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Overhead lines –
Testing of foundations for structures

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.

3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

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5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.

6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 1773 has been prepared by IEC technical committee 11: Overhead lines.

The text of this standard is based on the following documents:

FDIS	Report on voting
11/111/FDIS	11/117/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

Annexes A, B, C, D, E and F are for information only.

The contents of the corrigendum of March 1997 have been included in this copy.

OVERHEAD LINES –

TESTING OF FOUNDATIONS FOR STRUCTURES

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]*).

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.

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* Figures in square brackets refer to the bibliography given in annex A.

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).

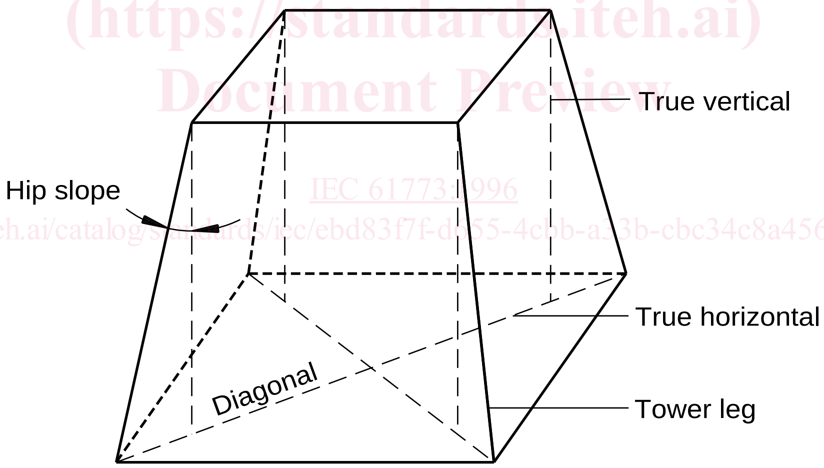

Figure 1 – Leg slope (hip slope) for towers with the shape of a regular frustum or truncated cone

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:

$$L = e + 0{,}7 \times a \quad \text{(m)}$$

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:

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

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 figures 6 a and 6 b);
- hydraulic jack and deadman (see figure 6 c);
- hydraulic jack and weighted platform (see figure 6 d).

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

- single cable line and power source (see figure 7 a);
- multiple-part cable line and power source (see figure 7 b);
- loading line arranged between top of pole and power source (see figure 7 c).