# British Standard

BRITISH STANDARD

**BS EN 61773:1997**
**IEC 61773: 1996**
*Including Corrigendum March 1997*

# Overhead lines — Testing of foundations for structures

The European Standard EN 61773:1996 has the status of a British Standard

ICS 29.240.20

# National foreword

This British Standard is the English language version of EN 61773:1996. It is identical with IEC 61773:1996 including Corrigendum March 1997.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by a side line in the margin.

The UK participation in its preparation was entrusted to Technical Committee PEL/11, Overhead lines, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

**Cross-references**

Attention is drawn to the fact that CEN and CENELEC Standards normally include an annex which lists normative references to international publications with their corresponding European publications. The British Standards which implement these international or European publications may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

**Summary of pages**

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 38, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

This British Standard, having been prepared under the direction of the Electrotechnical Sector Board, was published under the authority of the Standards Board and comes into effect on 15 December 1997



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**Amendments issued since publication**

| Amd. No. | Date | Comments |
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# Contents

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

# EN 61773

December 1996

ICS 29.240.20

Descriptors: Overhead lines, foundations for structures, soil investigation, beam, pile

English version

# Overhead lines
# Testing of foundations for structures

(IEC 1773:1996)

Lignes aériennes — Essais de fondations des supports
(CEI 1773:1996)

Freileitungen — Prüfung von Gründungen für Bauwerke
(IEC 1773:1996)

This European Standard was approved by CENELEC on 1996-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

**CENELEC**

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

**Central Secretariat: rue de Stassart 35, B-1050 Brussels**



Ref. No. EN 61773:1996 E

## Foreword

The text of document 11/111/FDIS, future edition 1 of IEC 1773, prepared by IEC TC 11, Recommendations for overhead lines, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61773 on 1996-10-01.

The following dates were fixed:

- — latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1997-08-01
- — latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1997-08-01

Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, Annex ZA is normative and Annex A, Annex B, Annex C, Annex D, Annex E and Annex F are informative. Annex ZA has been added by CENELEC.

## Endorsement notice

The text of the International Standard IEC 1773:1996 was approved by CENELEC as a European Standard without any modification.

## Contents

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## 1 Scope and object

This International Standard is applicable to the testing procedures for foundations of overhead line structures. This standard distinguishes between:

a) foundations predominantly loaded by axial forces, either in uplift or compression, acting in the direction of the foundation central axis. This applies to foundations of rigid lattice towers with typical individual footings, that is concrete pad and chimney foundations, steel grillages, concrete piers, piles and grouted anchors. Guy (stay) foundations are included when they are tested in line with their true guy inclinations;

b) foundations predominantly loaded by lateral forces, overturning moments, or a combination of both. This applies to single poles with typical compact foundations, for example monoblock foundations, concrete slabs, concrete piers, piles and poles directly embedded in the ground. It may also apply to H-frame structure foundations for which the predominant loads are lateral forces, overturning moments, or a combination of both;

c) foundations loaded by a combination of forces mentioned under a) and b).

Tests on reduced scale or model foundations are not included. However, they may be useful for design purposes.

Dynamic foundation testing is excluded from the scope of this document.

The object of this standard is to provide procedures which apply to the investigation of the load-carrying capacity and/or the load response (deflection or rotation) of the total foundation as an interaction between the foundation and the surrounding soil and/or rock. The mechanical strength of the structural components is not within the object of this standard. However, in the case of grouted anchors, the failure of structural components, for example the bond between anchor rod and grout, may predominate.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(466):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 466: Overhead lines.*

IEC 826:1991, *Loading and strength of overhead transmission lines.*

## 3 Definitions

For the purpose of this International Standard, the following definitions apply. The definitions listed below supplement those given in IEC 50(466).

**3.1**
**characteristic strength**

the value guaranteed in appropriate standards. This value is also called the guaranteed strength, the minimum strength, the minimum failing load or the nominal strength and usually corresponds to an exclusion limit, from 2 % to 5 %, with 10 % being, in practice, the upper limit (IEC 826, **1.2.1**)

**3.2**
**damage or serviceability limit load**

the load corresponding to the strength limit of the foundation, which, if exceeded, will lead to damage and noticeable deformation or reduction in strength of the supported structure. The damage load is normally related to displacement criteria and may also be known as the serviceability limit load

NOTE When applying this standard to testing foundations which are designed using deterministic loading criteria, reference to this term may be necessary.

**3.3**
**design load**

the limit load or factored working load or the load derived with respect to a specific return period of a climatical event, for which the foundation has been designed

**3.4**
**failure load**

the maximum load which can be applied during testing. It is also known as the limit state failure load and is usually associated with displacements leading to failure of the structure

**3.5**
**maximum proof load**

the maximum load applied to the foundation tested during a proof test

**3.6**
**test report**

final document summarizing the results of investigations and foundation tests

**3.7**
**working load**

the maximum load likely to be experienced by the foundation under normal working conditions, during the life of the line, with no overload factors included

NOTE The term working load does not apply to limit states design methods and is not compatible with IEC 826. However, when applying this standard to testing foundations which are designed using deterministic loading criteria, reference to this term may be necessary.

## 4 Categories of tests

With respect to the purpose of the test, the level of investigation and the method of execution, this standard refers to two categories of tests:

a) design tests;

b) proof tests.

### 4.1 Design tests

Design tests are normally carried out on specially installed foundations, with one or more of the following objectives:

a) to verify design parameters or methodologies;

b) to verify construction procedures;

c) to establish geotechnical design parameters and/or a design methodology for a specific application;

d) to verify compliance of foundation design with specifications;

e) to determine the average failure load and coefficient of variation of the design type in specified soil conditions.

Tests according to c) and/or d) are also known as type tests.

#### 4.1.1 *Full scale tests*

Design tests should preferably be carried out with full scale units. When tests are carried out to verify design parameters, the test foundation shall be as identical as possible to those proposed for production (see **6.1**).

Design tests are carried out to at least the design load or to failure, especially when testing according to **4.1** c) and/or **4.1** d), using limit state design. Limitations of displacements, deflection or rotation under load shall be considered where applicable. The level of instrumentation and of investigation should be appropriate for the purpose of the test.

#### 4.1.2 *Reduced scale tests*

In the case of large dimension foundations, it might be impractical to undertake design tests on a full size foundation. Design tests on smaller dimension test foundations may be considered, subject to the following conditions:

a) the test foundation is installed using the same techniques and materials as the production foundation;

b) where necessary, the test foundation is instrumented in such a manner that the base and shaft resistances can be derived separately;

c) for foundation types where the capacity is determined by lateral friction, the ratio of the test foundation lateral dimensions to the production foundation lateral dimensions is not less than 0,5. The depths should be equal.

Evaluation of reduced scale tests shall be carried out with great caution, unless the load capacity is based entirely on skin friction (for example piles, caissons or grouted anchors). Great care shall be taken with area/depth ratios and their absolute values.

### 4.2 Proof tests

These are intended for use during the installation of production foundations to act as a check on the quality of the installation, on the materials being used, and on the absence of any major variations in the assumed geotechnical design parameters. Proof tests may also be carried out on foundations installed in heterogeneous soil conditions where a wide variation in the foundation load-resistance capacity may be expected. Consistency, speed, economy and effectiveness are the key considerations.

Proof tests are taken to a specific percentage of the design load (usually 60 % to 75 %), as stipulated in the contract, but may not exceed the serviceability limit load. Limitations of the displacement shall be considered. The level of instrumentation and investigation may be low, but the reliability of the equipment and procedure shall be high.

Dynamic testing of piles after suitable calibration of the test equipment with design tests may also be used for proof testing.

Typically, proof tests are carried out on foundations installed for structures of a specific line. The foundations shall be fully serviceable after successfully passing the tests.

## 5 Geotechnical data

### 5.1 General

An initial soil investigation should be completed prior to the selection of a design test site. A preconstruction soil investigation may be eliminated, either where the geotechnical parameters are based on data derived during the actual installation (for example rock anchors), or where proof tests are used to check installation criteria. However, in this case records should be kept of previous soil investigations and of any assumptions made prior to or during the construction of the foundations.

Procedures for detailed soil investigations are beyond the scope of this standard. However, some general criteria, basic requirements and methods are included in Annex B. This standard provides only general criteria for soil investigations of test sites. For details, reference should be made to the appropriate international or national standards and/or to recognized codes of practice (for example [1][1)]).

### 5.2 Soil investigation results

The results of the soil investigation and any subsequent laboratory testing shall be accurately recorded, together with a sketch map of the site showing all the pertinent physical and geological features.

### 5.3 Geotechnical design parameters

The geotechnical parameters used in the design of the foundations being tested, together with the method used to calculate these values, either from laboratory tests or from empirical considerations, shall be recorded.

### 5.4 Soil conditions during foundation installation

During the installation of any test foundation, the following information shall be recorded:

a) visual description, including weathering, discontinuities, etc. of each soil/rock stratum and corresponding soil/rock classification;

b) ground water level;

c) any local soil/rock phenomena experienced during construction, for example side instability, bottom heave, water ingress, etc.;

d) relevant meteorological data.

If the foundations are backfilled, the physical and geotechnical properties of the backfill should be established by using field and/or laboratory tests. Details of the method used for backfilling and compaction should be recorded.

## 6 Foundation installation

### 6.1 General

Proof tests are conducted on production foundations. Therefore, there should be no difference between the foundations tested and those not subjected to tests. Design tests are generally carried out on specially installed foundations which shall be constructed using the specified materials, to dimensions as close as possible to those required by the design.

### 6.2 Variations on foundations for design tests

For design tests, the following variations may be considered:

a) The connection (for example the stub or reinforcing steel) between the foundation and the test apparatus may require modifications to ensure adequate strength when, and if, the foundation is stressed to loads approaching or in excess of its design load. In this case, the connection should have a minimum strength of 1,5 times the maximum test load during the design test. Any such modification shall not intrinsically alter the designed behaviour of the foundation in the ground, for example the lateral stiffness of long, slender columns.

b) Due to the hip slope of the leg, production foundations might not be loaded vertically. However, the effect of inclined loading on the foundation capacity is low when the true leg slope is limited. Therefore, in order to ease foundation testing, the foundation may be modified so that its test axis is vertical, and the loads may be applied vertically where the maximum true hip slope is less than 20 % (one horizontal to five vertical, see Figure 1).

[1)] Figures in square brackets refer to the bibliography given in Annex A.

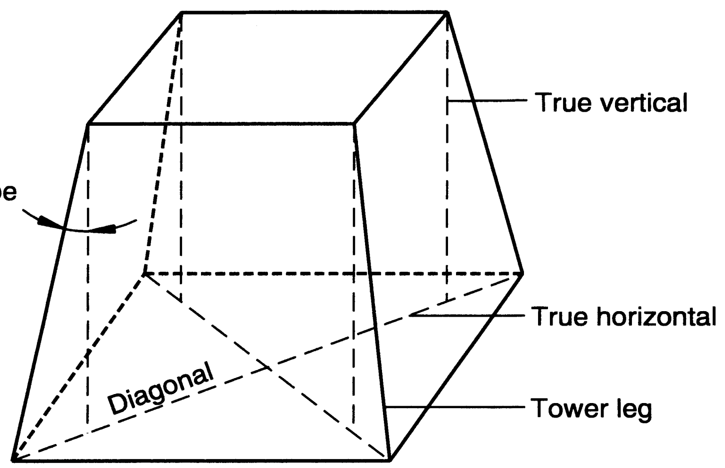



**Figure 1 — Leg slope (hip slope) for towers with the shape of a regular frustum or truncated cone**

### 6.3 Installation techniques for foundations subject to design testing

It is essential that all items which will affect the strength of the test foundations, for example method of construction and compaction of fill material, shall be equivalent to those used for the production foundations.

The techniques used for installation of the test foundations, should, where possible, be as close as is practical to those which are intended to be used on the production foundation.

If the foundation is set so that its top is some distance below ground level, for example a pile or an anchor set into the base of a buried cap, but the test foundation is extended to the ground surface for ease of testing, then the extended portion of the foundation shall be sleeved, or other precautions taken, to reduce the interaction between foundation and soil over the extended portion.

### 6.4 Installation records

In the case of foundations for design testing, all relevant details of foundation size, construction and installation shall be recorded. These records shall contain details relating both to design requirements for the foundation and to the actual data for the as-built test foundation (typical record formats are given in Annex D).

Full details of soil conditions, description of excavation walls, quality, quantity, and method of backfilling, compaction, etc., as required in **5.4**, shall be recorded.

All details shall also be accurately recorded on an appropriate sketch.

For proof testing of production foundations, it is recommended that the record formats given in Annex D be used. These formats may be simplified, depending on the type of foundation and test.

### 6.5 Minimum period of time required between installation and testing

A sufficient period of time shall elapse between the installation of the foundation and the beginning of testing, to ensure adequate strength of concrete or grout, and to permit reasonable relaxation of the strength-related properties of the soil, such as dissipation of pore pressures.

Minimum time periods between installation and testing are:

| | | Days |
|---|---|---|
| — steel grillage (from completion of backfill) | | 1 |
| — concrete components of a foundation (see note) | — reinforced | 14 |
| | — unreinforced | 28 |
| — grouted anchors (see note) (after grouting, depending on grout strength) | | 7 to 14 |
| — prefabricated piles driven in non-cohesive or free-draining soils (after driving) | | 7 |
| — prefabricated piles driven in cohesive soils (after driving) | | 21 |
| — concrete piles augered or drilled and cast *in situ* | | 14 |

NOTE A shorter time may be allowed if the concrete/grout sample strength tests have reached a value of not less than twice the maximum bearing stress to be imposed during the test. Testing of stressed anchors may be performed immediately after tensioning.

## 7 Test equipment

### 7.1 Load application

The load application mechanism shall be able to mobilize the foundation capacity, or overcome the deflection design criteria, or both. Loading arrangements should, if possible, apply axial and shear loads simultaneously where lateral loading is likely to have a significant influence on foundation capacity.

Loads may be applied by a hydraulic jack, a winch system, or another loading mechanism, as required. Motorized pumps should only be used preferably when automatic logging of foundation movement is available. The ability to maintain load can lead to sudden and rapid failure with little warning. If using motorized pumps or loading devices, a suitable control system shall be used to avoid over-riding the load envisaged.

If loads are applied by hydraulic jack, the jack shall have a stroke able to mobilize the foundation capacity, or overcome the deflection design criteria, or both. If the jack is unable to produce such movement, the test procedure shall allow for adjustments of the loading system. The hydraulic jack shall have a reasonably safe capacity, that is not less than 25 % but preferably 50 % in excess of the expected maximum test load for design tests, and 10 % to 25 % respectively for proof tests.

Both the jack and the hydraulic pressure gauge shall be calibrated as a single unit, together with a record of the pressure applied to the jack, and an independent measurement of the load.

Any winch or other mechanism used to apply load shall have a reasonably safe capacity, using the same guidelines as for a hydraulic jack. For ropes under tension, their ultimate tensile strength (UTS) shall be not less than three times the maximum load.

The loads applied to the test foundation may be measured by load cells, by the pressure gauge on a calibrated hydraulic jack, by dynamometers installed on the winch line, or by another acceptable apparatus. For design tests, a back-up system is recommended, for example load cells and pressure gauge. Accuracy of measurement shall be within 5 % (preferably 1%) of the maximum test load. It is recommended that the load measuring device be installed as close as possible to the load application point.

All equipment operating under hydraulic pressure including the hydraulic jack shall be capable of withstanding, without leaking, a pressure of a minimum of 1,5 times, but preferably 2,0 times, the equivalent maximum load expected in the test.

The loading mechanism (bearing plates, struts or blocks, etc.) shall possess an adequate structural stiffness, and a minimum ultimate design capacity equivalent to 1,5 times the maximum applied test load.

All test equipment shall be installed in such a manner that no individual or cumulative component failure can cause a hazard to any person working on the site. All works shall be conducted in accordance with the appropriate safety codes and national standards.

### 7.2 Test loading arrangements

#### 7.2.1 *Axially-loaded foundations*

Test loads can be applied by the following means:

- — test loading beam and supports (see Figure 3);
- — fulcrum beam arrangement (see Figure 4);
- — A-frame (see Figure 5);
- — hydraulically operated crane (uplift tests).

In the case of compression tests, the reaction can be transferred to the subsoil by tension piles or ground anchors.

The minimum clear distance ($L$) between reaction supports (see Figure 3) should be chosen carefully to prevent any influence on the behaviour of the foundation. This distance should be increased if advisable due to the expected failure mode, and if suitable test equipment is available. Suggested minimum distances for proof tests (see Figure 2 for meaning of symbols) are given by:

a) pad and chimney, grillages, concrete block foundations, or buried anchors:

$L = e + 0,7 \times a$ (m)

where

$e$ is the width of foundation in metres;

$a$ is the depth of foundation in metres;

$L$ is the distance between nearest points of reaction supports.

b) for concrete piers, driven piles, drilled and grouted piles, or helix anchors:

$L = 3 \times e$ (m) or 2 (m), whichever is greater.

In the case of design tests, it is advisable to increase these distances. Annex C discusses basic considerations for establishing minimum clear distances between reaction supports.

**7.2.2** ***Laterally loaded foundations, foundations under overturning moments***

Lateral test loads can be applied directly to foundations by the following means:

— hydraulic jack and reaction foundation (see Figure 6a and Figure 6b);

— hydraulic jack and deadman (see Figure 6c);

— hydraulic jack and weighted platform (see Figure 6d).

Lateral/overturning test loads can be applied by the following means:

— single cable line and power source (see Figure 7a);

— multiple-part cable line and power source (see Figure 7b);

— loading line arranged between top of pole and power source (see Figure 7c).

The minimum clear distance ($L$) between reaction supports and the test foundation (see Figure 6) should be chosen carefully to minimise any influence on the behaviour of the test foundation. This distance should be increased if suitable test equipment is available.

Suggested minimum distances between supports and the test foundation (see Figure 6) for concrete piers, or for driven piles being pushed apart or pulled together (see Figure 2 for meaning of symbols) under proof tests are given by:

$L = 3 \times e$ (m) or 2 (m), whichever is greater.

For proof tests when pulling together or for design tests, it is advisable to increase these distances (see Annex C for basic considerations).

**7.3 Reference beam — Design tests**

The reference beam, for measuring foundation displacement during design tests, should comply with the following requirements.

The reference beam should be stiff enough to support the instrumentation without excessive deflection. If more than one beam is used, the beams should be cross-connected to provide additional rigidity.

Supports for the reference beam shall be at a distance of not less than $C$ from the edge of the test foundation (see Figure 3 and Figure 8), characterized by the dimension $e$, or from the edge of the reaction support, where:

| | |
|---|---|
| $C = 0,35\ a + 0,5$ (m) | for foundations listed in **7.2.1** a); |
| $C = (1,0\ e + 0,5)$ (m) or 1,5 (m), | whichever is greater for foundations listed in **7.2.1** b); |
| $C = 2,0 + 0,5\ e$ (m) | for laterally loaded foundations. |

The depth of the supports for the reference beam should preferably be between 1 m and 3 m, depending on the soil type. At rock sites, even surface conditions may be satisfactory. However, in highly compressible soils, for example soft clays, the supports should be sleeved so that the support is not in contact with the compressible soil. Possible vertical displacement of the reference beam supports shall be checked periodically using an optical level.

To minimize temperature effects, the use of either a wooden or steel reference beam, supported on rollers at one end, is recommended. In the latter case, the free end should be effectively restrained against lateral and vertical movement.

**7.4 Displacement measurement devices — Design tests**

**7.4.1** ***Primary measurement system***

Mechanical dial gauges with a recommended resolution of 0,1 mm (or less) and a recommended range of travel of 50 mm to 150 mm, preferably 150 mm, may be used for design and proof tests.

It is recommended that the dial gauge should be clamped to the reference beam in such a manner that the gauge will expand as the load is applied, in order to prevent damage to the instrumentation in the event of a sudden failure of the foundation or equipment.

Glass slides or machined plates may be fixed to test foundations to provide a smooth bearing surface for the dial gauges.

For uplift/compression tests, a minimum of two gauges shall be mounted equidistant from the vertical axis of the foundation and from each other.

For laterally loaded foundations, two gauges shall be mounted horizontally on opposing faces of the foundation and on the plane of loading to measure load deflection response. Two gauges may also be mounted vertically on opposing faces of the foundation and on the plane of loading to measure load rotation response (see Figure 8). Alternatively, inclinometers with an accuracy of ± 0,1° can be used. It is recommended that a gauge be installed horizontally and a gauge be installed vertically on a plane at 90° from the plane of loading. These gauges will record any out-of-plane movement that the test foundation might experience during loading (see Figure 8).

**7.4.2** ***Secondary measurement system***

As a check/control on the primary measurement system, a secondary system should be used for all design tests.

An optical level may be used, with a fixed benchmark and a scale. The scale should be attached either to the foundation or to the foundation steelwork, as closely as possible to the surface of the foundation. Minimum distance of level and benchmark from the centre line of the test foundation and/or reaction system shall be 10 m.

Alternatively, an electronic linear variable differential transformer (LVDT) or a potential displacement transducer (PDT) with a resolution of less than ± 0,1 mm may be used. All electronic systems require careful checks before and during testing to ensure that they function properly.

**7.4.3** ***Ground surface and subsurface displacement***

Additional data may be provided by wooden pegs, tell-tales (for example vertical steel rods in steel or plastic sleeves) attached to foundation components, optical levels, photographic and video camera records.

**7.4.4** ***Protection of instruments***

All measuring instruments shall be protected against incident sunlight, wind, rain, snow or icing that could lead to distortion of the readings.

**7.5 Displacement measurement devices — Proof tests**

The minimum level of measurement for proof tests should be a record of the applied load and the corresponding displacement of the foundation, using an optical level. Resolution of the optical level should be less than 0,5 mm.

**7.6 Calibration of measuring instruments**

All measuring instruments shall have a valid calibration certificate.

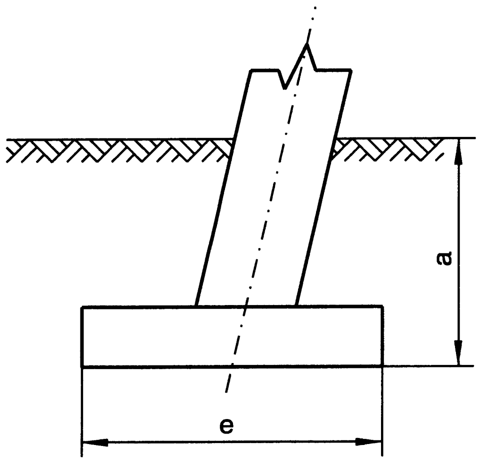



**Figure 2a – Pad and chimney foundations, grillages**

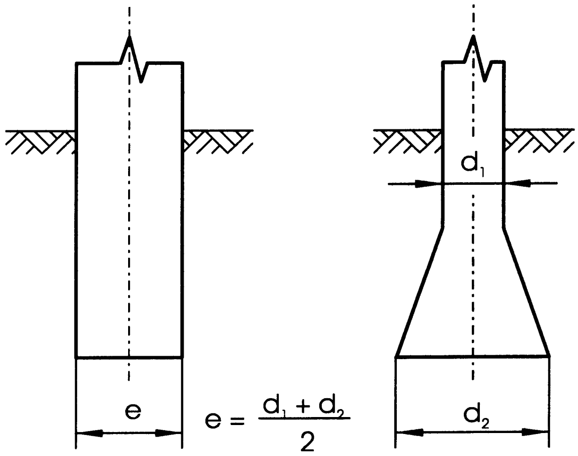



**Figure 2b – Concrete piers, straight and undercut**

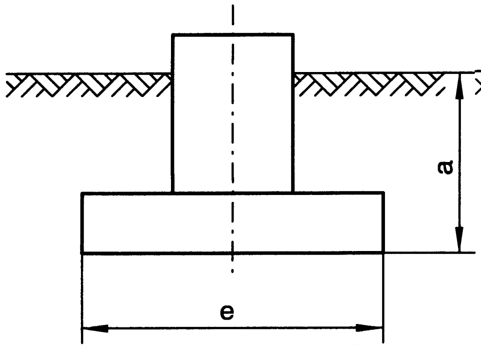



**Figure 2c – Concrete slab**

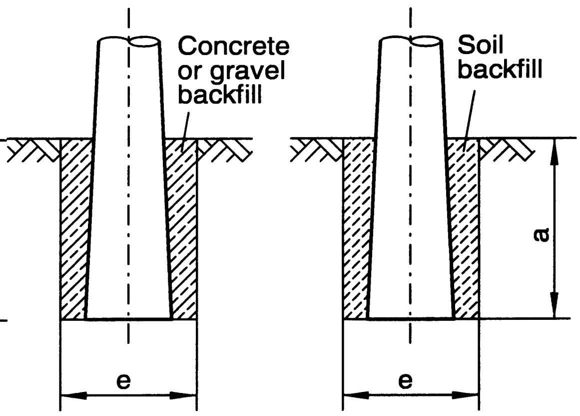



**Figure 2d – Directly embedded poles**

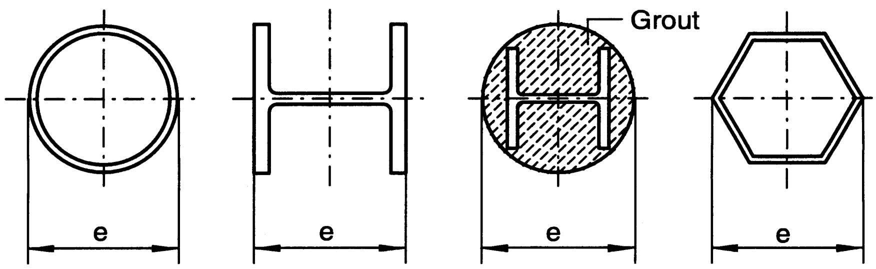



**Figure 2e – Piles**

**Figure 2 — Reference dimensions to establish minimum clear distance of reaction support from test foundation**

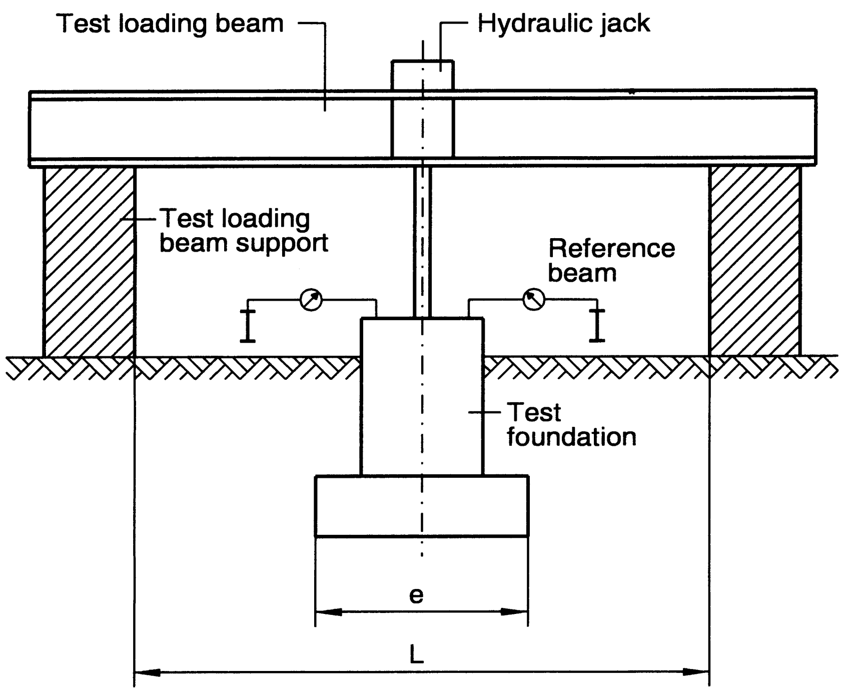



**Figure 3a – Elevation**

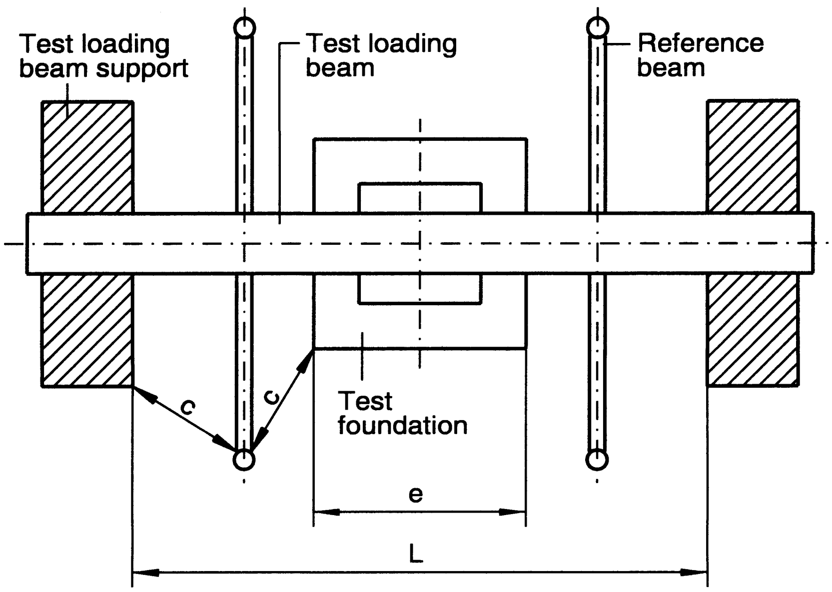



**Figure 3b – Plan layout**

**Figure 3 — Elevation and plan layout of typical test loading beam arrangement**

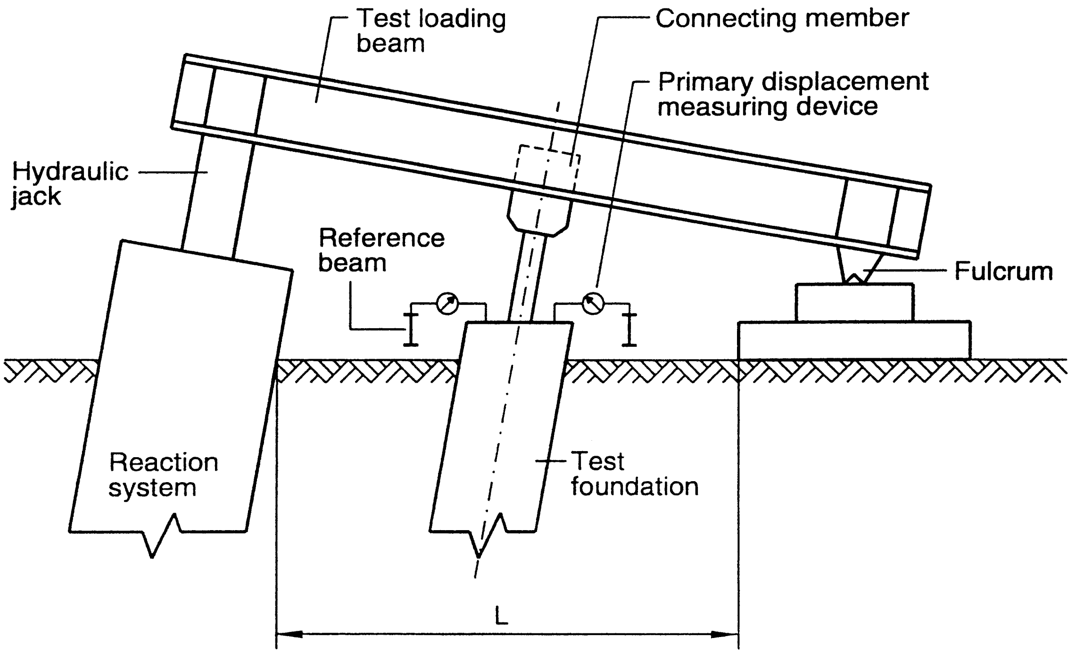



**Figure 4 — Load application by means of hydraulic jack and fulcrum beam**

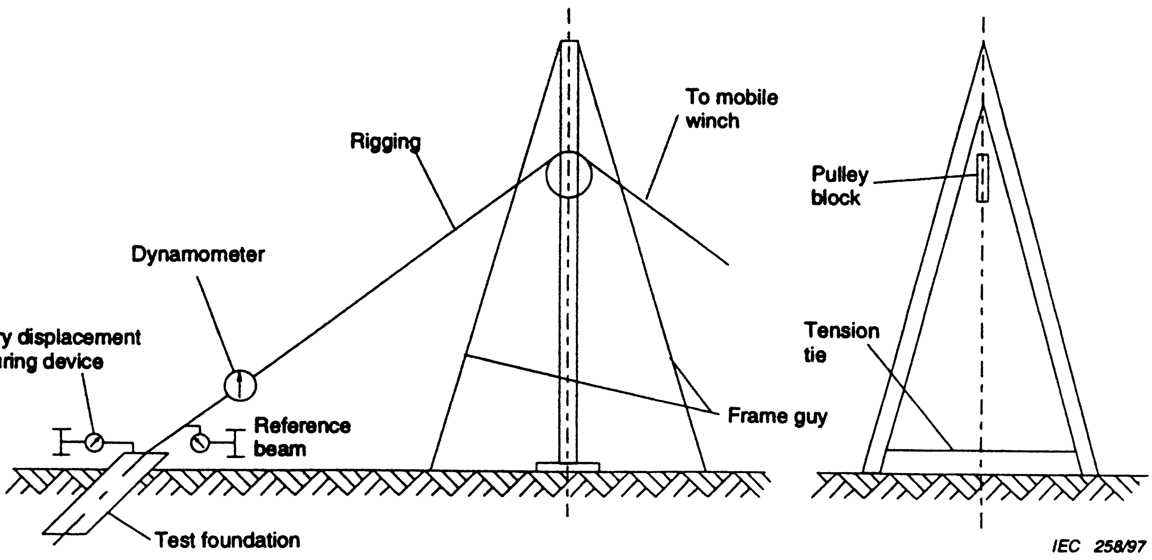



**Figure 5 — Load application by means of a frame tensioner system**

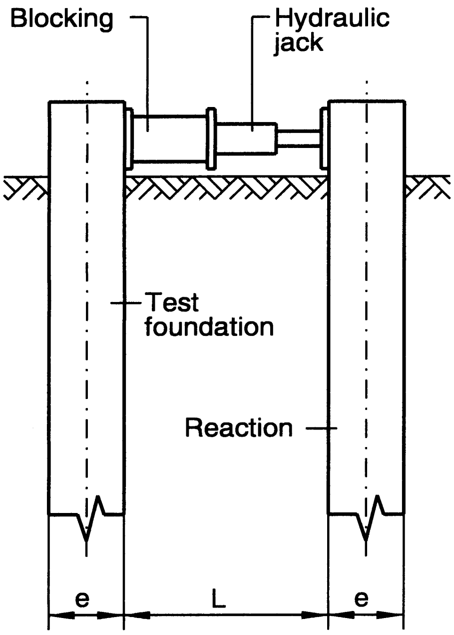



**Figure 6a – Reaction foundation, pushing apart**

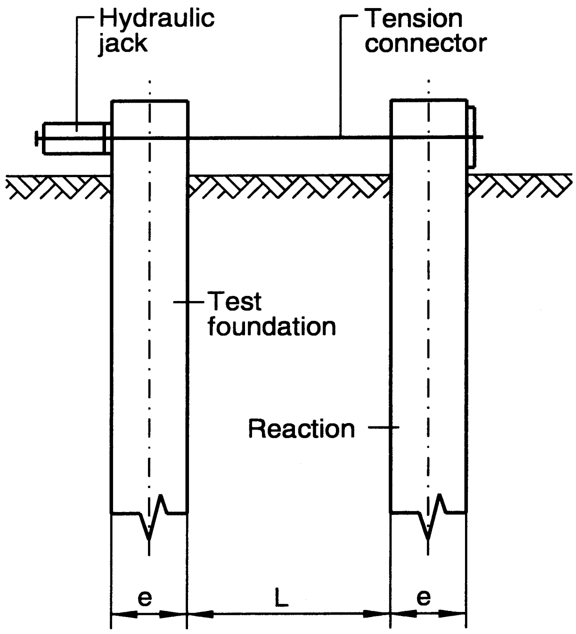



**Figure 6b – Reaction foundation, pulling together**

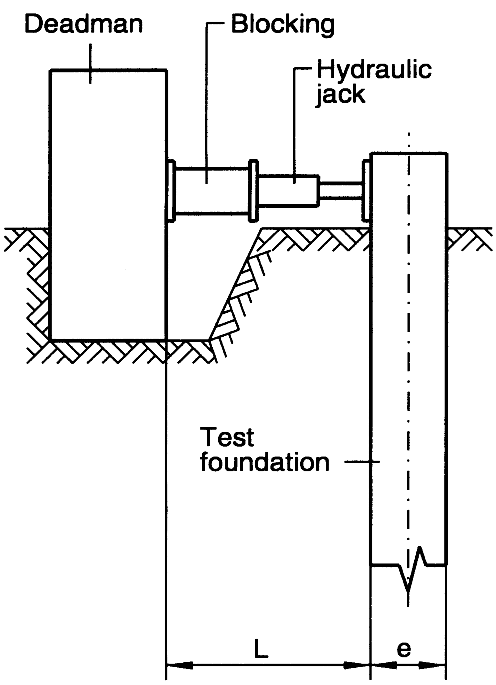



**Figure 6c – Deadman**

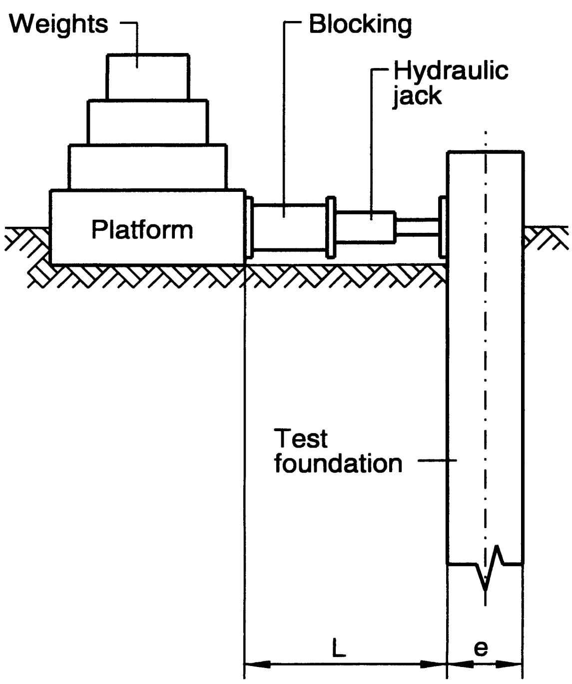



**Figure 6d – Weighted platform**

**Figure 6 — Lateral load test setups using conventional hydraulic jack**

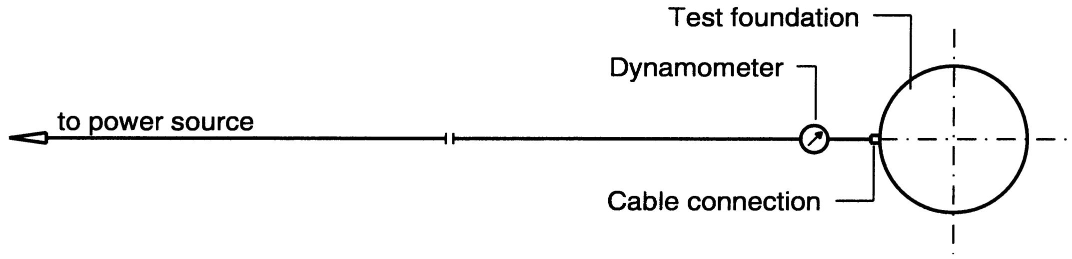



**Figure 7a – Single line arrangement**

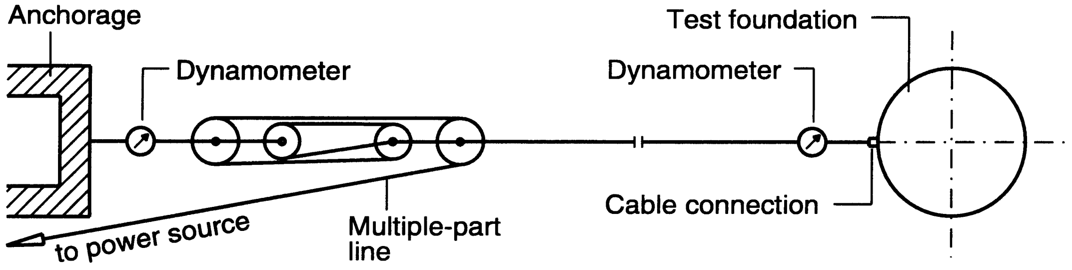
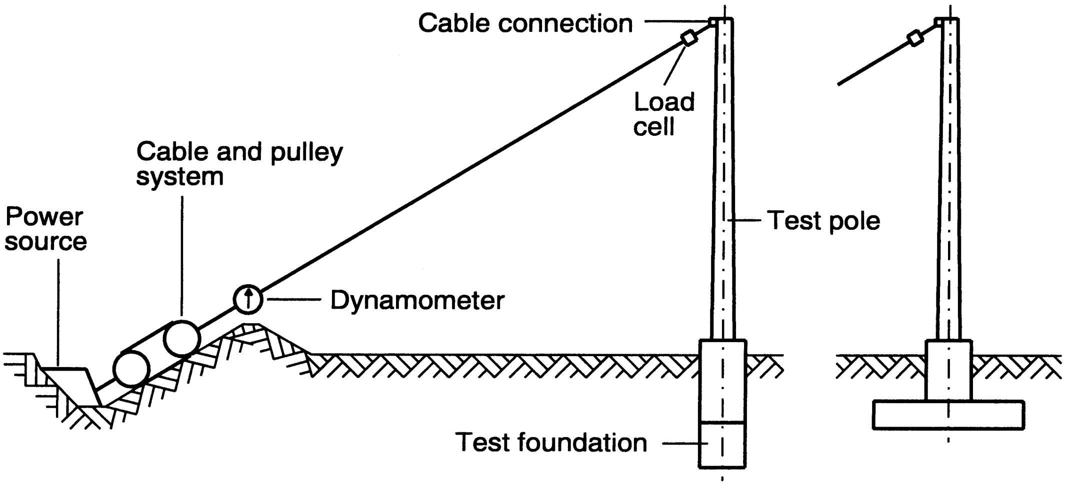



**Figure 7b – Multiple-part line arrangement**




NOTE The winches should be arranged so that the vertical load during testing will be approximately equal to the vertical design load.

**Figure 7c— Typical application of overturning load**

**Figure 7 — Lateral moment load test setups using cable and winch arrangements**

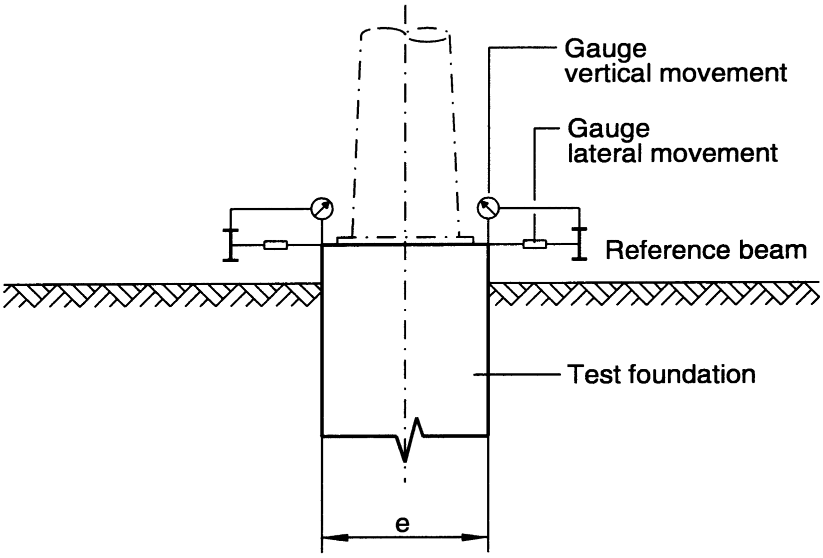



**Figure 8a – Elevation**

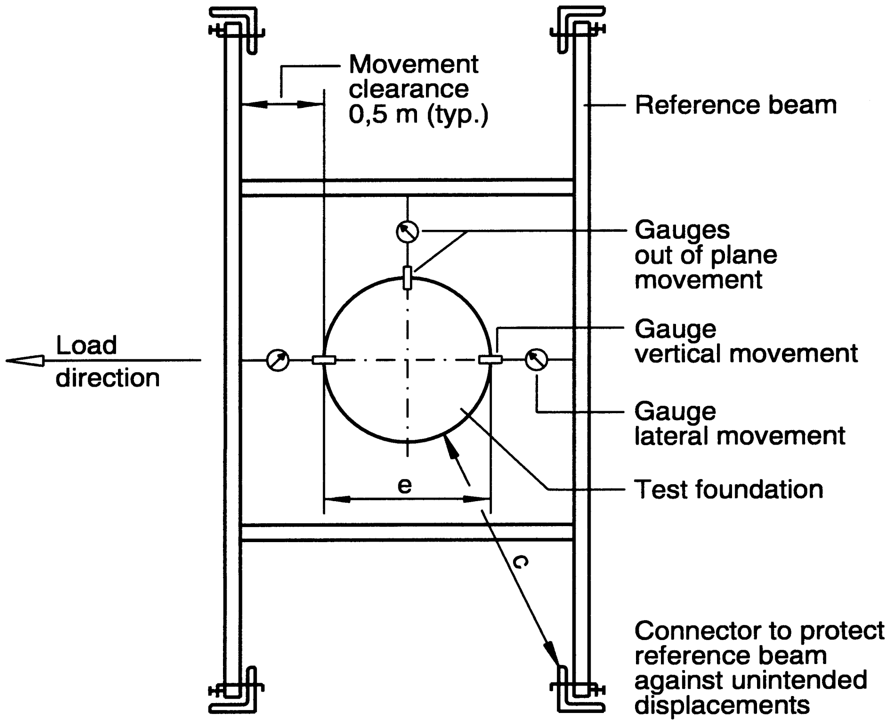



**Figure 8b – Plan layout**

**Figure 8 — Elevation and plan layout of typical arrangement of surface instrumentation**

## 8 Test procedure

### 8.1 Number of tests

The number of tests to be undertaken will depend on the following factors:

— nature of test, such as design or proof;

— significant variations in geotechnical parameters along the transmission line route;

— proposed method of analytical review of the test results.

#### 8.1.1 *Design tests*

Wherever possible, statistical techniques should be used to evaluate the results of design tests, especially if the characteristic strength of the foundation is required (see IEC 826). By this means, the results from at least three identical foundation tests in similar soil conditions, under the same test loading regime, can be satisfactorily analyzed using the Student's T-distribution.

Therefore, at least three identical foundations should be included in a design test programme, though a greater number would be preferable.

#### 8.1.2 *Proof tests — Axially loaded foundations*

Proof tests may be required on foundations, the capacity of which depends mainly on friction between foundation and subsoil (for example concrete piers, piles or grouted anchors), or depends on friction angle and cohesion of soil (for example undercut pad and chimney foundations). When the capacity of a foundation depends predominantly on the weight of soil and of the foundation itself (for example concrete block foundations), this foundation does not need to be included in a proof test programme.

The number of foundations subjected to proof testing will depend on the soil type, the extent of soil investigations, the heterogeneity of subsoils, the type of foundation and the reliability of the design.

Where proof tests are considered necessary, it is recommended that at least 5 % of the relevant foundations or relevant individual elements, for example piles, depending on size of population and level of confidence, should be included in a proof test programme. Depending on the test results, the number of tests required should be adjusted by considering the variations of subsoil, the types and dimensions, of foundations, and the quality of the site supervision to be expected during installation.

#### 8.1.3 *Proof tests — Laterally loaded foundations*

Where proof tests are considered necessary, it is recommended that at least 5 % of the constructed foundations should be included in the proof test programme. Depending on the test results, the number of tests required should be determined by considering the variation of the subsoil and the type and dimensions of foundations.

### 8.2 Testing of pile groups

Testing of foundations made up of a group of piles as a whole would be the ideal way of assessing the strength of the foundation, but would be technically and economically prohibitive in most cases. Alternatively, the performance of piling systems may be assessed by carrying out tests on individual piles. When evaluating the results to determine the overall capacity, the load displacement relation observed during testing, and the interaction of individual piles shall be duly considered.

### 8.3 Loading procedure

Table 1 gives minimum requirements for the typical range of values and rate of loading to be applied under both test categories. A preliminary stabilization cycle of up to 10 % of the test load may be required to ensure that all the test equipment has been adequately stabilized.

### 8.4 Test recording

Each test shall be recorded. A typical test recording form is given in Annex D.

#### 8.4.1 *Design tests*

The record of a design test should include the following information:

a) general topographic map of test location, clearly identifying principal geological features, boreholes, test pits, and foundation test installation;

b) soil profile and geotechnical design parameters, including details of surface and underground drainage (where significant), possible rock outcrops, sinkholes, or other geotechnical discontinuities;

c) plan and elevation of test foundations, reaction systems, fixed reference points for measurement of horizontal and vertical displacements, and details of connection, of test foundation to load application systems. The plan should give a unique reference number for each gauge or displacement monitor, as well as for each of the load application points;

d) plan and elevation of test foundation arrangement, giving dimensions and directions of movements recorded during tests;

e) degree of accuracy of each recording instrument, including details of calibration, certification, etc;

f) complete record of environmental conditions, including ambient temperature variations, ice, wind or snow (if any), depth to water table and presence of any heavy traffic or other vibrating equipment;

g) depending on the type of equipment used to measure the applied loads and the corresponding deflections, the following data shall be recorded for each load/deflection measurement:

1) time at start and end of each load application, as well as the date;

2) applied loads as measured by:

— load cell;

— hydraulic pressure gauge;

3) displacement readings as measured by:

— dial gauge;

— optical level;

— linear variable differential transformer (LVDT);

— potential displacement transducer (PDT);

4) displacement readings shall be recorded at the following intervals:

— at start of load cycle;

— at regular time intervals during load application;

— immediately prior to removal of load;

— under no-load conditions;

h) a typical test recording form is given in Annex D. Alternatively, using LVDTs, PDTs, load cells and electronic control of the jack pressure, the entire set of readings may be recorded automatically on a data logging device or a personal computer. Using electronic equipment in wet weather may lead to sudden failure of key components. A suitable back-up system should always be available. Weather-proofed printed test data sheets are recommended for standardized test programmes;

i) during the execution of the test, the readings of load versus displacement shall be plotted on a graph to ensure that any unexpected variations or anomalies are checked carefully. For design tests, graphs of load versus time and displacement versus time shall also be produced;

j) for those tests which have been taken to failure, the test report should include a brief description of the probable mechanism of failure.

**8.4.2** ***Proof tests***

For proof tests, items c), d), f), h) and j) of **8.4.1** are recommended for use.

**Table 1 — Loading schedule**

| Test category | Testing condition | Loading steps in % of target load according to test condition | Minimum time for maintaining loading steps |
|---|---|---|---|
| Design | Design or failure load | 25, 50, 70, 80, 90, 100, 0 | 10 min[a] |
| Proof | Maximum proof load | 50, 75, 90, 100, 0 | 3 min[b] |
| Cyclic tests for foundations in uplift | Permanent set | 20, 35, 0; 35, 50, 0;<br>50, 60, 0; 60, 70, 0;<br>70, 80, 0; 80, 90, 0;<br>90, 100, 0. | 3 min[c] |

NOTE For design tests carried out to failure, further load increments of 10 % should be made beyond the design load until failure occurs.
In the case of cohesive soils, loading steps of 70 % and above should be maintained for at least 30 min.

[a] In the case of design tests, loading may be continued until failure occurs, subject to satisfactory provisions for sudden failure before the maximum load has been attained. The maximum load during testing may be defined as the design load or the failure load (see clause **3** and **4.1**). The design load shall be maintained for a minimum of 30 min, to ensure that no significant movement has occurred. Foundation displacement/rotation readings shall be taken at the intervals specified in **8.4.1** g) 4), to assess the yield limit of the foundation. The subsequent loading steps to the point of failure may be maintained only for 3 min per increment, subject to a rate of movement of less than 0,2 mm/min.

[b] In the case of proof tests, the maximum (proof) loads will be based on an agreed percentage of the design load, (for example 75 %, see **4.2**), and the time that each load application is maintained will be governed by the minimum period necessary to obtain the readings and to ensure that soil conditions have stabilized. At the conclusion of the load test, after the load has been released, the final set of readings of deflection and/or rotation shall be recorded.

[c] Loading-unloading cycles may be required in a design test to determine the permanent set of the test foundation after it has experienced predetermined load levels. It is recommended that at least one intermediate load be scheduled during the unloading and during the reloading portions of the cycle. For special cases where creep may occur, it may be considered necessary, after each load increment, to load and unload the foundation five times before the load application is maintained for 3 min to 10 min.

# 9 Test evaluation

## 9.1 General

The test results for each foundation shall be evaluated in relation to the as-constructed conditions. Prior to any testing, the foundation load capacity and, if possible, the related displacement/rotation should be calculated, based on the parameters derived from the initial geotechnical investigations. The characteristic strength of the foundation may be determined in accordance with IEC 826 (**1.6.3.3** and Tables 21 and 25).

In the case of foundations composed of multiple elements, due consideration shall be given to group effects (see **8.2**).

## 9.2 Design tests

The results of a design test should be either evaluated against the design parameters used, or compared with the results of similar tests in different soil conditions. If there is a marked discrepancy between the theoretical and practical results, further tests may be required to identify the probable cause of the discrepancy, to achieve a satisfactory correlation between soil parameters and test results, and to ensure that an effective set of soil parameters is used for the final design to achieve the necessary characteristic strength.

### 9.2.1 *Uplift/compressive load capacity of foundation*

The following methods, which are outlined in greater detail in Annex E, may be used to derive the uplift/compressive load capacity of a foundation from the results of design tests taken to failure:

a) if the load-displacement curve shows a distinctive turning point between the elastic and plastic ranges, the load capacity of the foundation should be evaluated by using the tangent-intersection method (see Figure E.1) or log-log method (see Figure E.2);

b) if the load-displacement curve does not permit definite conclusions to be drawn on the load capacity of the foundation, the load capacity may be defined as a given percentage of the failure or test load, for example 90 % (see Figure E.4), or by the parabolic model (see Figure E.3);

c) for deep foundations, for example friction piles, the hyperbolic method (see Figure E.5) is proposed for the determination of foundation load capacity;

d) for foundations where displacement becomes the ruling factor, for example in foundations in cohesive soils, or where foundations undergo large displacements before failure, such as steel grillage, or pad and chimney foundations without an undercut subface, or cast against formwork, the slope-tangent method (see Figure E.6) is proposed for determining foundation load capacity. The 4 mm displacement limit suggested in **E.6** is based upon testing experience, and may be modified if validated by test results gained during design tests.

### 9.2.2 *Lateral load capacity of foundation*

There are no general, methods available for defining the lateral load capacity of a foundation. Often this load capacity is related to a specified limit of movement or rotation of the foundation, for example 1,5° of rotation for drilled shaft or concrete pier foundations for mono-pole structures (see Table 21 of IEC 826).

## 9.3 Proof tests

Results of proof tests may be evaluated against predetermined criteria according to the test method and the requirements of the design or, for that particular site, in accordance with IEC 826. The installation shall be checked for its adequacy to fulfill its purpose.

# 10 Acceptance criteria

## 10.1 General

Suitable acceptance criteria should be established before the tests are made. Values of admissible displacements associated with applied design load or proof load, including any load factors that may apply, should be agreed upon during the design of the foundations, based on the proposals made in Annex E. If applicable, national standards and regulations should also be considered and followed as mandated.

## 10.2 Design tests

The results of a design test shall be deemed satisfactory if the following conditions have been fulfilled:

— the specified design load has been validated by the test;

— the associated displacement remains within specified limits which are compatible with the function of the structure.

If the test results do not meet these requirements, the design and/or construction procedure, soil investigation and foundation testing shall be reviewed. Depending on the outcome of this review, it may be decided to redesign the foundation or to repeat the testing.

If the testing reveals a load capacity of the foundation well in excess of the specified load, taking into account the standard deviation of the foundation type, while still within the allowable range of foundation movement, a re-design or up-rating of the foundation may be considered.

**10.3 Proof tests**

The results of a proof test shall be deemed satisfactory if the value of the measured displacement at the specified load is equal to or less than the limits specified. The limits depend on the ability of the structure, which is to be supported by this foundation, to absorb or to accommodate movements.

If the observed displacement exceeds these specified limits, or if the assessment of the test results raises doubts about the capacity of the foundation, the following measures shall be taken:

— additional tests shall be made on at least two adjacent foundations (for four-legged towers) to enable a statistical evaluation to be made of the results of the first test, which can then be used to determine the acceptability of the foundations tested;

— if the results of the additional tests confirm the previous ones (that is the foundations are not sufficiently reliable), the foundations shall be considered as unsatisfactory;

— all foundations deemed unsatisfactory as a result of the proof test shall be strengthened or re-designed accordingly.

## 11 Test report

A test report shall be prepared for each test programme conducted. It shall include:

— identification and description of the project;

— details of the foundations tested;

— subsurface conditions;

— construction of test foundations;

— testing arrangement and procedure;

— test records, evaluation and assessment of test results.

# Annex A (informative) Bibliography

[1] CIGRE SC22-WG07, *Foundation testing*, Technical Brochure, Ref. 81, WG22-07, 1994.

[2] ISSMFE, *Axial pile loading test, part 1, static loading, recommended procedure,* 3rd draft, 1983 (International Society of Soil Mechanics & Foundation Engineering). Available from General Secretary, ISSMFE, c/o University Engineering Laboratory, Trumpington Road, Cambridge, UK.

# Annex B (informative) Soil investigations

## B.1 General

Soil investigation is, in principle, beyond the scope of this standard. However, it is deemed appropriate to present some general criteria for soil investigation of test sites. For details, reference should be made to relevant international or national standards and/or to qualified codes of practice.

## B.2 Extent of soil investigations

The scope and extent of soil investigations will depend on the purpose of the test and the type of subsurface material encountered. The level of investigation will be decided by the parties concerned and will depend on the purpose of the test.

### B.2.1 *Design tests*

Recommended levels of soil investigation should include:

— in hard/dense soil: visual examination, open test pit, exploratory drilling, augering (100 mm to 120 mm diameter), hand probe at foundation base, vane shear test (VST), Shelby tube or split spoon samples, pressuremeter test (PMT), standard penetration test (SPT);

— in weak soil: visual examination, hand probe at foundation base, cone penetration test (CPT), PMT, SPT;

— in rock: visual inspection, core drilling, rock quality designation (RQD) (see **B.5**).

### B.2.2 *Proof tests*

Recommended levels of soil investigation should include:

— in hard/dense soil: visual examination, exploratory drilling, augering (100 mm to 120 mm diameter) open test pit, hand probe at foundation base, PMT, SPT;

— in weak soil: visual examination, hand probe at foundation base, CPT (static or dynamic), PMT, SPT, VST;

— in rock: visual examination, *in situ* drilling for test footings.

In every case, the extent of soil and rock testing shall be sufficient to determine the design parameters necessary for foundation design.

## B.3 Soil investigation criteria

The following criteria shall be applied to every test programme to ensure a reasonable degree of uniformity in the recording of test results:

a) soil investigations shall be conducted at the test foundation location or as near as possible to the foundation itself without disturbing the soil conditions or jeopardizing the quality of the test installation;

b) soil investigation shall be co-ordinated with the foundation test to ensure that soil and/or rock parameters are consistent with those assumed for the capacity and load response of the test foundation;

c) the depth of the investigation shall not be less than the foundation depth in the case of uplift, and shall be adequately augmented in the case of compression.

Recommended investigation depths for compression tests are the greatest of:

— 1,1 times the footing depth; or

— maximum horizontal dimension plus depth of foundation. However, the depth of soil investigations need not be deeper than 3 m below the foundation base;

— for rock sites, cores should be sampled to a minimum depth of 3 m.

For laterally loaded foundations, the depth of the investigation will depend on the design method, and shall be at least one diameter (or largest foundation plan dimension) below the bottom of the foundation.

For tower sites where pile foundations might be expected, the depth of investigation should be determined prior to carrying out the test. The depth of investigation may be limited to the maximum depth of penetration by the SPT;

d) the number of soil and rock tests and the intervals between tests shall be adequate for the purpose of the test and for the design methodology. Recommended values are not less than two per test hole, with an interval between tests of 1 m to 3 m, or at changes of strata, depending on the nature of the subsoil;

e) the soil/rock descriptions may be based on disturbed samples;

f) the range of water levels observed during the test shall be recorded. For design tests, if the time lapse between soil investigation and foundation testing is likely to exceed one week, a groundwater observation well (standpipe or piezometer) should be left installed;

g) all relevant meteorological and ground surface conditions (for example surface drainage) shall be recorded.

Items c), d), e) and g) shall be in accordance with the applicable international or national standards and/or codes of practice unless otherwise agreed in advance of tests.

### B.4 Soil classification and strength

Soil classification and strength may be derived from at least one or more of the following methods:

a) visual examination of all types of soil, including any disturbed samples;

b) empirical correlations from *in situ* tests, that is standard penetration tests (SPT), cone penetration tests (CPT), vane shear tests (VST), and pressuremeter tests (PMT);

c) laboratory tests on disturbed samples, such as:

| *Non-cohesive soil* | *Cohesive soil* |
|---|---|
| particle size distribution | particle size distribution |
| specific gravity | moisture content |
| relative density | degree of saturation |
| | Atterberg limits |

d) additional laboratory tests on undisturbed samples:

| *Non-cohesive soil* | *Cohesive soil* |
|---|---|
| direct shear box | unconfined compressive strength |
| bulk density | laboratory vane shear |
| | triaxial compression |
| | bulk density |

NOTE It is virtually impossible to obtain truly undisturbed samples of any soils.

Laboratory and *in situ* tests should be carried out in accordance with accepted international or national standards. For proof tests, soil classifications and empirical determination of strength according to a) and b) may be acceptable.

### B.5 Investigation in rock

For investigations of rock anchor or rock foundation sites, it is recommended that the following data be included in the results:

a) predominant rock type, hardness, and presence of any visible faults;

b) extent and nature of any weathering;

c) extent and distribution of solution channels in soluble rocks, underground streams, and loss of drilling mud due to voids;

d) discontinuities, for example bedding planes, cleavages, faults and joints as determined by drilling and coring, in addition to any surface irregularities mentioned in a) or underground voids found in c), to assess the groutability of the rock;

e) rock core samples may be used for strength tests, in accordance with standard procedures.

These data can be obtained by core-drilling. In addition, the rock quality designation (RQD) should be recorded as accurately as possible. RQD is defined in Annex F. RQD values are used mainly for classification purposes. RQD values may depend on the drilling equipment. The strength and deformation characteristics of the rock mass may be estimated by *in situ* tests such as the borehole dilatometer, hydrofracture, etc. Also, some geophysical exploration techniques, such as seismic refraction, may help to characterize the rock mass at the test site.

## Annex C (informative) Comments on clear horizontal distance between reaction supports and test foundation

### C.1 Background

When testing foundations, the reaction forces are transmitted both to the soil and to the foundation, thus leading to possible side-effects on the results of the test, especially in the case of uplift tests. Therefore, the soil reaction shall be arranged in such a way that its effect on the test results is within acceptable limits. To avoid any major effects, a wide margin of clearance between the test specimen and the reaction forces is desirable. However, application of such testing devices could prove to be both impractical and perhaps prohibitively expensive. Therefore, the minimum specifications in **7.2** aim at providing a simple and economic method for foundation testing which would encourage public utility services and contractors to carry out such tests. During these tests, the capacity of the foundation in uplift would be assessed with sufficient accuracy for practical applications.

Adopting a reasonable programme for testing foundations can help reduce the dimensions of the foundations and the cost of installing them, thus resulting in more economic foundations and in an increase in the reliability of the line.

The stipulations given in **7.2** are in line with the proposals made by working group 07 of CIGRE SC22 (see [1]) and reflect current practice in some countries as well as current standards.

### C.2 Axially loaded foundations

For the determination of clear distances between reaction supports for foundation tests, different stipulations are in effect, which reflect the different theoretical considerations behind the analyses of foundations in uplift. In principle, the choice of a suitable clear distance between the reaction supports should be adjusted to the theoretical model of the foundation/soil reaction which was used to determine the foundation capacity under uplift. Three possibilities may be considered:

a) The uplift capacity of the foundation is represented by an inverted frustum of soil, starting with a given angle at the bottom of the foundation. This model is very often used to determine the uplift capacity of stepped concrete blocks, pad and chimney, or grillage foundations. Even full scale uplift load tests have shown that the failure pattern at the ground surface is similar to the shape of the buried foundation, though somewhat enlarged. In this case, the reaction support should be located outside the area defined by the intersection of the chosen plane of the frustum with the surface (see Figure C.1).

b) The foundation capacity is represented by a body of soil with rotational symmetry, and with a curved line to show the soil limit contributing to bearing capacity. This curved line starts with a certain angle at the bottom of the foundation and ends vertically (more or less) at the surface. This shape of soil reaction under uplift is typical of under-reamed drilled shafts and similar designs (see Figure C.2).

c) The uplift capacity of the foundation is determined by limiting friction on the soil/foundation interface. During full scale uplift testing, typically the observed failure pattern has been in close proximity to the foundation (see Figure C.3). This applies especially to long slender structures such as driven piles, concrete piers, caissons, etc. However, there are cases where short piles embedded in dense soils have failed in such a manner that the failure pattern at the ground surface resembled an inverted truncated cone. Thus a minimum clear distance is required that is at least a few times larger, in the case of piles, than the foundation width.

According to these assumptions, the formula in **7.2.1** a) will cover alternatives a) and b) above, while the formula in **7.2.1** b) will relate to c). The given formulae correspond in principle with the practice in different countries such as Germany, USA, etc.

This specification is based on theoretical considerations established by WG 07 of CIGRE SC22, which demonstrated that, by using these distances, the uplift capacity will be increased by a maximum of 3 % due to the additional friction created by the compressive stress in the soil under the reaction support. To allow for this apparent additional capacity in an uplift test, ultimate design capacity of the foundation in uplift as determined by the test may be reduced by 5 %. Where suitable devices are available, the clearance between the foundations under test and the abutments may be increased.

## C.3 Laterally loaded foundations

In cases of laterally loaded slender structures, such as concrete piles, theoretical and experimental evidence suggests that the soil is substantially affected within two diameters from the face of the foundation, and less beyond this range. However, for laterally loaded foundations, the mutual influence between test specimen and reaction will be limited when adopting the arrangements shown in Figure 6a (pushing apart), Figure 6c (deadman), Figure 6d (weighted platform) or Figure 7 (cable and winch). Therefore, minimum clearances as indicated in **7.2.2** will be quite sufficient. Only in the case of Figure 6b (pulling together) will a significant effect be expected theoretically. For such an arrangement, the clear distance can be increased substantially as recommended in **7.2.2** without a significant increase in cost, since the tension member is not limited in length. A clear distance of at least twice the value given in **7.2.2** is recommended for this case.

## C.4 Reference beam

The distances between the test foundation or the reaction support and the supports of the reference beam stipulated in **7.3** are based on test experience. They result in a relatively inexpensive component; and increased distances may well be justified at sites where soil conditions are less stable. The problem does not occur with proof tests where optical levels and remote benchmarks are used.

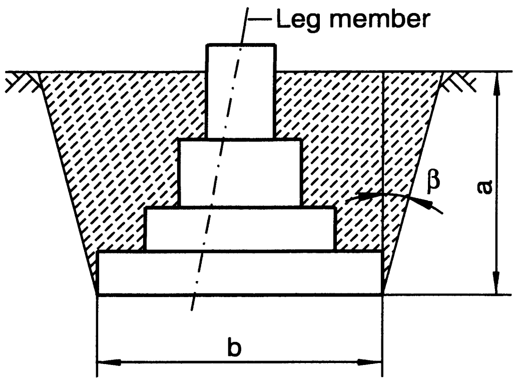



**Figure C.1 — Inverted frustum representing uplift capacity**

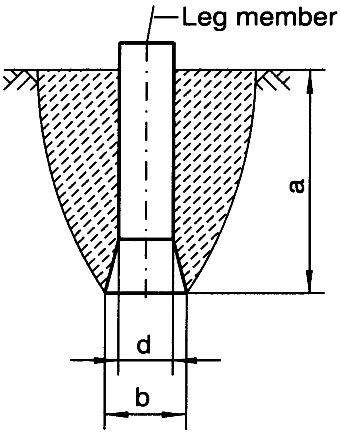



**Figure C.2 — Soil reaction in case of under-reamed shafts**

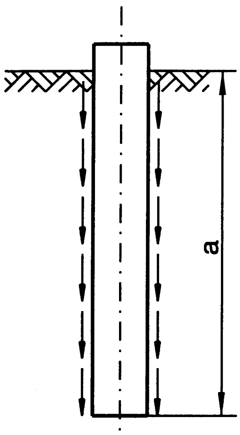



**Figure C.3 — Reaction of slender structures**

## Annex D (informative)
## Formats for records of installation and testing

For installation and test records, the following formats are recommended:

### D.1 Installation records

**Table D.1 — Concrete pad and chimney, steel grillage or buried anchor**

| | | | Design | As-built |
|---|---|---|---|---|
| Depth of foundation (mean) | | m | ______ | ______ |
| Length of base (foundation) | | m | ______ | ______ |
| Width of base (foundation) | | m | ______ | ______ |
| Inclination (rake) to vertical | | % | ______ | ______ |
| Undercut dimensions (if used) | | | | |
| length | | | ______ | ______ |
| width | | m | ______ | ______ |
| height (above base) | | m | ______ | ______ |
| Excavation dimensions (excluding undercut) | | | | |
| length | | m | ______ | ______ |
| width | | m | ______ | ______ |
| depth (mean) | | m | ______ | ______ |
| Concrete strength: | 7 day cube/cylinder | $N/mm^2$ (MPa) | ______ | ______ |
| | 28 day cube/cylinder | $N/mm^2$ (MPa) | ______ | ______ |
| | concrete slump | mm | ______ | ______ |
| Concrete volume | | $m^3$ | ______ | ______ |
| Elapsed time from mixing to placing | | h | ______ | ______ |
| Number of batches | | — | ______ | ______ |
| Concrete temperature | | °C | ______ | ______ |
| Steel grillages: | net base area | $m^2$ | ______ | ______ |
| | gross base area | $m^2$ | ______ | ______ |
| | steel mass | kg | ______ | ______ |
| Backfill compaction method | | | | |
| Data: | average density or unit mass | $kg/m^3$ | ______ | ______ |
| | grain size analysis | | ______ | ______ |
| | moisture content | % | ______ | ______ |
| Dates: | excavation | | ______ | ______ |
| | concrete placement | | ______ | ______ |
| | backfill compaction | | ______ | ______ |
| Meteorological conditions: | | | ______ | ______ |
| air temperature | | °C | ______ | ______ |
| precipitation | rain | mm | ______ | ______ |
| | snow | cm | ______ | ______ |
| wind | | m/s (or km/h) | | |
| Where applicable, a sketch showing details of the design including the as-built dimensions of the foundation and their positions in relation to the centre of the structure should be added. | | | | |

**Table D.2 — Concrete pier foundation**

| | | | Design | As-built |
|---|---|---|---|---|
| Shaft diameter (mean) | | m | ______ | ______ |
| Total embedded length | | m | ______ | ______ |
| Under-ream diameter (mean) | | m | ______ | ______ |
| Under-ream height | | m | ______ | ______ |
| Inclination (rake) to vertical | | % | ______ | ______ |
| Concrete volume | | $m^3$ | ______ | ______ |
| Concrete strength: | 7 day cube/cylinder | $N/mm^2$(MPa) | ______ | ______ |
| | 28 day cube/cylinder | $N/mm^2$(MPa) | ______ | ______ |
| | concrete slump | mm | ______ | ______ |
| Details of concrete placement: | | | | |
| elapsed time from mixing to placing | | h | ______ | ______ |
| number of batches | | | ______ | ______ |
| admixtures employed | | | ______ | ______ |
| concrete temperature | | °C | ______ | ______ |
| Depth bored | with temporary casing | m | ______ | ______ |
| | with permanent casing | m | ______ | ______ |
| Drilled under muds | bentonite | m | ______ | ______ |
| | others (specify) | m | ______ | ______ |
| Excavation (drilling) method | | | ______ | ______ |
| Density of mud (for drilling) | | | ______ | ______ |
| Anchor bolt details | | | ______ | ______ |
| Dates | excavation | | | |
| concrete placement | start | | ______ | ______ |
| | completion | | ______ | ______ |
| Meteorological conditions: | | | ______ | ______ |
| air temperature | | °C | ______ | ______ |
| precipitation | rain | mm | ______ | ______ |
| | snow | cm | ______ | ______ |
| wind | | m/s (or km/h) | ______ | ______ |
| Include notes on any problems encountered: such as sides caving, bottom heaving, alignment of excavation walls, etc. Where applicable, a sketch showing details of the design including the as-built dimensions of the foundation and their positions in relation to the centre of the structure should be added. | | | | |

**Table D.3 — Piled foundation**

| | | | | Design | As-built |
|---|---|---|---|---|---|
| Types of installation: | | | | | |
| Driven | steel | | | ______ | ______ |
| | concrete | | | ______ | ______ |
| | wood (species) | | | ______ | ______ |
| Bored | with temporary casing | | | ______ | ______ |
| | with permanent casing | | | ______ | ______ |
| Drilled under muds | | bentonite | m | | ______ |
| | | others (specify) | m | | ______ |
| | Other methods | | | | |
| Circular pile diameter (mean) | | | m | ______ | ______ |
| Non-circular pile surface area per m length | | | $m^2$ | ______ | ______ |
| Cross-section area | | | $m^2$ | ______ | ______ |
| Steel grade (yield strength) | | | $N/mm^2$ | ______ | ______ |
| Reinforcement details | | | | ______ | ______ |
| Total embedded length | | | m | ______ | ______ |
| Under-ream diameter (mean) | | | m | ______ | ______ |
| Under-ream height | | | m | ______ | ______ |
| Inclination (rake) to vertical | | | % | ______ | ______ |
| Cap dimensions (if any): | | length | m | ______ | ______ |
| | | width | m | ______ | ______ |
| | | depth | m | ______ | ______ |
| Concrete volume | | | $m^3$ | ______ | ______ |
| Concrete strength: | | 7 day cube/cylinder | $N/mm^2$(MPa) | ______ | ______ |
| | | 28 day cube/cylinder | $N/mm^2$(MPa) | ______ | ______ |
| | | concrete slump | mm | ______ | ______ |
| Details of concrete placement | | | | | |
| elapsed time from mixing to placing | | | h | ______ | ______ |
| admixtures employed | | | | ______ | ______ |
| concrete temperature | | | °C | ______ | ______ |
| Dates | excavation | | | ______ | ______ |
| | concrete placement | start | | ______ | ______ |
| | | completion | | ______ | ______ |
| Meteorological conditions: | | | | | |
| air temperature | | | °C | ______ | ______ |
| precipitation | | rain | mm | ______ | ______ |
| | | snow | cm | ______ | ______ |
| wind | | | m/s (km/h) | ______ | ______ |

For driven piles, include details of driving resistance, for example final set (number of blows to achieve 25 mm penetration), % rebound, any re-driving, use of pre-boring, jetting, use of dynamic pile monitoring, etc. Where applicable, a sketch showing details of the design including the as-built dimensions of the foundation and their positions in relation to the centre of the structure should be added. It should also include soil test results (SPT profile) if available.

**Table D.4 — Drilled or driven anchors**

| Item | Unit | Design | As-built |
|---|---|---|---|
| Type of anchor: | | | |
| *Grouted anchor* | | | |
| Anchor hole diameter (mean) | m | ______ | ______ |
| Total embedded length | m | ______ | ______ |
| Bonded length | m | ______ | ______ |
| Anchor rod diameter | mm | ______ | ______ |
| Inclination (rake) to vertical | % | ______ | ______ |
| Anchor rod type and quality | N/mm$^2$ | ______ | ______ |
| Yield stress | | | ______ |
| Method of drilling | | | ______ |
| Method of grouting, grout mix, etc. | | | ______ |
| Maximum grout pressure (if applied) | N/mm$^2$ (MPa) | | ______ |
| Grout volume (approximate) | m$^3$ | | ______ |
| Grout strength: 7 day cube/cylinder | N/mm$^2$(MPa) | | ______ |
| Grout strength: 28 day cube/cylinder | N/mm$^2$(MPa) | | ______ |
| Details of grouting[a] | | | |
| elapsed time from mixing to placing | | | ______ |
| admixtures employed | | | ______ |
| pre-stress applied: initial | kN | | ______ |
| pre-stress applied: final | kN | | ______ |
| Dates: drilling | | | ______ |
| Dates: grouting: start | | | ______ |
| Dates: grouting: completion | | | ______ |
| Dates: pre-stressing: initial | | | ______ |
| Dates: pre-stressing: final | | | ______ |
| *Helix anchor* | | | ______ |
| Total installed depth | m | | ______ |
| Pitch and diameter of helices | m/mm | | ______ |
| Number of helices | | | ______ |
| Maximum installation torque | kN.m | | ______ |
| Meteorological conditions: | | | |
| air temperature | °C | | ______ |
| soil temperature | °C | | ______ |
| precipitation: rain | mm | | ______ |
| precipitation: snow | cm | | ______ |
| wind | m/s (km/h) | | ______ |

[a] If multistage injection procedures are used, the drilling method and pressure at each injection stage should be recorded.

Where applicable, a sketch showing details of the design including the as-built dimensions of the foundation and their positions in relation to the centre of the structure should be added.

**Table D.5 — Typical test recording form**

Project............................................ Test foundation number.......................... Sheet...................of....................

Location ......................................... Foundation type .................................... Temperature .............................

Date................................................. Drawing reference ................................. Weather ...................................

Eng./Techn ..................................... Remarks.................................................

| Clock time | Elapsed time | Required load | Hydraulic jack pressure | Dynamometer | Foundation displacement (note 1) mm | | | | | | | | | Ground surface displacement (note 2) | | Subsurface displacement (note 2) | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | K | Gauge 1 | | Gauge 2 | | Gauge 3 | | Mean | Optical level scale mm | | mm | | mm | | |
| | min | kN | (note 3) | Gauge load (note 3) | | Σ | | Σ | | Σ | | | Σ | | Σ | | Σ | |
| | | | | | Reading | Change | Reading | Change | Reading | Change | | Reading | Change | Reading | Change | Reading | Change | |
| | | | | | | | | | | | | | | | | | | |

NOTE 1 The number of foundation displacement gauges is indicative only.
NOTE 2 Results of all ground surface and subsurface displacements, together with their unique reference identification, should be shown.
NOTE 3 Units to be stated; both required and actual readings to be given

## Annex E (informative) Guidance notes for graphical determination of foundation uplift or compression capacity

Individual foundation types perform differently under loading. In some cases, there is a distinct failure. However, their behaviour is often characterized by steadily increasing displacement, and the definition of load capacity is difficult. In these cases, one of the following approaches may be used to define the load capacity. Other procedures may also be used if they are clearly defined.

### E.1 Tangent intersection method (Figure E.1)

The load capacity of the foundation in uplift is defined as the load related to the intersection of two tangents to the load-displacement curve, one representing the elastic range and the other the plastic range.

### E.2 Log-log method (Figure E.2)

The load-displacement data are replotted using a logarithmic scale, and the two straight line portions of the graph are drawn. The foundation uplift capacity is defined as the load related to the intersection of the straight line portions of the graph.

### E.3 Parabolic model (Figure E.3)

The load-displacement data are plotted using transformed axes with the ordinate (y-axis) representing the square root of the displacement divided by the load, that is:

$$\sqrt{displacement}/load$$

and the abscissae (x-axis) representing the displacement. The foundation uplift capacity is determined from the y-intercept ($c_2$) and the slope ($c_1$) of the graph by:

$$R_C = \frac{1}{2 \cdot \sqrt{C_1 \cdot C_2}}$$

### E.4 90 % criterion (Figure E.4)

The foundation uplift capacity is defined as the load that gives twice the displacement obtained at 90 % of that load. Note that this is a trial and error method, since it is necessary to assume an initial capacity, determine 90 % of that capacity, and check that the displacement at the 100 % foundation capacity value is twice that at the 90 % value.

### E.5 Hyperbolic model (Figure E.5)

The load-displacement data are plotted using transformed axes with the ordinate (y-axis) representing the displacement divided by the load and the abscissae (x-axis) the displacement. The foundation uplift capacity is determined from the inverse slope of the graphe.

$R_C = 1/c_1$

### E.6 Slope tangent method (Figure E.6)

The foundation uplift capacity is determined from the intersection of a line drawn parallel to the initial linear portion of the load-displacement curve at a distance equivalent to a displacement of 4 mm. This displacement has been recognized as approximate for various types of foundations. If required by different experience or design requirements, other displacement limits should be adopted.

NOTES 1 From the examples in Figure E.1 to Figure E.6 it can be seen that the approaches in **E.1**, **E.3** and **E.4** tend to give results with a reasonable degree of consistency. Approach **E.5** clearly gives a higher value while **E.2** and **E.6** tend to a considerably lower value for the uplift capacity.

NOTES 2 For compressive tests, the expression compression may be substituted for uplift in the above text.

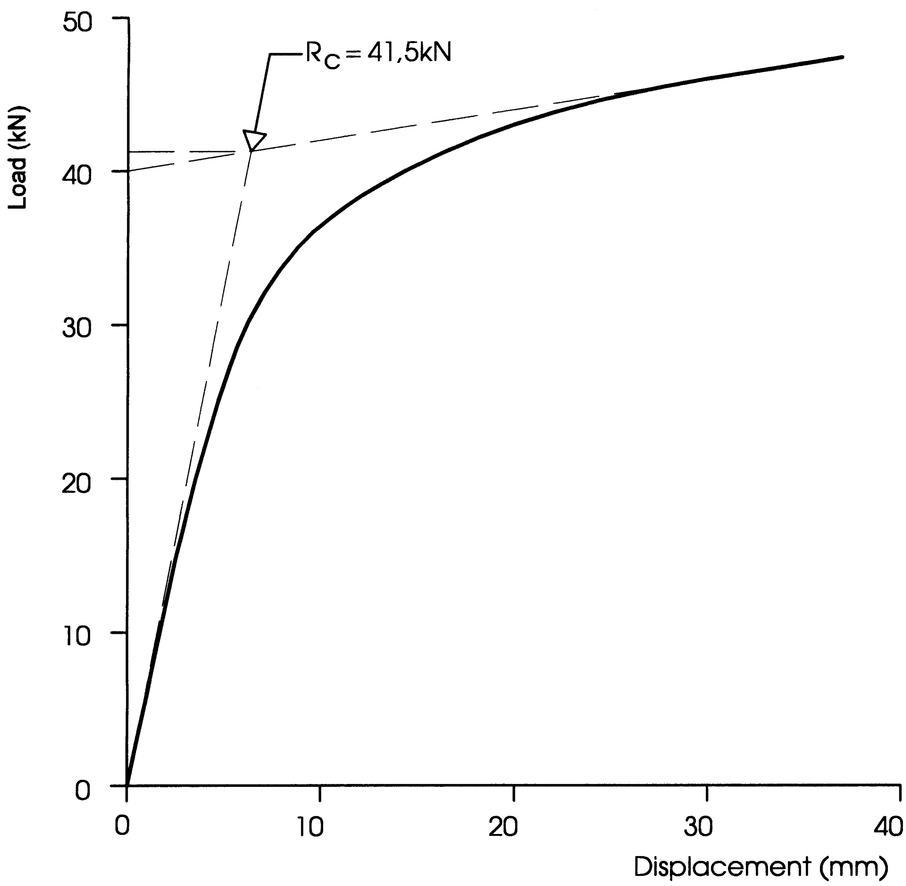



**Figure E.1 — Tangent insertion method**

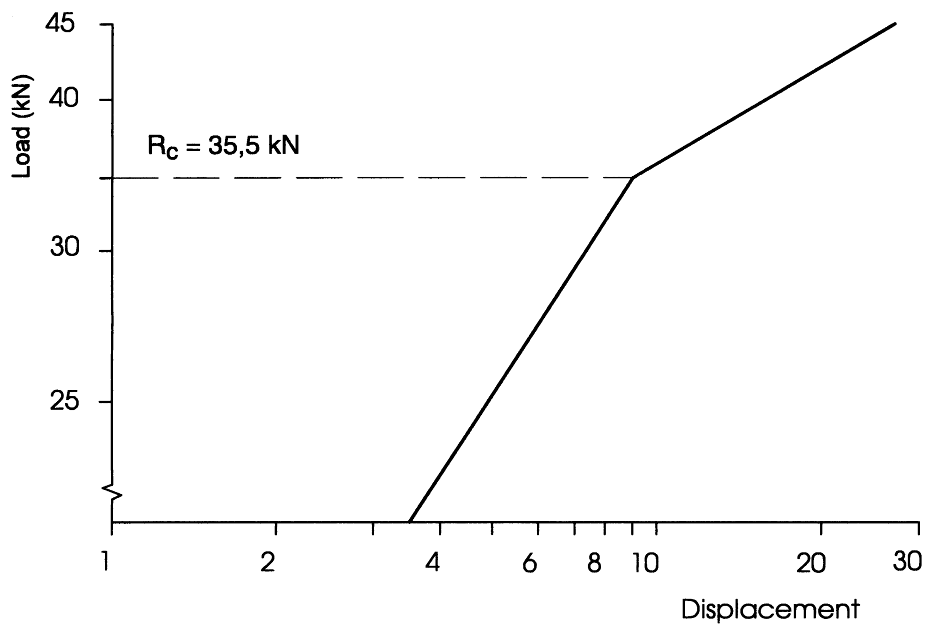



**Figure E.2 — Log-log method**

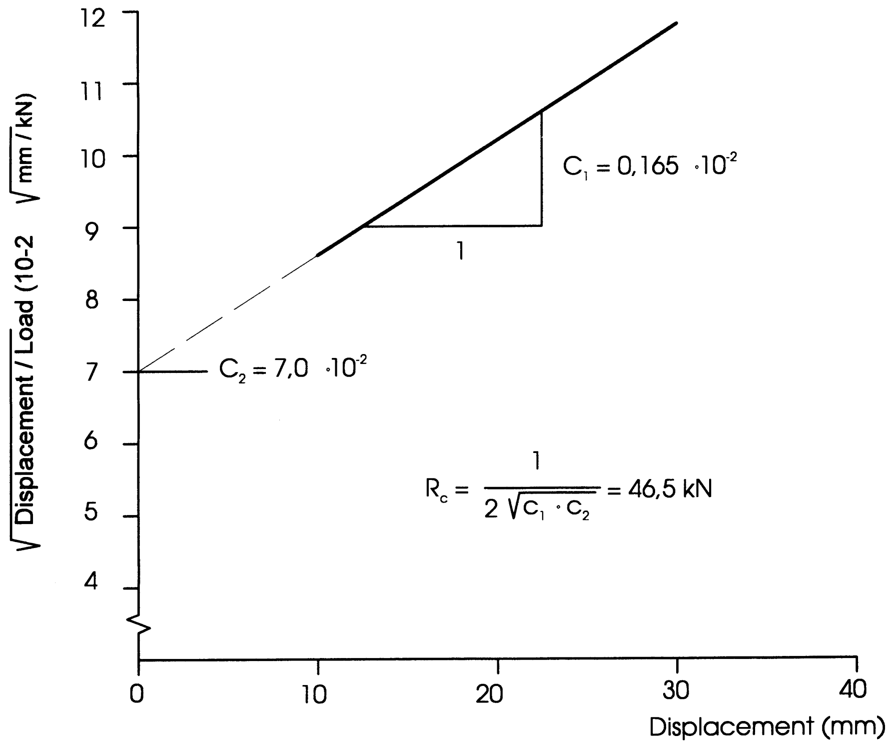



**Figure E.3 — Parabolic model**

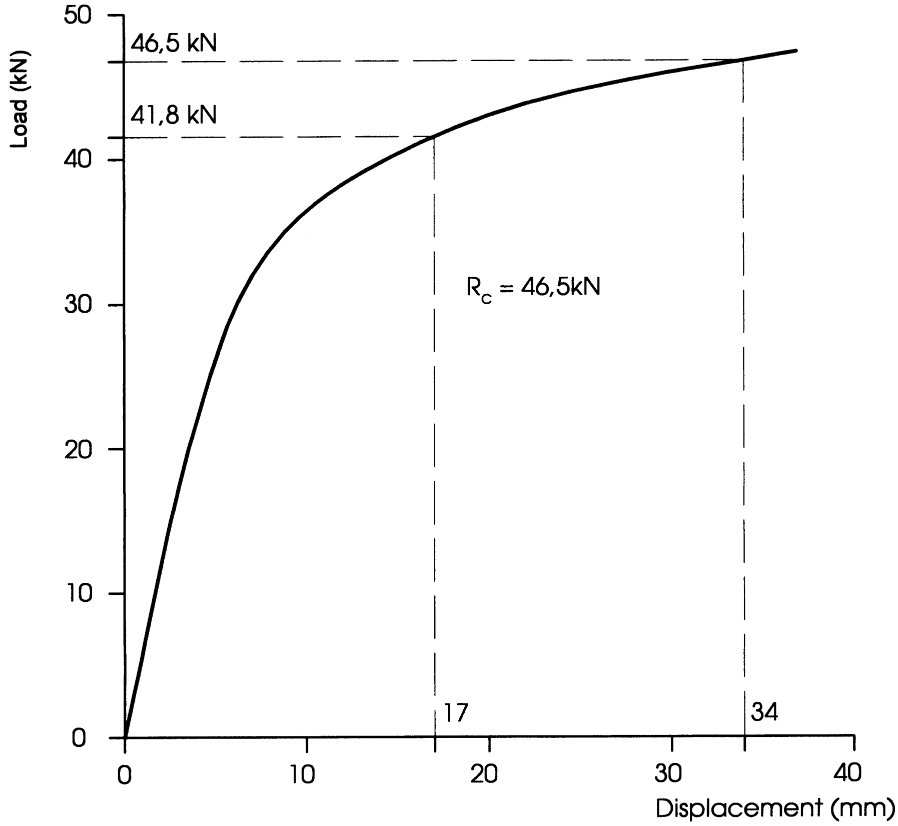



**Figure E.4 — 90 % criterion**

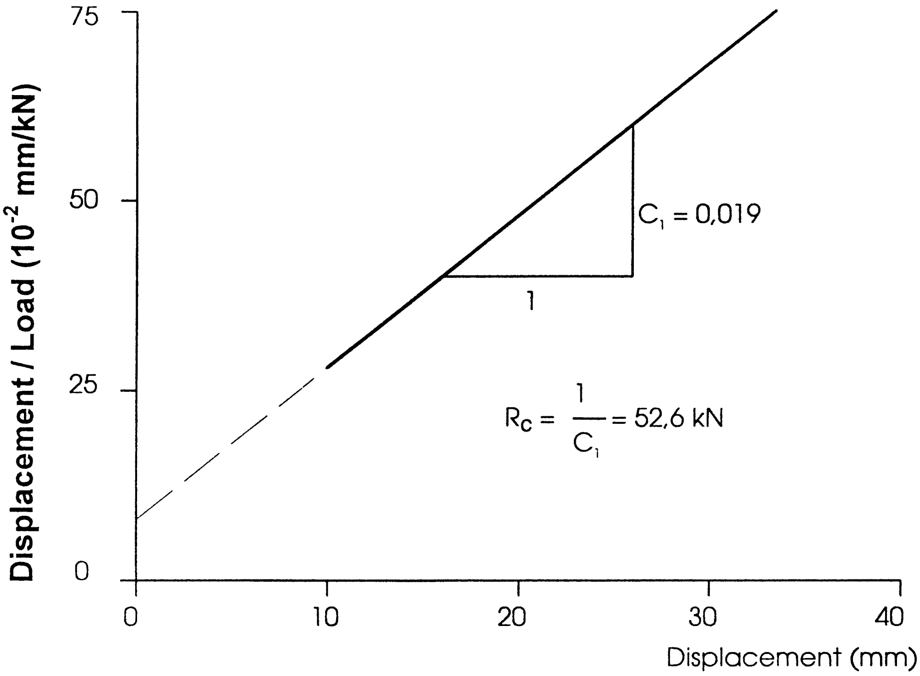



**Figure E.5 — Hyperbolic model**

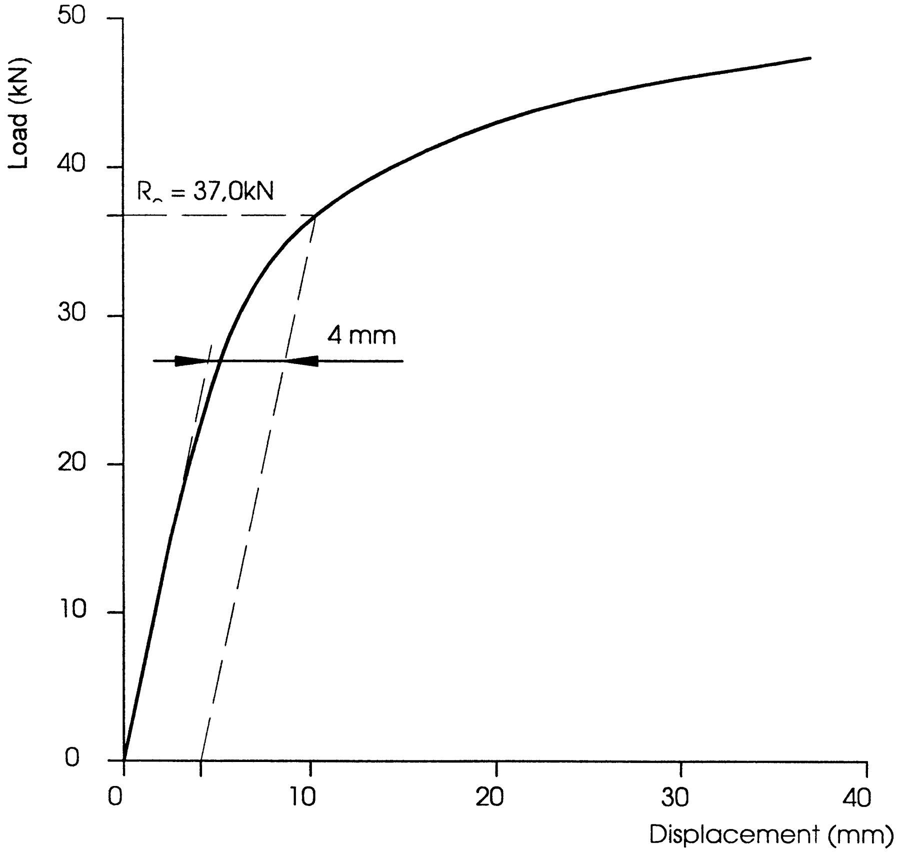



**Figure E.6 — Slope tangent method**

## Annex F (informative) Glossary of terms and explanations

**Atterberg limit**: Laboratory tests carried out on samples of cohesive soil to determine their degree of plasticity. The liquid limit ($W_L$) and plastic limit ($W_p$) are determined by standard laboratory tests. The plasticity index ($I_p$) is given by

$$I_P = W_L - W_P.$$

**borehole dilatometer**: A pressuremeter device specifically designed for use in a rock borehole. It is a stronger version of the pressuremeter, using one cell instead of three.

**bulk density** (unit density): The ratio of mass per unit volume of soil measured under normal conditions of moisture content and degree of compaction.

**concrete pier**: Concrete column constructed in the ground by boring, drilling or augering, or by using caisson driving techniques, for example excavating by some suitable means within a casing. The term may also be known as bored, drilled, augered or drilled shaft foundation or as caisson (the latter may often be of a larger diameter than other types of concrete piers).

**cone penetration test (CPT)**: Any test in which a cone on the base of a series of rods is moved through the ground by pressure or by the application of dynamic blows. It is possible to use a cone at the base of a standard penetration test apparatus, a Dutch or static cone test, a hand probe test, or even other dynamic test devices. See also static (Dutch) cone penetration test.

**degree of saturation**: The ratio of the volume of water to the total volume of soil voids, expressed as a percentage.

**direct shear box**: A laboratory device used to measure the shear strength of cohesionless soils under varying pressures.

**driven pile**: Pile installed in the ground by the action of dynamic hammer blows. The pile may be either solid (for example reinforced concrete) or hollow (for example tube of steel, concrete, etc.) within which *in situ* concrete and reinforcing steel can be set.

**dynamic cone penetration test**: A test to assess ground strength, in which a metal cone at the bottom of a series of steel rods is driven into the ground by means of dynamic hammer blows on an anvil at the top of the rods. The number of blows required to drive the cone a fixed distance into the stratum can be correlated with the relative density and shear strength of the soil.

**ground**: In this standard, ground is used as a term which includes soil and rock.

**hand probe**: A light hand-held dynamic cone penetrometer used for assessing the strength of the strata below ground level. The most commonly used probes are the *Mackintosh prospecting tool* (U.K. and derivatives) and the *Künzelstab* (Germany).

**hydro-fracture**: The process known as hydraulic fracturing or hydro-fracture is used to determine the *in situ* strength of rock at any required depth. It is particularly useful in anisotropic rock and is limited in depth only by the length of the borehole. It effectively consists of applying a shock wave by hammer blow to water constrained within a borehole drilled in the rock mass. The method is not limited by widely varying rock strength, and is not adversely affected by discontinuities in the borehole wall, provided that precautions are taken to prevent the fracturing fluid from coming into contact with the discontinuities during the pressurization stage.

**inclinometer**: A device which allows measurement of the angle between the principal plane of a member and the horizontal or vertical plane.

**laboratory vane shear test**: While the vane shear test is essentially a field test, an undisturbed sample of cohesive soil may be tested in the laboratory by means of special vane shear equipment.

**linear variable differential transformer (LVDT)**: An electrical transducer, which converts movement into electrically measurable outputs by means of a coil with a movable solid core, is used to measure the relative movement of the core, which causes small changes in the magnetic field, and hence in the current flowing in the coil. Maximum displacements are less than 200 mm, and accuracy of measurement is in the region of 0,1 %.

**potential displacement transducer (PDT)**: An electrical transducer, which converts movement into electrically measurable outputs by means of a resistance strip or a closely wound coil of resistance wire with a variable point of contact, is used to measure the movement of the contact point relative to the strip or coil. The corresponding change in resistance can be measured as a change in voltage. Larger measuring distances can be accommodated than with the LVDT, but it is less accurate.

**pressuremeter test**: An *in situ* test in which a pressuremeter probe is inserted into a pre-drilled hole to the required depth. The top and bottom parts of the probe are guard cells which are expanded to reduce end-condition effects. The middle cell is used to obtain the volume versus cell pressure relationship. The self-boring pressuremeter test (SHBPMT) is a recent modification which does not require a special hole to be pre-drilled. These tests can only be used in soils capable of retaining their shape after drilling until the probe is inserted.

**rock**: Any cemented or coherent and relatively hard naturally formed mass of mineral matter. It may be identified by its resistance to hand excavation and by its ability to support the pressure of a 50 mm × 50 mm square peg under a person's weight without any signs of indentation.

**rock quality designation (RQD)**: The modified core recovery percentage in which all pieces of sound core over 100 mm in length are recovered and measured. It is used when drilling rock to provide a measure of comparative quality.

RQD (%) = 100 · (*total length of core recovered*)/(*total length of hole drilled*)

**seismic refraction**: A procedure for estimating the density and type of subsurface strata, particularly those of rock-like materials. The technique is based on the fact that the speed of sound varies depending on the density of the strata through which it travels. For seismic waves generated by hammer blows or by explosives, the time taken to travel to recording devices can be analyzed to give indications of the thickness and composition of subsurface strata.

**Shelby** (thin wall) **tube sampler**: A soil sampler used for obtaining undisturbed samples of cohesive soil.

**soil**: Uncemented sediments composed chiefly of solid mineral particles derived from the physical and chemical weathering of rock.

— Hard or dense: can be excavated by hand using a pick; a 50 mm × 50 mm square wooden peg is hard to drive with a hand-held hammer.

— Weak or loose: can be excavated by hand using a spade; a 50 mm × 50 mm square wooden peg can be driven easily with a hand-held hammer.

**split spoon (sampling spoon or split barrel) sampler**: A soil sampler using a driving shoe and split barrel. It is more robust than a thin wall sampler and can be used in a wider range of soil conditions.

**standard penetration test (SPT)**: The number of blows of a 63,5 kg weight falling through a height of 762 mm required to drive the standard split barrel sampler the last 305 mm of penetration gives the N number.

**standpipe**: An open-ended tube with perforations in the circumferential surface which is set in the ground to give a visual indication of the level of the ground water surface.

**static cone penetration test** (also known as the Dutch cone penetration test): A test used initially in the Netherlands to assess soil strength for the purpose of driving piles. The device consists of a cone attached to rods. In addition, a tube of diameter equal to the diameter of the cone is set co-axially over the rods. The device is pushed down into the soil using hydraulic pressure (generally); there are no hammer blows. Initially, the tube and cone are pushed down together (equivalent to the total resistance of a pile). Then, the cone is pushed down by itself (equivalent to the toe resistance of a pile). Soil strength can be related to cone resistance, while the ratio between toe resistance and the skin friction of the tube gives an indication of soil type.

**tell-tale**: Device which is used to give a clear indication of the behaviour of an element of a structure which might otherwise be more difficult to observe. In this case, the term refers to solid rods extending below the ground surface on to an element of the foundation to give visible indications of any movement of the element.

**test loading beam**: A device used to apply a test load to a foundation from a jack. The beam which may be of a simple or multiple structure, is supported at suitable locations away from the foundation under test.

**triaxial compression test**: A laboratory test carried out on undisturbed soil samples contained in an elastic membrane so that a confining pressure can be applied while the sample is tested in direct compression.

**unconfined compressive strength**: The strength of a cohesive soil sample as determined by means of a simple uniaxial compressive test, usually carried out in the field on undisturbed soil samples which are not subjected to any lateral constraints.

**vane shear test**: A test carried out by inserting a standard vane into the soil at varying depths and measuring the torque applied to achieve failure.

## Annex ZA (normative)
## Normative references to international publications with their corresponding European publications

This European 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 publications are listed hereafter. For dated references, subsequent amendments to or revisions, of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| IEC 50(466) | 1990 | International electrotechnical vocabulary (IEV) — Chapter 466: Overhead lines | — | — |
| IEC 826 | 1991 | Loading and strength of overhead transmission lines | — | — |

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