concerned. Embedded guyed supports shall be analysed using an initial out of straightness or inclination.

The slackening of one or more guys as a result of the load distribution in the different load cases applied shall be taken into consideration.

An eccentricity tolerance of 20 mm (in addition to the design eccentricity value) at the ends of a hinged lattice leg shall be applied when calculating bending stresses in the compression leg. The tolerance shall act in the most unfavourable direction considering the response or stress concerned. A smaller value may be used, if this is based on measurements.

If an end eccentricity at the ends of hinged lattice legs is used to compensate for the bending effects of the wind load on the leg, an additional special load case shall be checked as follows: extreme gust wind load on the conductors and extreme 10 min mean wind load on the support.

7.7.4.4 Maximum slendernesses

Maximum slendernesses of structural elements in guyed supports are listed below. The values for legs concern also each span of the leg, if the support contains more than one guy level. For tapered tubular or wood legs the average diameter shall be used for slenderness verification.

- Lattice steel leg (overall slenderness) 150
- Tubular steel leg 150
- Wood leg 250
- Horizontal beam between legs 250 (in multi-guyed portal supports)

7.7.5 Serviceability limit states

The serviceability limits are related to the tower geometry and shall be defined in compliance with the required electrical clearances (to ground and to structure) as given in Clause 5 “Electrical Requirements”.

7.7.6 Design details for guys

The design of the guys shall be based on the tested values of the parameters given in the relevant standards or by the manufacturer.

The effective modulus of elasticity of the guy determined from standard, manufacturer or test shall be used in the analysis. The methods and design parameters of EN 1993-1-11 shall be used, when applicable.

Galvanised steel wire strands or steel ropes with steel core shall be used for the guys. To withstand high fault current in the guy, the steel wires can be complemented with aluminium wires, type AL1/STYZ.

The guys shall be equipped with devices for retightening. The connection between the guy rope and the anchor device shall be accessible. The connections and tightening devices shall be secured against loosening in service.

In the attachment of the guy thimbles, wedge clamps or other relevant equivalent fittings, reliable and documented type tests shall be used. These shall have a reasonable bending radius (proven by tests), if the guy wire will be bent. However, rope clamps are not accepted. See requirements and details in EN 1993-1-11. Additional information may be given in NNA and Project Specification.

The guys used in structures such as V-tower, portal, catenary and double-guyed timber leg tower are generally pretensioned to a small force after the erection of the structure. The effect of this force, usually not greater than 20 kN, may be neglected in the calculations.

The guys used in other structures are generally pretensioned to a specified value in order to reduce the deformation at extreme loads. The pretensioning stress shall be specified as a percentage of the breaking or maximum stress. The angle towers shall be vertical after the stringing of the conductors at the reference condition temperature.

In order to minimise the possibility of guy vibrations the pretension should be normally less than 15 % of the breaking load of the guy. In angle towers higher values may be needed.

At guyed towers, where tubular sections are used as legs, crossarms or horizontals, special attention shall be paid to preventing possible vibration, galloping and fluttering phenomena in the tubular elements.

Where cast steel sockets or cast wedge sockets are used in the guy terminations, freedom from defects in the casting should be ensured by an acceptable non-destructive test or manufacturer's certificate.

The actual out of straightness of the tower leg shall be checked by inspection before erection and shall comply with the design value.

The possible pre-tensioning of the guys shall be checked and maintained during periodical inspections. For a multi-level guyed support, instructions for the erection work are needed because the structure is sensitive to the pre-tensioning of the guys.

Due care shall be taken for protection of the guy in populated areas from possible flashover. In some cases, insulation of the guy may be necessary / recommended. Also, guys that may become slack or made loose by the wind, maintenance or other event shall be considered with respect to electrical safety.

All guys that are anchored in the ground shall be equipped with some means of making the guy as visible as possible.

Due care shall be taken for the protection of the guy from possible exposure to voltage. All guys for wood poles and poles of materials with insulating properties located at a distance less than 0,5 m +D_{el} from live parts, shall be equipped with a sufficiently designed insulator unless the guy is electrically bonded to earth at the ground end or structure end. The earthing shall be such that in the event of failure of the guy, no part shall become live and remain as an electrical risk to the public. If needed, the earthing shall be undertaken at both ends.

For all other guyed poles, the guys shall be included in the support earthing system. They shall be equipped with a guy insulator, if specified in the Project Specification.

The distance between the lower part of the guy insulator and ground shall normally be at least 3,5 m + D_{el}. This distance shall be at least 3,0 m + D_{el} to take account of a guy that has become slackened or loosened at the lower end.

Additional guidance may be given in NNA.

7.8 Other structures

Other structures shall be designed in accordance with the requirements of the parent Eurocodes: EN 1992-1-1 and EN 1993-1-1.

The analysis and the design of other specific structures not covered by the above subclauses shall be agreed between the client and the designer/manufacturer prior to the commencement of the contract.

7.9 Corrosion protection and finishes

7.9.1 General

The supports shall be protected against corrosion in order to fulfil their intended working life according to Clause 3 “Basis of design”, taking into account the intended maintenance regime. The following subclauses include minimum requirements, but enhanced requirements, including compliance with local environmental regulations, may be included in the NNAs or the Project Specification.

7.9.2 Galvanising

Unless otherwise stated in the Project Specification, after completion of all fabrication procedures, all steel material shall be hot-dip galvanised and tested in accordance with EN ISO 1461. The coating mass (unless otherwise stated) shall be in accordance with the requirements of EN ISO 1461.

All steel materials prior to galvanising shall be free from any substance or impurities, which may adversely affect the quality of finish. The preparation for galvanising and the galvanising itself shall not adversely affect the mechanical properties of the coated material. All bolts, screwed rods and nuts, including the male threaded portions, shall be hot-dip galvanised (see EN ISO 1461:2009 – C.2.2).

7.9.3 Metal spraying

Unless otherwise stated in the Project Specification, when pieces are too large or difficult to galvanise, they shall be protected against corrosion by thermal spraying a zinc coating over the base metal, performed according to EN ISO 14713 and in accordance with EN ISO 2063. Zinc deposit thickness shall be not less than 80 µm. When this system is used, the inside surface of hollow sections shall also be protected.

7.9.4 Paint over galvanising in plant (Duplex system)

When a paint coating is to be applied in plant after hot-dip galvanising of steel structures, this coating shall be done as soon as possible.

The coating material shall be lead-free according to national general employee protection regulations. Recommended materials, giving an excellent adherence to new galvanised steel, shall preferably be mono-component materials in a base of vinyl or acrylic copolymers in aqueous dispersion. Usually single layer coatings are applied with dried out thickness of 70 µm to ensure proper protection.

If required by the technical chart of the coating material supplier, the galvanised steel parts shall be shot blasted before coating. As a blasting material, corundum or granules of high grade steel with a size of 0,25 mm to 0,50 mm shall be used for best results. The blasting pressure and distance are determined so that the maximum thickness of zinc blasted away is 10 µm.

The zinc surface of all parts, which are to be coated, shall be dust-free, oil-free and free from all foreign substances as well as free from all zinc corrosive products. These parts shall be coated immediately after surface treatment. Surface preparation and actual painting shall be carried out indoors.

After coating, the part number on each construction part shall remain legible for proper erection work. Connecting parts like gusset-plates need not be coated.

The drying out of coated construction parts shall be carried out sufficiently in the plant, so that no damage to the coated surfaces can arise through transport. In order to avoid transport damage, pieces of double-sided aluminium-coated cardboard or equivalent material shall be inserted between each individual section.

The bundle weight of the coated construction parts shall be assessed such that those elements, which are on the bottom, do not suffer damage due to pressure.

After assembling of supports, all minor uncoated parts (bolts, nuts, gusset-plates, etc.) or parts with damage to the coating shall be coated on site.

7.9.5 Decorative finishes

For daytime aircraft warning systems, attention is drawn to the fact that the paint system used shall be compatible with the underlying surface finish. Due reference to International Civil Aviation Organisation (ICAO) Regulations - annex 14 Chapter 6 or local regulations shall be included in the NNAs or the Project Specification.

7.9.6 Use of weather-resistant steels

The use of weather resistance steels requires special design considerations and full-scale test experience. They shall be used with caution in areas where limited corrosion occurs since some corrosion is necessary to provide the weathering layer.

7.9.7 Protection of wood poles

Wood poles shall be protected from deterioration by impregnation with salt or creosote, or other approved preservative agents against rotting, birds and insects. This protection increases the design service life of the wood.

Particular attention shall be given to augured holes and scarfings, whether they are made before or after impregnation of preservative.

7.10 Maintenance facilities

7.10.1 Climbing

Facilities to allow safe access to structures by authorised personnel shall be as stated in the Project Specification and/or in the NNAs. Where appropriate, this shall include access for live line maintenance. Access to pole cross-arms shall be made preferably by a lightweight, removable device, designed to support the required loads. The design of structures shall take into account the requirements of safe climbing procedures. Each NC shall record in the NNAs the safe method of access to the pole support.

Account shall be taken of the requirements to prevent unauthorised access to supports as specified in 7.10.3.

7.10.2 Maintainability

In addition to climbing attachments, the provision of other attachments/holes for installation of maintenance equipment shall be as stated in the Project Specification and/or in the NNAs.

7.10.3 Safety requirements

The requirements and methods of providing for the following shall be as stated in the Project Specification and/or in the NNAs and shall take into account relevant national (and international) legal obligations such as:

- provision of safety information for the general public (e.g. warning signs, telephone number for emergency contact);
- prevention of unauthorised climbing;
- provision of aids to authorised personnel to enable them to correctly identify energised and de-energised conductors (e.g. circuit identification markings);
- provision for bonding of earth wire and earthing of the support.

7.11 Loading tests

Loading tests on overhead lines supports shall be carried out in accordance with EN 60652.

7.12 Assembly and erection

The workmanship for assembly and erection shall be in conformity with the minimum requirements of EN 1992-1-1, EN 1993-1-1, EN 1995-1-1 and EN 1090-1.

8 Foundations

8.1 Introduction

Foundations fulfil the task of transferring the structural loads from the support to the subsoil, as well as protecting the support against critical movements of the subsoil.

The general requirements of EN 1997-1:2004 (Sections 1 to 5) and EN 1997-2:2007 should be considered.

The following subclauses give complementary details for the specific purpose of the foundations of overhead lines.

Subclause 8.2 introduces the basis of geotechnical design (section 2 of EN 1997-1:2004). Sample calculation models are given in Annex M.

Subclause 8.3 deals with soil investigation and geotechnical data (section 3 of EN 1997-1:2004 and EN 1997-2:2007).

Subclauses 8.4 and 8.5 refer to supervision of construction, monitoring and maintenance (section 4 of EN 1997-1:2004) as well as fill, dewatering, ground improvement and reinforcement (section 5 of EN 1997-1:2004).

Detailed specifications and additional requirements to those detailed in this clause shall be specified in the NNAs or Project Specification.

Foundations for supports may take the form of single foundations or separate footings for each leg.

The loading on single footings is predominantly in the form of an overturning moment, which is usually resisted by lateral soil pressure, together with additional shear and vertical forces resisted by upwards soil pressure.

Common types of single foundations are monoblock footings, pad or raft footings, grillage footings, caisson or pier foundations, and single pile or pile group foundations.

When separate footings are provided for each leg the predominant loadings are vertical downward and uplift forces. Uplift is usually resisted by dead weight of the foundation bulk, earth surcharges and/or shear forces in the soil. This also applies to guy foundations. Compression loads are countered by the soil resistance.

Common types of separate footing foundations are (stepped) block footings with or without undercut (“pad and chimney”, spread footings), auger bored footings with or without expanded base, pier or caisson foundations, grillage foundations and vertical or raked pile foundations.

8.2 Basis of geotechnical design (EN 1997-1:2004 – Section 2)

8.2.1 General

Foundations for supports shall be considered as foundations of Geotechnical Category 1 or 2 (see Subclause 2.1 of EN 1997-1:2004).

Foundations for overhead lines not exceeding AC 45 kV may be considered as foundations of Geotechnical Category 1 whereas foundations for overhead lines exceeding AC 45 kV should be considered as foundations of Geotechnical Category 2.

8.2.2 Geotechnical design by calculation

The calculation model may consist of any of the following:

- an analytical model;
- a semi-empirical model;
- a numerical model.

The models to be used to determine the foundation resistance are those given in the appropriate code of practice, as given in EN 1997-1, or in the NNAs, or in the relevant literature, or those which have been used with satisfactory practical experience.

Sample analytical models for uplift resistance calculation are given in Annex M.2 for:

- concrete stepped block footings with undercut;
- concrete stepped block footings without undercut.

Sample semi-empirical models for resistance estimation are given in Annex M.3 for:

- monoblock foundations, slab foundations;
- grillage-type slab foundations;
- single-pile foundations;
- separate stepped block foundations ("pad and chimney");
- auger-bored and excavated foundations;
- separate grillage foundations;
- pile foundations.

It shall be verified that the ultimate limit states are not exceeded:

- internal failure or excessive deformation of the structure or structural elements, including footings, piles or basement walls, in which the strength of structural materials is significant in providing resistance (STR);
- failure or excessive deformation of the ground, in which the strength of soil or rock is significant in providing resistance (GEO).

NOTE 1 Limit state GEO is often critical to the sizing of structural elements involved in foundations or retaining structures and sometimes to the strength of structural elements.

When considering a limit state of rupture or excessive deformation of a structural element or section of the ground (STR and GEO), it shall be verified that:

$$E_d \leq R_d$$

E_d is the total design effect of actions on foundations resulting from all the actions on the supports as defined in Clause 4 and from the supports themselves. Partial factors for actions, which depend on the reliability level, are already included in the calculation of the actions on the supports.

R_d is the design resistance of foundations.

Partial factors may be applied either:

- to resistances (R): $R_d = R\{X_k\} / \gamma_R$ (EN 1997-1 Design Approach 2)
- to ground properties (X): $R_d = R\{X_k / \gamma_M\}$ (EN 1997-1 Design Approach 3)

The set of partial factors to be applied to the main ground properties (or soil parameters) in Design Approach 3 is given in the following Table 8.1:

Table 8.1 — Partial factors for soil parameters (according to Annex A of EN 1997-1:2004)

Soil parameters	Symbol	Value
Angle of shearing resistance*	$\gamma_{\phi'}$	1,25
Effective cohesion	$\gamma_{c'}$	1,25
Undrained shear strength	γ_{cu}	1,4
Unconfined strength	γ_{qu}	1,4
Weight density	γ_{γ}	1
* : This factor is applied to tan ϕ'		

Partial factors γ_R to be applied to resistances could be:

- found in Annex A of EN 1997-1:2004 (if it is relevant),
- determined by test or by calculation.

In the former case, the determination of γ_R could be undertaken according to Annex D of EN 1990:2002 (Design assisted by testing).

NOTE 2 Annex M.3 gives partial factors, γ_R for some semi-empirical models for resistance.

The choice of the Design Approach and the values of partial factors shall be specified in NNAs or Project Specification.

EN 1997-1 Design Approach 1 may also be specified in NNAs or Project Specification. In that case, the set of partial factors for actions that shall be used is given in EN 1997-1:2004, Annex A.

In foundation design, limiting values for the foundation movements should be specified in NNAs or Project Specification.

As guidance, limit movement values given in IEC 60826 or in Annex H of EN 1997-1:2004 may be adopted.

8.2.3 Design by prescriptive measures

The foundation of self-supporting wood poles in medium or good soils can be constructed according to the sample rule:

> “Self supporting wood poles shall be erected using direct embedment in the ground. The depth shall be at least 1/7 of the pole length and not less than 1,5 m. The excavation shall be filled with gravel and stones, which shall be carefully compressed to ensure the lateral rigidity of the embedment. Concrete may be used if there is no risk of standing water.”

Good quality backfill or concrete may be required in poor soils.

8.2.4 Load tests and tests on experimental models

Details concerning the preparation of the tests, testing arrangement, test procedure and evaluation are given in EN 61773.

8.3 Soil investigation and geotechnical data (EN 1997-1:2004 – Section 3)

Prior to determination of the type of foundation, and its form and dimensions, the structure of soil below the surface down to a depth of at least the effective width of the foundation, and in the case of a piled foundation, greater than the pile tip depth, shall be known in sufficient detail. Natural risks shall also be considered in the choice of the type of foundation.

Geotechnical investigations shall be planned, taking into account the type of foundation and the required parameters for the design of the foundation.

The soil investigations shall be carried out to such a depth that all layers, which significantly influence the foundation strength, are included. When determining the extent and depth of soil investigations, information already available concerning the pattern, uniformity and characteristics of the individual layers should be taken into consideration. Where justified, further soil investigation may be omitted.

Annex M.1 gives complementary information about geotechnical parameters of soils and rocks.

8.4 Supervision of construction, monitoring and maintenance (EN 1997-1:2004 – Section 4)

Prior to the start of the construction, a plan of contingency actions should be devised which may be adopted if excavations reveal soil characteristics or behaviour outside acceptable limits.

8.5 Fill, dewatering, ground improvement and reinforcement (EN 1997-1:2004 – Section 5)

If backfill is used, its compaction shall be undertaken carefully in order to achieve soil characteristics as close as possible to those of the undisturbed soil.

8.6 Interactions between support foundations and soil

Special attention shall be paid to the interaction of:

- loads deriving from the support;
- loads resulting from active soil pressures and the permanent weight of foundation and soil;
- buoyancy effects of ground water on soil and foundation. These, together with the reaction forces of the soil strata, shall be taken into account in the calculation of the support foundations.

Also, the limit state criteria for:

- acceptable/unacceptable settlement of the foundation, including uneven settlement;
- imposed deformations on the support or support members;
- inclinations of the support (especially angle and dead-end supports),

shall be defined and taken into consideration.

9 Conductors and earth-wires

9.1 Introduction

This clause gives the requirements for conductors and earth wires (ground wires) with or without telecommunication circuits which are attached to overhead line supports.

Conductors and earth wires shall be designed, selected and tested to meet the electrical, mechanical and telecommunications requirements as defined by the line design parameters. Consideration shall also be given to the necessary protection against fatigue due to vibration. Design life may be subject to agreement between the supplier and the purchaser.

Lines strung with covered conductors (in accordance with EN 50397-1) and overhead, insulated cable systems with nominal system voltage exceeding AC 1 kV up to and including AC 45 kV shall be designed according to this standard.

In the following subclauses the term "conductor" should be taken to include "earth wires" and where appropriate, conductors and earth wires with telecommunication circuits.

NOTE This standard does not apply to wrapped cables or all dielectric self supporting (ADSS) telecommunication cables. Similarly it does not include metal clad telecommunication cables which are not used as earth wires.

9.2 Aluminium based conductors

9.2.1 Characteristics and dimensions

Conductors shall be manufactured from round or shaped wires of aluminium or aluminium alloy and can contain zinc coated steel wires or aluminium clad steel wires for strengthening. Earth wires shall be designed to the same standards as phase conductors.

Homogeneous round or formed wire conductors, both all aluminium (AL1) and all aluminium alloy (ALx), and composite round or formed wire conductors, aluminium or aluminium alloy conductor steel reinforced (AL1/STyz or ALx/STyz), aluminium or aluminium alloy conductor aluminium clad steel reinforced (AL1/yzSA or ALx/yzSA) and aluminium conductors aluminium alloy reinforced (AL1/ALx) shall be designed according to EN 50182, EN 62004 or EN 62219 as appropriate.

For conductors with cross-sectional aluminium area in excess of 50 mm² it is recommended that the diameter of the outer layer round wires shall not be less than 2,33 mm.

Material specifications for wire used in these conductors shall be according to EN 50183, EN 50189, EN 60889, EN 61232 and EN 62004 and the design arrangements shall be specified in the Project Specification or agreed by the purchaser with the supplier.

For some projects types of conductors or materials not included in existing EN standards may be used in overhead line construction. In such cases, and in the absence of definitive standards, the Project Specification should specify all the required characteristics together with the relevant methods of test, making reference as appropriate to EN standards.

When materials are used which differ from those in the referenced standards their characteristics and their suitability for each individual application should be verified as specified in this standard or in the Project Specification.

The design of a conductor, including its construction and the characteristics of the materials, shall take into consideration the effect of permanent elongation (long term creep) on the conductor sag.

NOTE Guidance on the methods of design calculation, including an assessment of conductor creep and other characteristics, can be found in IEC 61597 and in EN 61395.

9.2.2 Electrical requirements

The resistivity of the aluminium or aluminium alloy wire shall be selected from the values in EN 50183, EN 60889, EN 62004 and EN 62219. The DC resistance of the conductor at 20 °C shall be calculated according to the principles of EN 50182.

The resistances of a preferred range of round wire conductors are given in EN 50182.

For conductors with different wire sections the conductor resistance shall be calculated using the resistivity of the wire, the cross-sectional area and stranding parameters of the conductor.

The current carrying capacity (ampacity) and the performance under short circuit conditions, particularly the effect on strength, shall be verified against the requirements of the Project Specification. Consideration shall also be given to the predicted radio noise level and audible noise level of conductors for higher voltage systems against the requirements of the Project Specification (see 5.10.1 and 5.10.2).

9.2.3 Conductor service temperatures and grease characteristics

The maximum service temperatures of aluminium based conductors under different operating conditions shall be specified either in the NNAs or in the Project Specification. This shall give some or all of the requirements under the following conditions:

- maximum service temperature at normal line loading;
- maximum short duration temperature for specified times at different line loading(s) above the normal level;
- maximum temperature due to a specified power system fault.

NOTE 1 The use of certain special alloys generally permits the use of higher service temperatures.

Information on the calculation of temperature rise due to short circuit currents is given in EN 60865-1 and in CIGRE Technical Brochure n°207 "Thermal behavior of overhead conductors". Alternatively and with suitable precautions the actual temperature rise due to short circuit currents may be measured during a test.

The Project Specification shall specify the characteristics of the conductor grease to allow for the maximum conductor temperature during normal service and during short duration overloads following a power system fault.

Greases containing soap additives and soap free greases are available. These two types of greases possess different performance characteristics, the most important of which are the oil separation point and the drop point. In the case of soap free greases the drop point may not necessarily exceed 100°C.

NOTE 2 Further information concerning greases and their application is given in EN 50326.

9.2.4 Mechanical requirements

The rated tensile strengths of aluminium based conductors, calculated in accordance with EN 50182 shall be sufficient to meet the loading requirements determined from Clause 4 in conjunction with the partial factors for conductors given in 9.6.2.

When considered necessary, the maximum permissible tensile load in the conductor shall be specified either in the NNAs or in the Project Specification.

9.2.5 Corrosion protection

The purchaser and supplier shall agree the requirement for corrosion protection of conductors, which may include grease and/or zinc coating or aluminium cladding of steel wires.

Grease, when used, shall comply with the requirements of EN 50326. The Project Specification shall specify the type and required amount of grease to be applied during stranding of the conductor. Normally, this shall be selected from one of the cases defined in Annex C of EN 50182. For voltages in excess of 100 kV, grease shall not be applied to the outer layer of wires of the conductor. The properties of the grease shall not allow its migration to the conductor surface during its service life.

The requirements for coating or cladding of steel wires with zinc or aluminium shall be specified in the Project Specification by reference to EN 50189 or EN 61232, as appropriate.

9.2.6 Test requirements

The test requirements for aluminium based conductors shall be as specified in EN 50182.

The Project Specification may also specify requirements for a conductor creep test, or an elastic modulus test.