration shall be carried out at an ambient temperature between 10 °C and 35 °C. The ambient temperature at which the calibration is carried out shall be recorded.

A1.4.2.6 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.

A1.4.2.7 When using plate loading apparatus with a settlement-measuring device based on the "weigh beam principle," the lever ratio h_p:h_M shall be taken into account.

A1.5 Calibration Report Contents

A1.5.1 The calibration report shall include the following information:

A1.5.1.1 Applicant.

A1.5.1.2 Manufacturer of apparatus.

A1.5.1.3 Type of apparatus.

A1.5.1.4 Apparatus identification number.

A1.5.1.5 Year of manufacture.

A1.5.1.6 Ambient temperature during calibration.

A1.5.1.7 Date of calibration.

A1.5.1.8 Name of calibration body and person(s) responsible for calibration.

A1.5.1.9 Reference instruments used, with traceability certificates.

A1.5.1.10 General condition of plate loading apparatus on delivery.

A1.5.1.11 Deviations of loading plate and contact arm dimensions from specified dimensions.

A1.5.1.12 Information on the lever ratio of the settlement-measuring device.

A1.5.1.13 Deviations of the actual readings on the force-measuring device from the target values, in %.

A1.5.1.14 Deviations of the actual readings on the settlement-measuring device from the target values, in mm.

A1.5.1.15 Calibration results (test result).