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Level 2

Design of Overhead Line Structures

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Ref:	NR/L2/CIV/073
Issue:	01
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Red requirements – no variations permitted

- Red requirements are to be complied with and achieved at all times.
- Red requirements are presented in a red box.
- Red requirements are monitored for compliance.
- Non-compliances will be investigated and corrective actions enforced.

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- Amber requirements are monitored for compliance.
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- Guidance is presented with a dotted green sidebar.
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Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
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Issue record

Issue	Date	Comments
01	December 2015	New standard, superseding NR/SP/ELP/27215: <i>Instruction for Design of Overhead Line Structures</i> (Formerly EHQ/ST/O/009)

Compliance

This Network Rail standard is mandatory and shall be complied with by Network Rail and its contractors if applicable from 05 March 2016.

When this standard is implemented, it is permissible for all projects that have formally completed GRIP Stage 3 (Option Selection) to continue to comply with the issue of any relevant Network Rail standards current when GRIP Stage 3 was completed and not to comply with requirements contained herein, unless stipulated otherwise in the scope of this standard.

Reference documentation

Statutory Regulations

The Railways (Interoperability) Regulations 2011 (SI 3066)

The Construction (Design and Management) Regulations 2015

The Health and Safety at Work Act 1974

Network Rail Standards

NR/L2/INI/02009 Engineering Management for Projects

NR/L2/CIV/003 Technical Approval of design, construction and maintenance of Civil Engineering Infrastructure

NR/L2/CIV/072 Wind Loading of Overhead Line Structures

British and European Standards

BS EN 50119 Railway applications – fixed installations – electric traction overhead contact lines (2009 + A1:2013)

BS EN 50122 Railway applications - Fixed installations

Part 1: Protective provisions relating to electrical safety and earthing (2011 + A1:2011)

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

Structural Eurocodes

BS EN 1990	Eurocode 0: Basis of structural design
BS EN 1991	Eurocode 1. Actions on structures
BS EN 1992	Eurocode 2. Design of concrete structures
BS EN 1993	Eurocode 3. Design of steel structures
BS EN 1994	Eurocode 4. Design of composite steel and concrete structures
BS EN 1995	Eurocode 5. Design of timber structures
BS EN 1996	Eurocode 6. Design of masonry structures
BS EN 1997	Eurocode 7. Geotechnical design
BS EN 1998	Eurocode 8. Design of structures for earthquake resistance
BS EN 1999	Eurocode 9. Design of aluminium structures

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Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

Contents

1 Purpose	6
2 Scope	6
3 Definitions	7
4 Engineering assurance	7
5 Fundamental design data	8
6 Basis of design	11
7 Actions on overhead contact lines and support structures	12
8 Load cases and load combinations	18
9 Support structure design	24
10 Support structure construction requirements	26
Appendix A Structural design examples	27
Appendix B Non-contradictory complementary information: background to NR/L2/CIV/073	28
Appendix C Decisions where choice is permitted in BS EN 50119	42
Figure B.1 – Extreme air and conductor temperatures against wind speed (reproduced from Fig 1 in TM-ETR-101)	34
Table 1 – Horizontal deflection criteria for standard systems	10
Table 2 – Recommended return periods for climatic actions in conjunction with construction or maintenance activities	17
Table 3 – Values of ψ factors for Overhead Line Structures	20
Table 4 – Design values of actions	21
Table 5 – Combinations of climatic effects	21
Table 6 – Load combinations: ULS persistent and transient design situations	22
Table 7 – Load combinations: ULS accidental design situations	22
Table 8 – Load combinations: SLS characteristic combination	23
Table 9 – Load combinations: SLS frequent and quasi-permanent combinations	23
Table 10 – Principal Eurocode parts typically required for overhead line structure design	25
Table B.1 – Applicability of Civil Engineering Assurance Forms	29

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

1 Purpose

This standard enables Network Rail to achieve economy, safety and performance in the design of overhead line equipment.

Guidance is provided to the application of design to the structural Eurocodes, as well as supplementary information to the application of BS EN 50119: 2009.

The relevant national standard transposing a European standard is BS EN 50119:2009. NR/L2/CIV/073 has the following relationship with BS EN 50119:2009:

- a) the scope of NR/L2/CIV/073 corresponds with BS EN 50119 section 6;
- b) NR/L2/CIV/073 provides supplementary information which is required to apply BS EN 50119 section 6 to Network Rail infrastructure; therefore NR/L2/CIV/073 takes precedence over BS EN 50119 Section 6;
- c) the purchaser specification referred to in BS EN 50119 should be taken as NR/L2/CIV/073, supplemented by project-specific contract requirements;
- d) as permitted by BS EN 50119, NR/L2/CIV/073 provides the following decisions (listed for completeness in Appendix C):
 - 1) values where alternative values or informative values only are given in BS EN 50119, including values which may be provided in the purchaser specification;
 - 2) country specific data including detail of ice and wind loads;
 - 3) procedures to be used where alternative procedures are given in BS EN 50119;
 - 4) non-contradictory complementary information to assist the user to apply the standard;

NR/L2/CIV/073 has incorporated relevant provisions from BS EN 50119:2009 such that it can be used without direct reference to BS EN 50119:2009.

This standard is one of a suite of Civil Engineering Electrification standards for overhead line equipment as follows:

- NR/L2/CIV/072 Wind Loading of Overhead Line Equipment and Structures
- NR/L2/CIV/073 Design of Overhead Line Structures

These standards implement the structural Eurocodes EN 1990 to EN 1999 for structural design of overhead line equipment structures including foundations.

2 Scope

This standard defines the requirements for structural design of overhead line equipment.

It applies to the design and assessment of structures and foundations for overhead line equipment, including ranges of standard designs, allocation of standard designs and bespoke designs.

This standard should be used by Detail Designers, Assessment Engineers, Allocation Designers, and Project Engineers.

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

3 Definitions

For the purpose of this standard, key terms and definitions given in IEC 60050-811, BS EN 50119:2009 and BS EN 1990 apply, and a selection of the most commonly used terminologies is given below.

Catenary

A longitudinal cable supporting the contact wire or wires either directly or indirectly.

Conductor

The longitudinal cables carrying current, including the contact wire, catenary wires, feeder cables and earth returns.

Contact wire

A bare solid conductor being the lowermost of the wires forming the overhead line equipment. The pantograph carbons of electric trains press against the underside of this wire and collect the electric current required by the trains.

Cantilever

A support structure consisting of one or more transverse members projecting from a mast

Portal

A support structure consisting of a transverse beam and masts situated on either side of the tracks.

Blow-off

Lateral displacement of the contact wire between supports due to wind, excluding deflection of the supports and foundations.

NOTE This definition reflects usage of the term Blow-off in this standard and in NR/L2/CIV/072 Wind Wind Loading of Overhead Line Equipment and Structures. The lateral displacement of the contact wire is only one component of a blow-off failure, which is deemed to have occurred when the wire displacement relative to the pantograph exceeds a critical value. Section 5.4 gives further details.

Two-track cantilever

A structure consisting of a single mast supporting a cantilevered boom extending over two tracks on one side, from which OLE for both tracks may be supported.

4 Engineering assurance

The electrical power design shall be assured in accordance with NR/L2/ELP/27311.

Designs for overhead line equipment supports and foundations (i.e. the civil engineering aspects of the system design) shall be assured in accordance with NR/L2/CIV/003.

The forms to be submitted as part of the design and the design check category shall be agreed between the Contractor's Responsible Engineer and the Project Engineer (Building and Civil Engineering) and may be specified in a Project Specification.

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

Where standard designs are produced or used, they shall be assured in accordance with NR/L3/CIV/151.

NOTE NR/L3/CIV/151 includes further guidance on which approval forms are required.

Where structures are to be attached to existing infrastructure, e.g., viaducts, overbridges, retaining walls etc., details of imposed loadings shall be provided to the Project Engineer, and approval sought from the Asset Owner.

5 Fundamental design data

5.1 General

The structure designer shall obtain key design parameters of the overhead line system as required for the structure design.

They might include:

- a) permanent loads arising from the contact line including contact wire, catenary cable, insulators, tensioning equipment, etc.;
- b) conductor tensions and variations with temperature;
- c) wire set-up temperature (to allow calculation of wire movements with temperature);
- d) residual tensions and load redistributions following a wire-break event;
- e) maximum permitted horizontal and vertical deflections of structural and conductor systems (see Section 5.4).

They may be obtained from the system description manual for the OLE system under consideration, where available.

NOTE BS EN 50119 clauses 4 and 5 define the fundamental requirements for the overhead line system, the electrical system requirements and the mechanical requirements for the contact wire.

5.2 Design life

Major renewals of the structures and foundations shall be planned on the basis of a nominal asset life of 80 to 120 years, according to equipment type, usage and condition. The design life shall be specified by the Electrification & Plant Route Asset Manager.

NOTE: The rationale for the life range is based on twice the design life of the contact wire.

The designer shall provide details of assumed maintenance activities necessary to achieve this design life and of any components of the system which will need to be replaced during this design life.

5.3 Rail systems interfaces

Rail system interfaces shall be taken into account.

They might include the following:

- a) track clearance;

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

- b) structure clearance;
- c) platform edge distances;
- d) signal sighting;
- e) earthing and bonding
- f) anti-climb properties in public areas.

The designer shall establish the party with responsibility for overall interdisciplinary coordination of designs.

NOTE This will depend on the project and contractual arrangements.

The designer shall establish constraints on the support structure design (for example, the available space for construction) at the commencement of the design and shall coordinate with other parties as required.

5.4 Horizontal deflection criteria

The structure designer shall establish the limits for allowable movements of the foundation, structure and contact wire, compatible with the overall performance of the overhead line system.

Limits may be provided from the system description manual for the OLE system under consideration, where available. In the absence of further information, the values provided in Table 1 and clause 5.4.1 may be used.

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Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

Component of movement	Limit
Across-track horizontal displacement of structure alone at contact wire height	50mm
Along-track horizontal displacement of structure alone at contact wire height	100mm
Contact wire displacement (blow-off) between structures	To be considered as part of system design

Table 1 – Horizontal deflection criteria for standard systems

NOTE BS EN 50119 Clause 5.10.1 gives the fundamental requirement for the contact wire to be contained within the pantograph working width under normal operational circumstances. The relative movement of the contact wire and pantograph depends on the complex interaction of various parameters, including: contact wire deflection under wind; track tolerances; vehicle kinetic characteristics; pantograph characteristics; structure deflection under load; and, foundation rotation and deflection under load. Standard practice is to allocate tolerances to cover these parameters, such as those given in Table 1.

NOTE Requirements are also contained in the Energy TSI 1301/2014, BS EN 50367 and BS EN 15273, and these should be considered within the system design.

5.4.1 Two track cantilever deflections

Two track cantilever structures should be verified for these deflection limits:

- along track deflection of each catenary support shall be no greater than 100mm;
- vertical deflection of each piece of equipment on the two track cantilever bridge and conductors shall be no greater than 50mm.

5.5 Tolerances and limits

5.5.1 Height adjustment

Mast height shall be determined based on the height of required attachments and shall include these allowances for adjustment:

- cantilever masts shall have an additional 0.1m above the highest attachment;
- headspan masts shall have an additional 0.15m above the highest attachment.

This additional height shall be included when calculating the permanent load of the mast and wind loading on the mast in accordance with clause 7. Conductors may be assumed to be at their nominal heights.

Where structures are designed to allow future raising of the equipment, such as at bridge faces, then the structures shall be designed assuming the equipment is at the increased height.

5.5.2 Installation tolerances

When considering loads acting upon a structure, an allowance shall be made for increases in the loads due to installation tolerances. Unless specific control

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

measures are put in place, the following increases shall be applied to nominal dimensions:

- a) along-track span lengths shall be increased by 2m;
- b) across track span between headspan masts increased by 1m;
- c) a skew of 1m along track applied to headspan and portal structures.

5.5.3 Future provision

Provision for potential future equipment shall be agreed for the particular project with the Project Engineer or shall be stated in a Project Specification.

Other than as noted in this section, there is no requirement to consider a general increase over the known loads.

6 Basis of design

6.1 New structures

New structures for overhead contact lines shall be designed in accordance with the suite of structural Eurocodes BS EN 1990 to BS EN 1999, as supplemented by this standard.

NOTE This standard provides requirements specific for overhead line structures.

NOTE BS EN 50119 clause 6.1.1 permits the use of the structural Eurocodes as the basis of design.

The structural Eurocodes give requirements for structures to have adequate structural resistance, serviceability, durability and robustness.

The Eurocodes are based on a limit state philosophy and require checks to be made at the Ultimate Limit State and at the Serviceability Limit State. Ultimate Limit States are associated with collapse or failure. Serviceability Limit States concern performance in service such as displacements or deformations.

Design for the limit states is based on the use of structural and load models which cover all relevant design situations and load cases. Structural reliability is achieved by applying partial factors to actions and material properties. The values of the partial factors are given in this standard and vary for different load cases based on the level of structural reliability required.

NOTE The use of partial factors is a different approach to previous permissible stress methods which were based on an overall global factor of safety.

6.2 Existing structures

Existing structures for overhead contact lines may be assessed in accordance with the suite of structural Eurocodes BS EN 1990 to BS EN 1999, as supplemented by this standard which provides requirements specific for overhead line structures.

The designer may need to consider additional or amended provisions outside the scope of the structural Eurocodes in order to justify the retention or reuse of existing structures. This may include, for example, the use of historic or superseded standards which were used in the original design.

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

NOTE NR/L2/CIV/072 allows an accurate determination of wind loads for specific site locations. It is recommended that this should be followed for assessments as it is likely to be beneficial compared with previous standards.

The designer shall record the approach to be used in the assessment, including the applicable standards, in the relevant Engineering Assurance Forms (see clause 4).

7 Actions on overhead contact lines and support structures

7.1 Introduction

Apply these actions in the design of overhead line support structures and foundations:

- permanent actions including dead load and conductor tension (taking into account the variation both of tension and geometry with temperature);
- wind load;
- ice load;
- construction and maintenance loads;
- accidental actions (broken wires).

This section defines representative values of actions, in accordance with BS EN 1990.

Actions shall be applied to generate the worst case for the element being considered.

This might require beneficial actions to be omitted. Some examples are:

- an anchor structure with anchor loads applied but no cantilever loads or vice-versa;
- a back to back cantilever structure where one piece of overhead line equipment has not yet been attached;
- structures supporting a return conductor in addition to other overhead line equipment may be subjected to a worse loading condition if the return conductor is removed;
- double channel structures must be capable of supporting any permissible support combination, e.g., the return conductor is located on either channel;
- mid point and back to back anchor structures must withstand a single broken wire condition, i.e., the greatest individual tension of any wire supported by the structure.

7.2 Permanent actions

Self-weight of supports and their equipment such as cantilevers, tensioning equipment, insulators and span wires shall be applied as permanent loads.

Characteristic weights, G_k , of components and equipment may be obtained from the system design or may be assessed from BS EN 1991-1-1.

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

The tensile force of automatically tensioned conductor wires remains at the same force as the temperature varies and shall be considered as a permanent action, G_k . The magnitude of the tensile force shall be obtained from the system design.

The conductor tensile force of fixed termination equipment varies with temperature and shall be considered at the temperatures given in clause 7.6. This force shall be considered as a permanent action, G_k , applied in the relevant load combinations given in clause 8.

The designer shall establish and include relevant effects including:

- a) position of catenary and contact wires including versine, staggers and deviation at overlaps;
- b) wire movements based on wire set-up temperature and the applicable temperature for the relevant load case;
- c) horizontal across-track component of tension force, dependent on the angle subtended by the conductors at the support, which may vary due to changes in geometry of the support arrangements with temperature;
- d) offset of wire supports from cantilever centroid due to longitudinal wire movement causing eccentric load application about the (typically) minor axis of the support.
- e) auto-transformer feeders including deviation at overhead line structures;
- f) Earth Wires including deviation at overhead line structures.

7.3 Wind loads

Wind loads shall be calculated in accordance with NR/L2/CIV/072.

Differing values of wind load are applied in different load combinations:

- a) characteristic value of 1 in 50 year return period used in conjunction with partial factor on wind loading for Ultimate Limit State checks of structural resistance;
- b) combination value of wind coexistent with ice, used in conjunction with partial factor for Ultimate Limit State checks of structural resistance; this value is numerically equal to 50% of the characteristic 1 in 50 year return period wind load from (a) above;
- c) characteristic value of 1 in 3 year return period used unfactored for Serviceability Limit State checks of displacement; this value is numerically equal to 66% of the characteristic 1 in 50 year return period wind load from (a) above and accounts for the joint probability of a train being within a span coincident with maximum wind gust;
- d) the designer may establish an appropriate reduced wind load to be applied in transient design situations such as construction or maintenance; see 7.7.

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

7.4 Ice loads

Ice loads shall be taken to act upon all along-track conductors with the exception of the contact wire. They shall be assessed as being equivalent to 9.5 mm radial thickness.

Ice loads shall be taken to act upon all exposed parts of the structure and equipment, with the exception of insulators, also with 9.5 mm radial thickness.

An alternative reduced ice thickness may be proposed by the designer on a project-specific basis, subject to agreement in the Engineering Assurance Forms (see clause 4).

The designer shall include supporting justification taking into account the site location and relevant meteorological records.

The density of ice shall be taken as a single value in any particular load combination, being 9 kN/m³ where it increases the load-effect or 5 kN/m³ where it relieves the load-effect under consideration.

Any gaps of less than 75 mm shall be considered to be completely filled with ice.

7.5 Combined wind and ice loads

Combined actions of wind and ice load shall be applied in the design of overhead contact line installations and structures. 100% of the ice load shall be applied according to 7.4. The wind load calculated according to 7.3 and taking into account the increased section area including ice thickness shall be factored by 50%.

For some types and shapes of element, the drag factor for the iced section may be different to the drag factor for the section with no ice. Refer to NR/L2/CIV/072 for details of the drag factor.

7.6 Temperature effects

The effects of temperature shall be considered in conjunction with the other climatic actions:

- the minimum temperature to be considered with no other climatic action shall be determined for the specific site location. It shall be taken as the 1 in 50 year return period minimum shade air temperature in accordance with the NA to BS EN 1991-1-5;
- the ambient reference temperature for the extreme wind load condition shall be taken as 10 °C;
- the temperature to be assumed with combined wind and ice load shall be taken as -5 °C;
- the reference temperature for accidental design situations and quasi permanent effects shall be taken as -5 °C.

The effects of temperature include:

- variations in tensions (and hence horizontal components of tensions) in fixed conductors;

Ref:	NR/L2/CIV/073
Issue:	01
Date:	05 December 2015
Compliance date:	05 March 2016

- b) change to direction of application of the load and geometry of the OLE support arrangements for auto tensioned conductors.

7.7 Construction and maintenance loads

7.7.1 General

The designer shall establish appropriate construction and maintenance loads to be applied in the design.

This should take into account the envisaged construction sequence and reasonably foreseeable maintenance activities which could occur during the design life of the support structure and foundation. This may include consideration of future replacement of the conductor and contact line system, working procedures, temporary guying, lifting arrangements, etc.

In complying with the CDM Regulations, the designer shall check that the assumptions on construction and maintenance loads and future operations, including any restrictions on construction and maintenance, are clearly recorded on the design drawings and the designer's risk assessments. These risk assessments shall be included in the relevant engineering assurance forms.

If the overhead line will be operational (for example, during a phased construction sequence), the situation shall be considered as a permanent case (i.e., the construction or maintenance load shall be applied as a persistent design situation in accordance with BS EN 1990). No reduction in wind or ice loading shall be applied and the full range of Ultimate Limit State and Serviceability Limit State checks including displacement checks shall be carried out in accordance with clauses 8 and 9.

If the overhead line will not be operational during the application of the construction and maintenance loads, the construction or maintenance load shall be applied as a transient design situation and the Serviceability Limit State displacement checks should not be carried out.

7.7.2 Maintenance loads

Structural elements shall not be designed for loading arising from person-access during maintenance, where access will be mechanised or from independent platforms and will not load the structure.

Maintenance loads which can only arise due to the presence of people (for example, imposed weight of people or lifting loads) and which cannot remain in the absence of people, shall be considered to act in the absence of wind and ice, at a reference temperature of -5 °C. Structural elements which are intended to support one person shall be designed for a minimum characteristic vertical maintenance load of 1 kN.

In the absence of specific detail from the system design, on structures supporting Structure Mounted Outdoor Switchgear, an additional maintenance load of 3750 N shall be considered at 1500mm from the cress side face of the mast at the height of the installation and maintenance jib.