EUROPEAN ASSESSMENT DOCUMENT

EAD 340109-00-0106

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FLEXIBLE AVALANCHE PROTECTION KIT

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This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD applies to flexible avalanche protection kits used in starting areas of avalanches to decrease the probability of avalanche in works with various topographic scenario and snow height.

If the supporting surface and/or supporting structure are able to follow in a certain extent the movement of the snow layer, the supporting surface or supporting structure is called flexible. The supporting surface is formed by net and net supporting ropes, while the supporting structure is formed by posts and base structures (Figure 1.1.1).

This EAD is applicable to flexible avalanche protection kits for use in works for:

- Slope inclination 30°≤ ψ ≤ 50°
- Angle of posts from the surface of ground 60° ≤ α ≤ 80° or
- Angle of net chord from normal to the surface of ground -5° ≤ δ ≤ 30°.

The EAD for flexible avalanche protection kits applies for ground roughness classes as specified in Table A.3 for slope inclination as above and for any intended vertical height of snow cover (unless applicability of assessment methods is limited).

The flexible avalanche protection kits can be arranged in two main ways as continuous structures and separated structures. The continuous structures consist of long horizontal rows of structures extended across the entire controlled area. They are interrupted only in those sections of the terrain that are unaffected by starting zones (Figure 1.1.1). The arrangement of separated (interrupted) structures is derived from that of continuous structures by inserting gaps in the horizontal rows (Figure 1.1.1).

The flexible avalanche protection kits (Figure 1.1.1) are made up from components: principal net, support structure (posts and base structure) and connection components.

a) **Principal net** is made of up of metallic ropes, wires and/or bars of different types, for example rope nets joined with clamps or wires, submarine nets, ring nets, chain link wire nets or other types.

The principal net can deform elastically and/or plastically while transferring the snow load to the connection components or directly to the support structure.

b) **Support structure** made up of steel posts (for example hot rolled, cold-formed and welded sections) and base structures in different geometry and dimensions.

The post to base structure connection is rotation free.

The connection device to the foundation ensures the transmission of the forces to the foundations in a design-compliant direction.

c) **Connection components** consist of metallic ropes (net supporting rope, upper and lower rope, lateral rope, guy rope or other), wires, wire rope grips, rope clips, shackles and/or other types of connection members.

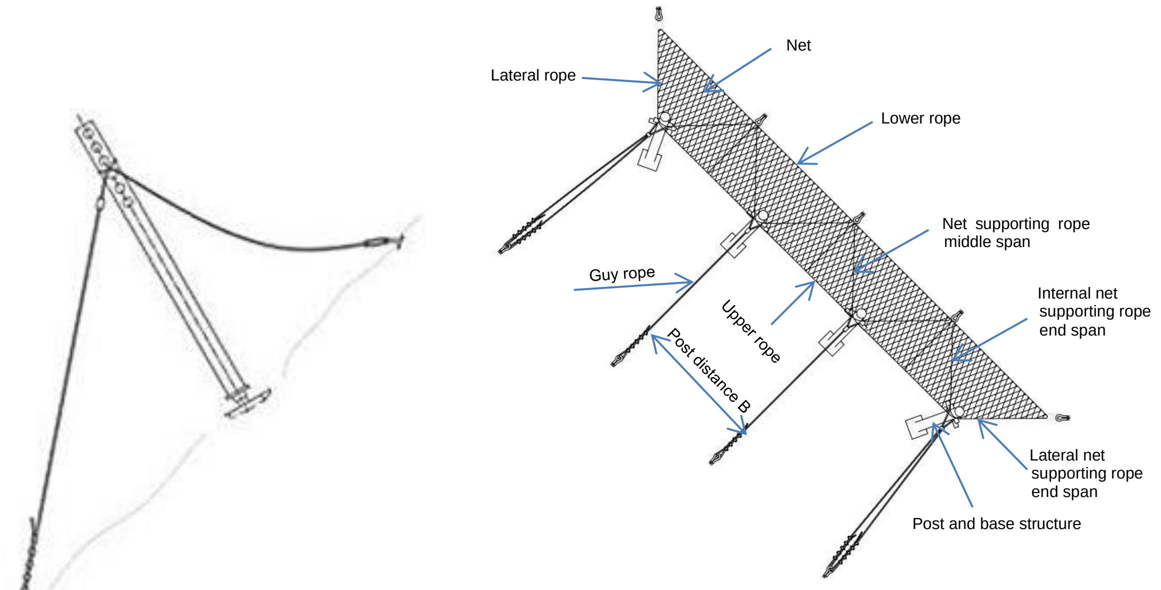
The basic dimensions of kit resulting from snow height, depicted in Figure 1.1.2, are:

1. Effective height of flexible avalanche protection kit D_K: distance, measured orthogonally to the idealised slope, of the upper edge of the supporting surface from the ground. The posts exceed the effective height at least by 500 mm.

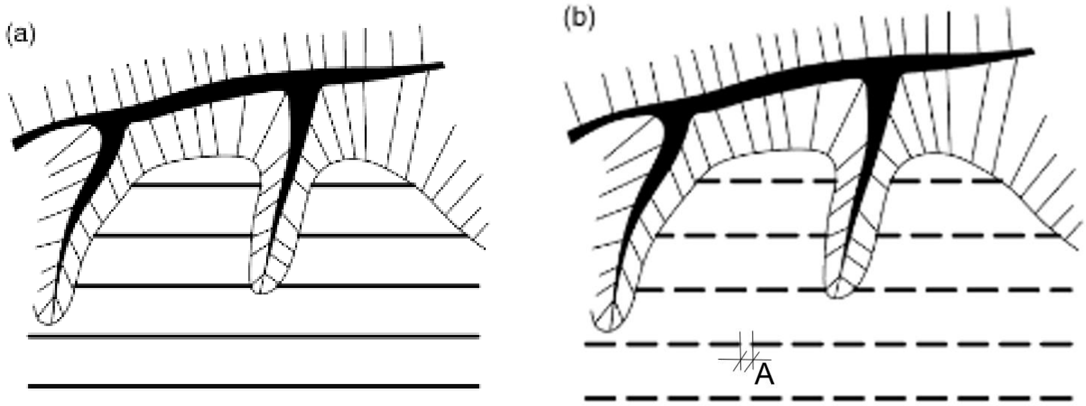
2. Net length B_K: length of the supporting surface (net and net supporting ropes) parallel to the contour line.

3. Height of structure H_K: vertical distance of the upper edge of the supporting surface from the idealised slope.

The foundations and anchorages are not covered in this EAD.



NOTE - Example of kit for which each rope (upper, lower, net supporting, guy and lateral) and post is protected with net.



Continuous structure

Separated, interrupted structure, the distance between the separated structures is *A*

Figure 1.1.1 – Example of flexible avalanche protection kit

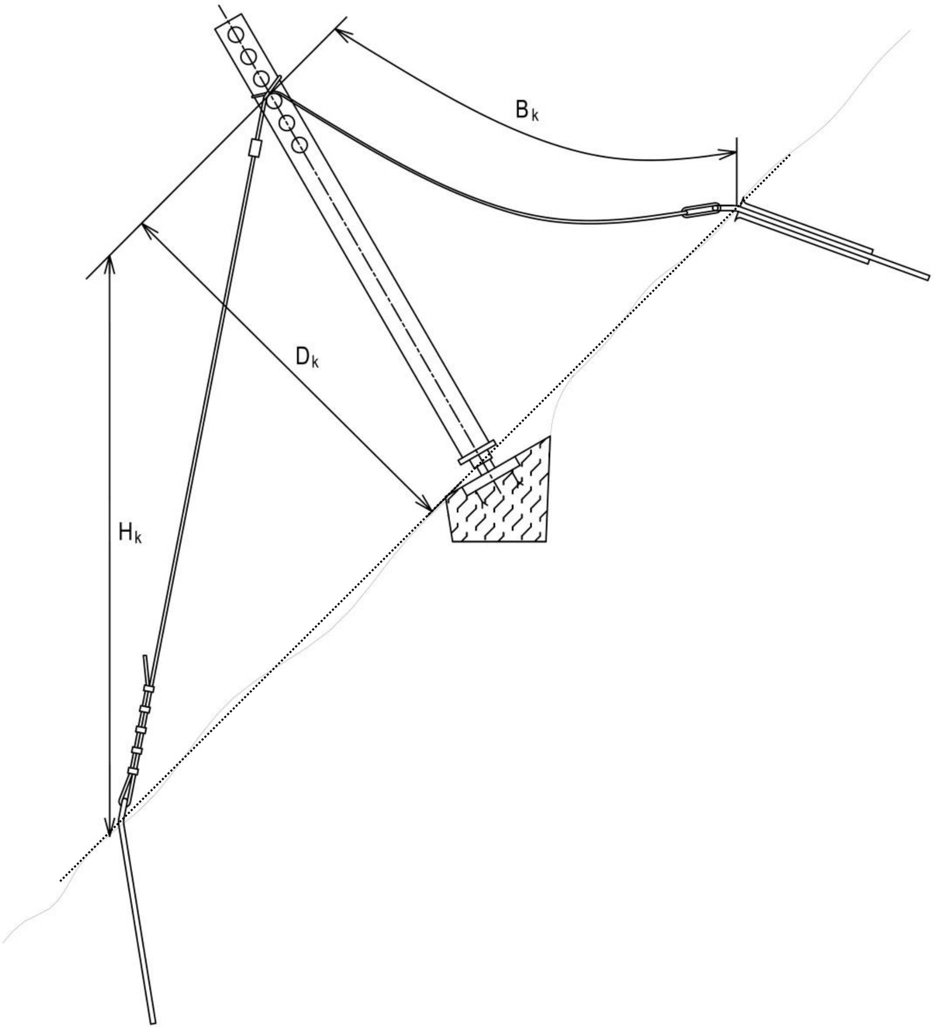


Figure 1.1.2 – Basic dimensions of kit

The product is not covered by a harmonised European standard (hEN).

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use(s)

Flexible avalanche protection kits are intended to be used on natural slopes for the given ground roughness classes and slope exposure and for the given vertical height of snow cover:

To avoid avalanches in the starting zone;

Keeping snow where it falls down and stabilizing steep snow-covered slopes.

This EAD covers a range of ambient temperature of [-20 °C; +50 °C].

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the Manufacturer's request to take into account a working life of the flexible avalanche protection kits for the intended use of 25 years, when installed in the works, provided that the kit is subject to appropriate installation, use and maintenance. This working life is intended to be assumed under consideration of the atmospheric conditions according to EN ISO 9223[1] in terms of corrosivity category C2. For corrosivity categories C3 and C4 according to EN ISO 9223 the working life of 10 years for products according to this EAD applies. These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product, the intended use as foreseen by the Manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product Manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

1.3 Specific terms used in this EAD

1.3.1 Symbols

f	Initial sag of net or ropes (m)
f_c	Altitude factor (-)
f_R	End-effect factor (-)
f_S	Reduction factor for flexible supporting surface (-)
g	Gravitational acceleration (m/s²)
h_k	Reduced height (m)
l_w	Cut off length of organic coated wire (m)
l_R	Length of assessed rope (m), (mm)
$n_{1,m}$, n_{2m} ,,$n_{3,m}$ $n_{1,e}$, n_{2e} ,,$n_{3,e}$	Area factors for attributed load on ropes (-)
p	Bearing capacity of subsoil (kN/m²)

1 All undated references to standards or to EAD's in this EAD are to be understood as references to the dated versions listed in clause 4.

2 The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

q_d	Maximum uniformly distributed load (kN/m)
$q_d(4)$	Maximum quasi-permanent load (kN/m)
$q_{d,end}(4)$	Maximum quasi-permanent load with end-effect (kN/m)
$q_d(5)$	Maximum variable load (kN/m)
$q_{d,end}(5)$	Maximum variable load with end-effect (kN/m)
$q_d(6)$	Maximum quasi-permanent load on the bottom (kN/m)
q_k	Characteristic uniformly distributed load (kN/m)
$q_k(4)$	Characteristic quasi-permanent load (kN/m)
$q_k(5)$	Characteristic variable load (kN/m)
$q_k(6)$	Characteristic quasi-permanent on the bottom (kN/m)
$q_{Nk,P}$	Characteristic direct transversal load on post not protected by net surface (kN/m)
$q_{Nk,R}$	Characteristic direct transversal load on rope not protected by net surface (kN/m)
ΔL	Length of load with end-effect (m)
A	Distance between separated structures (m)
A_m	Cross-sectional area of concerned rope (mm^2)
B	Post distance (m)
B_K	Net length (m)
D	Snow thickness (m)
D_c	Wire diameter with organic coating (mm)
D_K	Effective height (m)
E	Modulus of elasticity of concerned rope (N/mm^2)
$F_{1,m}, F_{2,m}, F_{3,m}$ $F_{1,e}, F_{2,e}, F_{3,e}$	Attributed areas to net, lower and upper ropes (m^2)
$F_{end,int}$	Upslope anchor force, internal anchor in end span (kN)
$F_{end,int}$	Upslope anchor force, external anchor in end span (kN)
$F_{end,guy}$	Anchor force of guy rope adjacent to end spans (kN)
F_{guy}	Anchor force of guy rope adjacent to middle spans (kN)
F_{int}	Upslope anchor force in middle spans (kN)
F_{prism}	Prism area (m^2)
G_k	Characteristic vertical prism load (kN/m)
G_k (4)	Characteristic quasi-permanent vertical prism load (kN/m)
G_k (5)	Characteristic variable vertical prism load (kN/m)
$G_{k\perp}(4)$	Characteristic quasi-permanent prism load orthogonally to the net chord (kN/m)
$G_{k\perp}(5)$	Characteristic variable prism load orthogonally to the net chord (kN/m)
G_{Nk}	Component of G_k parallel to the slope (kN/m)
G_{Qk}	Component of G_k normal to the slope (kN/m)
H	Horizontal reaction (kN), (N)
H_K	Height of structure (m)
H_S	Vertical height of snow cover (m)
K, K_1, K_2	Creep factor (-)

L	Length of net chord (m)
L_K	Length according to Figure A.3 (m)
L_N	Length of net rope (m)
L_P	Length of post (m)
L_R	Length of concerned rope (m)
M_{Ed}	Maximum bending moment in post (kNm)
$M_{Ed,max}$	Maximum bending moment in net (kNm)
$M_{pl,Rd}$	Plastic moment resistance (kNm)
N	Glide factor (-)
N_{Ed}	Maximum compression force in post (kN)
N_{int}	Characteristic action on foundation in intermediate post (kN)
N_{end}	Characteristic action on foundation in external post (kN)
P_{Ed}	Resultant of horizontal and vertical reactions (tension force in net or rope) (kN)
P_{Ek}	Characteristic resultant of horizontal and vertical reactions (kN)
P_{Rk}	Characteristic tension resistance of net (kN/m) or rope (kN)
Q_d	Average uniformly distributed maximum load (kN/m)
$Q_{d,end}$	Average uniformly distributed maximum load with end-effect (kN/m)
Q_{Nd}	Slope-parallel component of average uniformly distributed maximum load Q_d (kN/m)
$Q_{Nd,end}$	Slope-parallel component of average uniformly distributed maximum load Q_d with end-effect (kN/m)
Q_{Qd}	Component of average uniformly distributed maximum load Q_d orthogonally to the slope
$Q_{Qd,end}$	Component of average uniformly distributed maximum load $Q_{d,end}$ with end-effect orthogonally to the slope (kN/m)
R_k	Magnitude of characteristic resultant (kN/m)
$R_{k,end}$	Magnitude of characteristic resultant with end-effect load (kN/m)
$R_{k\perp}$	Characteristic component of resultant R_k orthogonally to the net chord (kN/m)
$R_{k\perp}(4)$	Characteristic quasi-permanent load component orthogonally to the net chord (kN/m)
$R_{k\perp,end}(4)$	Characteristic quasi-permanent load component orthogonally to the net chord with end-effect load (kN/m)
$R_{k\perp}(5)$	Characteristic variable load component orthogonally to the net chord (kN/m)
$R_{k\perp,end}(5)$	Characteristic variable load component orthogonally to the net chord with end-effect load (kN/m)
$R_{k\perp}(6)$	Characteristic quasi-permanent load component on the bottom orthogonally to the net chord (kN/m)
$R_{k\perp,end}$	Characteristic component of resultant R_k orthogonally to the net chord with end-effect (kN/m)
R_{kII}	Characteristic component of resultant R_k parallel to the net chord (kN/m)
$R_{kII,end}$	Characteristic component of resultant R_k parallel to the net chord with end-effect (kN/m)
R_{Nk}	Characteristic slope-parallel load component (kN/m)
$R_{Nk,end}$	Characteristic slope-parallel load component with end-effect (kN/m)

R_{Qk}	Characteristic load component orthogonally to the slope (kN/m)
$R_{\mathrm{Qk,end}}$	Characteristic load component orthogonally to the slope with end-effect (kN/m)
S_0	Length of rope with sag (mm)
$S_{\mathrm{k}\perp}(4)$	Characteristic quasi-permanent load (kN/m)
$S_{\mathrm{k}\perp}(5)$	Characteristic variable load (kN/m)
$S_{\mathrm{k}\perp}(6)$	Characteristic quasi-permanent load on the bottom (kN/m)
$S_{\mathrm{k}\perp}(7)$	Characteristic quasi-permanent end-effect load (kN/m)
$S_{\mathrm{k}\perp}(8)$	Characteristic variable end-effect load (kN/m)
S_{Nk}	Characteristic slope-parallel snow load (kN/m)
S_{Rk}	Increased characteristic snow load due to end-effect (kN/m)
U	Utilization (-)
V	Vertical reaction (kN), (N)
V_{Ed}	Maximum shear force in post (kN)
$V_{\mathrm{c,Rd}}$	Shear resistance of transversal post components (kN)
Z	Altitude (m)
Z_{C}	Tension force in guy rope (kN)
α	Angle of posts or ropes from the surface of ground (°)
$\gamma_{\mathrm{M,net}}$	Partial factor for tension resistance of net (-)
γ_{Q}	Partial factor for variable snow load (-)
$\gamma_{\mathrm{Q(S)}}$	Partial factor for “quasi-permanent” snow load (-)
δ	Angle of net chord from normal to the surface of ground (°)
ε_k	Direction of characteristic resultant from the idealised slope (°)
$\varepsilon_{k,end}$	Direction of characteristic resultant from the idealised slope with end-effect (°)
η_{k}	Influence factor (-)
ρ	Density of snow cover (kg/m^3)
ψ	Slope inclination (°)

Indexes for uniformly distributed characteristic and maximum snow loads in formulas (A.46) to (A.102)

m	Middle span
e	End span
nr	Net rope
lr	Lower rope
up	Upper rope
2	Load case 2
3	Load case 3
a	Distribution option “a”
b	Distribution option “a”
l	Lateral net rope in end span
i	Internal net rope in end span

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of flexible avalanche protection kit is assessed in relation to the essential characteristics.

Table 2.1.1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	Load bearing capacity expressed by characteristic snow load acting on the flexible avalanche protection kit	2.2.1	Level, S_{Nk} (kN/m)
2	Anchor forces, actions on foundations (forces) and their directions	2.2.2	Level (kN) and description
3	Durability	2.2.3	Description
Basic Works Requirement 3: Hygiene, health and the environment			
4	Content, emission and/or release of dangerous substances - leachable substances	2.2.4	Description

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as “shall be stated in the ETA” or “it has to be given in the ETA” shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

Testing will be limited only to the essential characteristics which the manufacturer intends to declare. If for any components covered by harmonised standards or European Technical Assessments the manufacturer of the component has included the performance regarding the relevant characteristic in the Declaration of Performance, retesting of that component for issuing the ETA under the current EAD is not required.

2.2.1 Load bearing capacity expressed by characteristic snow load acting on the flexible avalanche protection kit

Assessment method

The load bearing capacity expressed by characteristic snow load acting on the flexible avalanche protection kit shall be calculated according to the method described in Annex A.

Expression of results

The following information shall be stated in the ETA:

- The calculated characteristic snow load S_{Nk} (kN/m) acting on flexible avalanche protection kit.
- The effective height of kit D_K (m), glide factor N (-) and snow density ρ (kg/m^3) for which the characteristic snow load has been calculated.
- The applied load case/s for which the characteristic snow load has been calculated.

2.2.2 Anchor forces, actions on foundations and their directions

Assessment method

The forces acting on anchors and foundations shall be calculated according to the method described in Annex A.

Expression of results

The characteristic or maximum anchor forces (kN) acting on each anchor and actions on foundations together with the scheme of their acting points and directions shall be stated in the ETA.

2.2.3 Durability

The durability is assessed under consideration of the corrosivity categories according to EN ISO 9223 for each component, according to standards relevant for the given type of corrosion protection, as follows:

- Post and base structures (made of carbon steel) hot dip galvanized according to EN ISO 1461;
- For components made of stainless steel it shall be assessed according to EN 1993-1-4, Annex A if the component is suitable for the atmospheric conditions according to EN ISO 9223 for which the kit is intended to be used in and with respect to the intended working life.
- For ropes/wires it shall be assessed according to EN 10264-2/EN 10244-2 if the coating is suitable for atmospheric conditions according to EN ISO 9223 for which the kit is intended to be used in and with respect to the intended working life.
- Wire rope grips/clips, shackles and other ancillaries hot dip galvanized according to EN ISO 1461 or zinc plated according to EN ISO 4042 or non-electrolytically zinc flake coated according to EN ISO 10683 and EN 13858 or zinc-nickel coated according to EN ISO 19598.

Type and thickness/mass of coating shall be stated in the ETA.

2.2.4 Content, emission and/or release of dangerous substances

The performance of the product related to the emissions and/or release and, where appropriate, the content of dangerous substances will be assessed on the basis of the information provided by the manufacturer[3], after identifying the release scenarios taking into account the intended use of the product and the Member States where the manufacturer intends his product to be made available on the market The identified intended release scenarios for this product and intended use with respect to dangerous substances is:

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3 The manufacturer may be asked to provide to the TAB the REACH related information which he must accompany the DoP with (cf. Article 6(5) of Regulation (EU) No 305/2011). The manufacturer is **not** obliged:

- to provide the chemical constitution and composition of the product (or of constituents of the product) to the TAB, or
- to provide a written declaration to the TAB stating whether the product (or constituents of the product) contain(s) substances which are classified as dangerous according to Directive 67/548/EEC and Regulation (EC) No 1272/2008 and listed in the "Indicative list on dangerous substances" of the SGDS.
- Any information provided by the manufacturer regarding the chemical composition of the products may not be distributed to EOTA or to TABs.

S/W1: Product with direct contact to soil-, ground- and surface water.

The leaching of dangerous substances therefore has to be checked.

2.2.4.1 Leachable substances

For the intended use covered by the release scenario S/W1 the performance of the organic coating of wire, if organic coating is used, concerning leachable substances is to be assessed. A leaching test with subsequent eluate analysis must take place, each in duplicate. Leaching tests of the organic coating of wire are conducted according to CEN/TS 16637-2 for scenario I according to Annex A, clause A.1. The leachant shall be pH-neutral demineralised water and the ratio of liquid volume to surface area shall be (80 ± 10) l/m². Each test specimen to be tested shall be prepared by cutting off the piece of finally organic coated wire of length l_w (mm) calculated according to equation:

$$l\mathrm{w} = \frac{40000}{\pi \times D_c{}^2}$$

where l_w (mm) cut off length of organic coated wire

D_c wire diameter with organic coating, if relevant.

After that, cut off pieces of organic coated wire are wound into a coil of diameter suitable for following preparation of eluates.

In eluates of "6 hours" and "64 days", the following biological tests shall be conducted:

- Acute toxicity test with Daphnia magna Straus according to EN ISO 6341;
- Toxicity test with algae according to ISO 15799;
- Luminescent bacteria test according to EN ISO 11348-1, EN ISO 11348-2 or EN ISO 11348-3.

For each biological test, EC20-values shall be determined for dilution ratios 1:2, 1:4, 1:6, 1:8 and 1:16.

If the parameter TOC is higher than 10 mg/l, the following biological tests shall be conducted with the eluates of "6 hours" and "64 days" eluates:

- Biological degradation according to OECD Test Guideline 301, part A, B or E.

Determined toxicity in biological tests shall be expressed as EC20-values for each dilution ratio. Maximum determined biological degradability must be expressed as "…% within …hours/days". The respective test methods for analysis shall be specified.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the products covered by this EAD the applicable European legal act is: Decision 2003/728/EC(EU).

The system is: 1

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1.

The manufacturer (regarding the components he buys from the market with DoP) shall take into account the Declaration of Performance issued by the manufacturer of that component. No retesting is necessary.

Table 3.2.1 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC)					
1	Wire or wire of rope of principal net : Tension strength, breaking force bend (if relevant) torsion (if relevant), corrosion protection	EN 10264-2 EN 10244-2	EN 10264-2 EN 10244-2	5 samples/type (from different coils)	Once / year
2	Principal net: Dimensions Designation of principal net Tension strength	Mass-check by machine operator According to control plan	According to control plan According to control plan	According to control plan 5 samples per type	By each change of production Once / year
4	Posts and base structures: Steel grade Dimensions Corrosion protection Welding	EN 1090-2 EN 1090-2 EN 1090-2 EN 1090-2	According to control plan According to control plan According to control plan According to control plan	1 per type 1 per type 3 tests per lot are requested with at least 3 tests per 50 posts/base structures For each post, welding shall be verified by visual check	Each delivery (inspection document according to EN 10204, type 3.1 or 2.2) Each delivery In addition, at least one Non-destructive test - NDT (type of NDT shall be relevant for the selected weld) each year for each supplier shall be performed.

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
5	Ropes: Designation Breaking force Corrosion protection	EN 12385-2+A1 EN 12385-4+A1 EN 10264-2	According to control plan According to control plan According to control plan	Checking the inspection documents, each delivery	Inspection document of type 3.1 or 2.2 according to EN 10204
6	Ropes both sides with pressed loop: Breaking force	EN 13411-3+A1	According to control plan	5 samples per type	Once / year
7	Shackles: Breaking load limit (BLL) Corrosion protection or other connection component	EN 13889+A1 or control plan EN ISO 1461, EN ISO 4042, EN ISO 10683 or other relevant standard	According to control plan According to control plan	5 samples per type	Once / year

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.3.1

Table 3.3.1 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control *(for systems 1+, 1 and 2+ only)*					
1	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the "**flexible avalanche protection kits**"	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	When starting the production or a new line
Continuing surveillance, assessment and evaluation of factory production control *(for systems 1+, 1 and 2+ only)*					
2	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	1/year

4 REFERENCE DOCUMENTS

CEN/TS 16637-2:2014	Construction products. Assessment of release of dangerous substances. Part 2: Horizontal dynamic surface leaching test
EAD 230004-00-0106:11-2014	Wire ring mesh panels
EAD 230005-00-0106:11-2014	Wire rope net panels
EAD 230008-00-0106:03-2015	Double twisted steel wire mesh reinforced or not with ropes
EAD 230025-00-0106:12-2015	Flexible facings systems for slope stabilization and rock protection
EN 10204:2004	Metallic products. Types of inspection documents
EN 10244-2:2009	Steel wire and wire products. Non-ferrous metallic coatings on steel wire. Part 2: Zinc or zinc alloy coatings
EN 10264-2:2012	Steel wire and wire products. Steel wire for ropes. Part 2: Cold drawn non alloy steel wire for ropes for general applications
EN 1090-2:2018	Execution of steel structures and aluminium structures. Part 2: Technical requirements for steel structures
EN 12385-2:2002+A1:2008	Steel wire ropes. Safety. Part 2: Definitions, designation and classification
EN 12385-4:2002+A1:2008	Steel wire ropes. Safety. Part 4: Stranded ropes for general lifting applications
EN 1337-1:2000	Structural bearings. Part 1: General design rules
EN 13411-3:2004+A1:2008	Terminations for steel wire ropes. Safety. Part 3: Ferrules and ferrule securing
EN 13858:2006	Corrosion protection of metals. Non-electrolytically applied zinc flake coatings on iron or steel components
EB 13889:2003+A1:2008	Forged steel shackles for general lifting purposes. Dee shackles and bow shackles. Grade 6. Safety
EN 1990:2002/A1:2005/AC:2010	Eurocode 0. Basis of Structural Design
EN 1993-1-1:2005/A1:2014	Eurocode 3: Design of steel structures. Part 1-1: General rules and rules for buildings
EN 1993-1-11:2006/AC:2009	Eurocode 3. Design of steel structures. Part 1-11: Design of structures with tension components
EN 1993-1-4:2006/A2:2020	Eurocode 3. Design of steel structures. Part 1-4: General rules. Supplementary rules for stainless steels
EN 1993-1-8:2005/AC:2009	Eurocode 3. Design of steel structures. Part 1-8: Design of joints
EN ISO 10683:2018	Fasteners. Non-electrolytically applied zinc flake coatings
EN ISO 11348-1:2008/A1:2018	Water quality. Determination of the inhibitory effect of water samples on the light emission of Vibrio fischeri (Luminescent bacteria test). Part 1: Method using freshly prepared bacteria
EN ISO 11348-2:2008/A1:2018	Water quality. Determination of the inhibitory effect of water samples on the light emission of Vibrio fischeri (Luminescent bacteria test). Part 2: Method using liquid-dried bacteria
EN ISO 11348-3:2008/A1:2018	Water quality. Determination of the inhibitory effect of water samples on the light emission of Vibrio fischeri (Luminescent bacteria test). Part 3: Method using freeze-dried bacteria
EN ISO 1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods

EN ISO 19598:2016	Metallic coatings. Electroplated coatings of zinc and zinc alloys on iron or steel with supplementary Cr(VI)-free treatment
EN ISO 4042:2018	Fasteners. Electroplated coatings
EN ISO 6341:2012	Water quality. Determination of the inhibition of the mobility of Daphnia magna Straus (Cladocera, Crustacea). Acute toxicity test
EN ISO 9223:2012	Corrosion of metals and alloys. Corrosivity of atmospheres. Classification, determination and estimation
ISO 15799:2019	Soil quality. Guidance on the ecotoxicological characterization of soils and soil materials
OECD GUIDELINE 301 FOR TESTING OF CHEMICALS Adopted by the Council on 17th July 1992	Ready Biodegradability

ANNEX A: CALCULATION OF CHARACTERISTIC SNOW LOAD

A.1 Scope

The aim of this Annex is to calculate the characteristic snow load as the load bearing capacity acting on the kit. Considering the knowledge of behaviour of structure and predominantly static (quasi static) character of load, for assessment of components` load bearing capacities, structural analyses is considered to be sufficient.

A.2 Determination of characteristic snow load

A.2.1 Assumptions

a) For determination of characteristic snow load, iterative approach is employed. In this procedure the self-weight of kit is neglected.

b) The iterative approach is based on calculation of characteristic snow load, step by step gradually approaching the "first" total, or utilization (U) from the set of resistance checks.

c) The utilization U shall be from the interval $\langle 0{,}95;\ 1{,}0 \rangle$.

d) The value of snow density ρ is the variable parameter.

e) The selected and final snow density shall be from the interval (200 kg/m^3; 400 kg/m^3).

f) For determination of internal forces and moments the elastic global analysis and first order theory applies according to clause 5.4.2 of EN 1993-1-1.

g) Structural analysis for serviceability limit state is not required.

h) The elastic global analysis is performed by simplified hand calculations.

i) The load bearing capacity of kit shall be calculated from capacity of net and/or ropes.

j) The capacity of ropes is based on their minimum breaking force according to EN 12385-2, clause 3.10.10.

k) The structural steel components (posts and base structures) are assessed based on the characteristic snow load according to clause A.2.6.

A.2.2 Input data

A.2.2.1 Load cases

The permanent load (self-weight of structure) is neglected in the following load cases, only the snow load is taken into account (leading load):

a) Load case 1: the snow load acts on the full height H_K.

b) Load case 2: is derived from load case 1, when the same amount of snow, due to snow consolidation, acts on the reduced height $h_K = 0{,}77 \cdot H_K$ (Figure A.1).

   The resultant magnitude and its direction are calculated with the same method as for load case 1. The snow load is greater by 1/0,77 = 1,3 in comparison with load case 1. The location of application of resultant is theoretically in lower position, what means in height $h_K/2 = 0{,}385 \cdot H_K$ (see Figure A.1).

   The snow load in load case 2 is applied on full height H_K for the calculations. The resultant of snow load for assessment of net and ropes is considered to act in the centre line of height H_K.

   For calculations of loads on posts and forces in anchors and post supports (foundations), the snow load resultant is considered in position of $0{,}385 \cdot H_K$.

c) Load case 3: some configurations (seaside, heavy fluctuation of snow limit with heavy precipitation) the load case 3 applies (Figure A.2).

d) The applied load case/s shall be given in ETA.

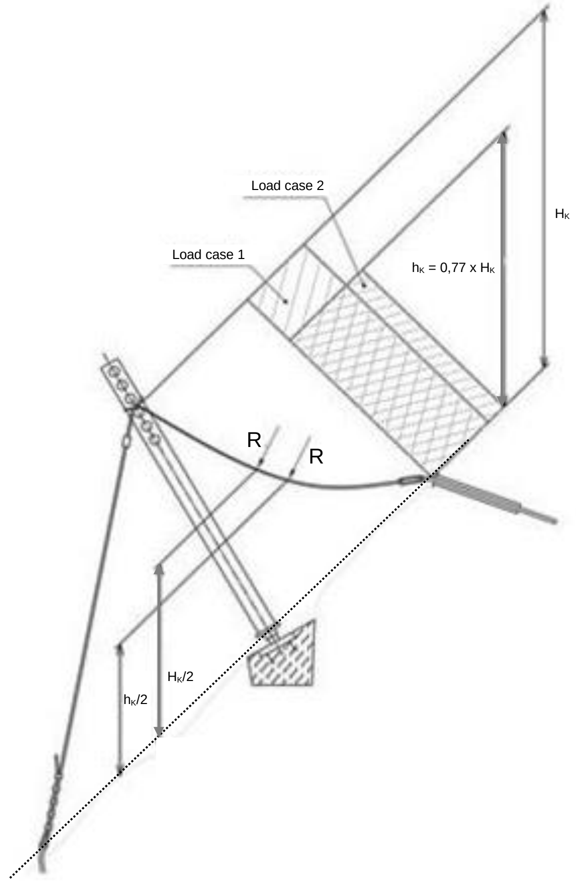
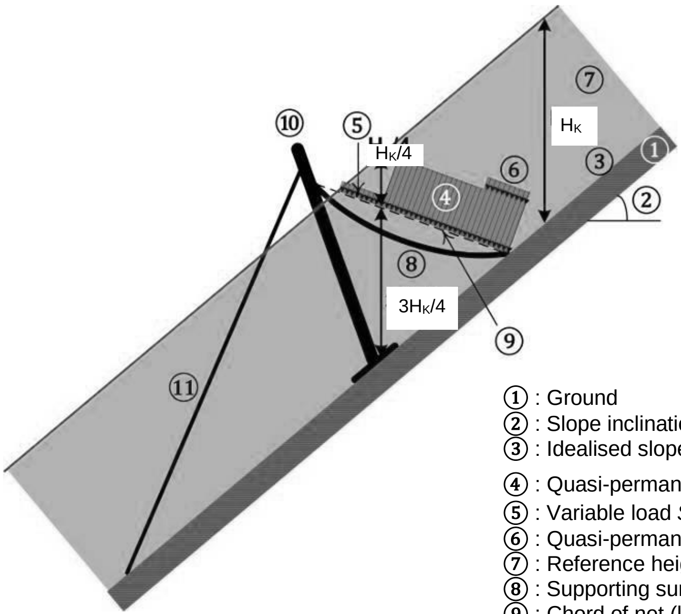


Figure A.1 – Application of snow load: load case 1 and load case 2



① : Ground
② : Slope inclination ψ
③ : Idealised slope
④ : Quasi-permanent load $S_{k\perp}(4)$ on length $3 \cdot L/4$
⑤ : Variable load $S_{k\perp}(5)$ on length $L/4$
⑥ : Quasi-permanent load $S_{k\perp}(6)$ on the bottom part of net on length $L/4$
⑦ : Reference height H_k (vertical height of snow cover)
⑧ : Supporting surface
⑨ : Chord of net (length L)
⑩ : Post and base plate – support structure
⑪ : Guy rope

Figure A.2 – Application of snow load: load case 3

A.2.2.2 Partial factors

The basic partial factors to be implemented into assessment are summarized in Table A.1.

Table A.1 – Basic partial factors

Partial factor for variable load action (snow):	$\gamma_Q = 1,5$	EN 1990, Table AI.2(A)
Partial factor for "quasi-permanent" snow load action:	$\gamma_{Q(S)} = 1,35$	Only in load case 3 EN 1990, Table AI.2(A)
Partial factor for tension resistance of net:	$\gamma_{M,net}$[1)]	

[1)] In case, the characteristic resistance and partial safety factor is not provided, the following procedure applies:
The characteristic 5%-fractile of tension resistance of net P_{Rk} (kN/m) measured in a test series (at least four samples in series) is calculated according to D7.2, EN 1990 for normal distribution and known coefficient of variation and value of k_n depending on the number of tests in series. The design value of tension resistance of net P_{Rd} (kN/m) is calculated according to D7.3, EN 1990 known coefficient of variation and value of $k_{d,n}$ depending on the number of tests in series.
The tensile tests on nets is performed for example according to:
For rope nets: EAD 230004-00-0106
For ring nets: EAD 230005-00-0106
For hexagonal double twisted wire nets with or without inserted ropes: EAD 230008-00-0106
For chain link wire nets: EAD 230025-00-0106

A.2.2.3 Input parameters

a) The slope inclination $\psi = 45°$ applied in calculations covers the range of applicable slope inclination $30° \leq \psi \leq 50°$.

b) The snow thickness D, ground roughness class and exposure are parameters to define the intended use.

c) The vertical height of snow cover is equal to vertical height of structure $H_S = H_K$.

d) The snow thickness D (according to formula (A.1)) is equal to the effective height of kit D_K measured orthogonally to the idealised slope.

e) The altitude Z is determined based on the snow density corresponding to the characteristic snow load.

Load case 2

f) The value α = (70° to 75°) applied in calculations covers the range of angle of posts from the surface of ground $60° \leq \alpha \leq 80°$.

Load case 3

g) The value $\delta = 30°$ used in calculations covers the range of applicable angle of net chord from normal to the surface of ground $-5° \leq \delta \leq 30°$.

h) In case, the post distance (see Figure 1.1.1) is not provided, the following distances apply for the given D_K:

D_K = 2,5 (for all N values): B = 4,0 m

D_K = 3,0 (for all N values): B = 4,0 m

D_K = 3,5 (for all N values): B = 3,5 m

D_K = 4,0 (for all N values): B = 3,5 m

D_K = 4,5 (for all N values): B = 3,5 m

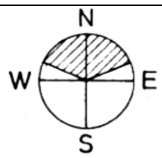
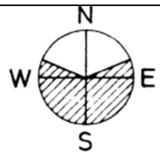
i) Creep factor depends on snow density and slope inclination and it is taken from Table A.2.

j) Glide factor N expresses the increase of snow load caused by movement of snow cover on the ground. Consequently, the glide factor depends on four ground roughness classes and two types of exposure. The glide factors are listed in Table A.3.

Table A.2 – Creep factor *K*

ρ (kg/m³)	200	300	400	500	600
$K/\sin(2\psi)$	0,70	0,76	0,83	0,92	1,05
For intermediate values of ρ interpolation is possible.					

Table A.3 – Informative values of glide factor *N*

Ground roughness classes	**Glide factor *N***	
	Exposure WNW-N-ENE	**Exposure ENE-S-WNW**
		
Class 1		
• Coarse scree (d ≥ 30 cm) • Terrain heavily populated with smaller and larger boulders	1,2	1,3
Class 2		
• Areas covered with larger alder bushes or dwarf pine at least 1 m in height • Prominent mounds covered with grass and low bushes (height of mounds over 50 cm) • Prominent cow trails • Coarse scree (from 10 cm to 30 cm)	1,6	1,8
Class 3		
• Short grass interspersed with low bushes (heather, rhododendron, bilberry, alder bushes and dwarf pine below approx. 1 m in height) • Fine scree (d ≤ 10 cm) alternating with grass and low bushes • Smallish mounds of up to 50 cm in height covered with grass and low bushes, and also those alternating with smooth grass and low bushes • Grass with shallow cow trails	2,0	2,4
Class 4		
• Smooth, long-bladed, compact grass cover • Smooth outcropping rock plates with stratification planes parallel to the slope • Smooth scree mixed with earth • Swampy depressions	2,6	3,2
For surface types lying between the specified classes, intermediate values of *N* may be interpolated. When the inclination of the terrain lies above 45°, strict conditions shall be applied in determining N. For inclinations below 35° the conditions can be less strict, but the lower values of glide factors shall be verified.		

A.2.3 Step by step calculation of snow load

The predominant load on snow supporting structures is the static snow load, which appears because of the:

- Creep movement (creeping pressure), when the translation movement on the soil is zero and maximum on the snow surface;

and where present

- Glide movement (gliding pressure), the entire snow cover is displaced uniformly.

Step by step procedure for snow loads calculation:

a) Select the snow density ρ for the first calculation step from range of 200 kg/m³ up to 400 kg/m³.

b) Calculate the snow thickness *D*.

$$D = H_S \cdot \cos\psi \quad \text{(m)} \tag{A.1}$$

where

H_S (m) vertical height of snow cover

ψ (= 45°) slope inclination

c1) Calculate the characteristic slope – parallel snow load component acting on flexible supporting surface of kit theoretically installed normally to the slope, **load case 2**.

The characteristic **slope – parallel component** of creeping and gliding pressure on flexible supporting surface of infinite length installed in normal direction to the slope is:

$$S_{\mathrm{Nk}} = \rho \cdot g \cdot K \cdot f_{\mathrm{S}} \cdot \frac{H_{\mathrm{S}}^2}{2} \cdot N \cdot f_{\mathrm{c}}/1000 \quad \text{(kN/m)} \qquad \text{(A.2)}$$

where

ρ (kg/m³) selected value of density of snow cover

g (≈ 10 m/s²) gravitational acceleration

f_S reduction factor for flexible supporting surface, for normal glide conditions is taken as 0,8

N glide factor as specified in Table A.3 for the ground roughness class and exposure

f_c altitude factor according to formula (A.3)

K creep factor depending on slope inclination ψ and snow density ρ see Table A.2

H_S (m) vertical height of snow cover, for load case 1 (and 2) equal to the effective height of kit $H_S = H_K$

The altitude factor f_c represents the increase of density of snow with altitude Z (metres above sea level). The increment of snow density with altitude between 1500 m and 3000 m above sea level is set to 2 % per 100 m:

$$f_{\mathrm{c}} = 1 + 0{,}02\left(\frac{Z}{100} - 15\right) \qquad \text{(A.3)}$$

Specific case

When taking into account the average density of snow ρ = 270 kg/m³ (is considered to be valid for basic site altitude of 1500 m above sea level and exposure WNW-N-ENE) and K = 0,74 (see Table A.2) for sin(2ψ) = 1,0 (slope inclination ψ = 45°) the multiple $\rho \cdot g \cdot K/2 = 270 \cdot 10 \cdot 0{,}74/2 = 999$ N/m³ ≈ 1,0 kN/m³. Substituting this multiple into equation (A.2) and replacing the vertical height of snow cover H_S with height of structure H_K the equation (A.2) is reduced to simplified formula (A.3.1).

The characteristic slope-parallel component (in kN/m) of creeping and gliding pressure of snow load for infinite length installed in normal direction to the slope and for specific conditions above is simplified to:

$$S_{\mathrm{Nk}} = 1 \cdot f_{\mathrm{S}} \cdot H_{\mathrm{K}}^2 \cdot N \cdot f_{\mathrm{c}} \quad \textit{(kN/m)} \qquad \textit{(A.3.1)}$$

c2) Calculate the snow loads for **load case 3** for infinite length installed normally to the slope.

In load case 3 the following loads are considered to **act orthogonally to the net chord**.

K_1 creep factor depending on slope inclination ψ and snow density ρ, see Table A.2.

K_2 creep factor depending on slope inclination ψ and snow density ρ/1,2, see Table A.2.

For other parameters see clause A.2.3, c1).

i) The characteristic quasi-permanent load (snow load $S_{k\perp}(4)$, see Figure A.2) is calculated according to formula (A.2) substituting "S_{Nk} = by $S_{k\perp}(4)$ =" for height H_K, snow density ρ and creep factor K_1.

ii) The characteristic variable load (snow load $S_{k\perp}(5)$, see Figure A.2) is calculated according to formula (A.2) substituting "S_{Nk} = by $S_{k\perp}(5)$ =" for height H_K/3, snow density ρ/1,2 and creep factor K_2.

iii) The characteristic quasi-permanent load on the bottom part of net (snow load $S_{k\perp}(6)$, see Figure A.2) is calculated according to formula (A.2) substituting "S_{Nk} = by $S_{k\perp}(6)$ =" for height $0{,}257 \cdot H_K$, snow density ρ and creep factor K_1.

d) Calculate the supplementary characteristic snow load acting on flexible supporting surface of kit installed not normally to the slope.

For kit installed not normally to the slope, vertically acting characteristic load G_k of snow prism formed by the net area and the area normal to the slope passing through the upslope edge of the net (see Figure A.3) shall be added to the snow load.

L**oad case 2:** vertical characteristic snow prism load G_k:

$$G_{\mathrm{k}} = F_{\mathrm{prism}} \cdot \frac{S_{\mathrm{Nk}}}{K \cdot N \cdot f_{\mathrm{S}} \cdot \frac{H_{\mathrm{K}}^2}{2}} \qquad \text{(kN/m)} \qquad \text{(A.3.2)}$$

where

F_{prism} (mm²) shaded area in Figure A.3.

Component of G_{k} parallel to the slope:

$$G_{\mathrm{Nk}} = G_{\mathrm{k}} \cdot \cos(\psi) \qquad \text{(kN/m)} \qquad \text{(A.3.3)}$$

Component of G_{k} normal to the slope:

$$G_{\mathrm{Qk}} = G_{\mathrm{k}} \cdot \sin(\psi) \qquad \text{(kN/m)} \qquad \text{(A.3.4)}$$

For calculation of prism area F_{prism} the initial shape of net sag is considered as circular arc. The recommended maximum value of initial sag is 15 % of length L of net chord.

The length L_k (m) for calculation of prism area is calculated from the geometry of the kit (Figure A.3).

L**oad case 3:** vertical characteristic snow prism loads $G_k(4)$ and $G_k(5)$:

i) The characteristic quasi-permanent vertical snow prism load $G_k(4)$ is calculated according to formula (A.3.2) substituting "G_k = by $G_k(4)$ =" (see Figure A.3) for height H_K, snow density ρ and creep factor K_1 and F_{prism}.

ii) The characteristic variable vertical snow prism load $G_k(5)$ is calculated according formula (A.3.2) substituting "G_k = by $G_k(5)$ =" (see Figure A.3) for height $H_K/3$, snow density $\rho/1{,}2$ and creep factor K_2 and F_{prism}.

Calculate the characteristic component orthogonally to the net chord of quasi-permanent and variable vertical snow prism load:

Quasi-permanent:

$$G_{k\perp}(4) = G_k(4) \cdot \sin(\psi + \delta) \qquad \text{(kN/m)} \qquad \text{(A.3.5)}$$

Variable:

$$G_{k\perp}(5) = G_k(5) \cdot \sin(\psi + \delta) \qquad \text{(kN/m)} \qquad \text{(A.3.6)}$$

For calculation of prism area F_{prism} the initial shape of net sag is considered as circular arc. The recommended maximum value of initial sag is 15 % of length L of net chord.

The length L_k (m) for calculation of prism area is calculated from the geometry of the kit (Figure A.3).

NOTE – In load case 3, the component parallel with the plane of net chord is neglected.

e) Calculate the course of snow load due to end-effect

The end-effect on the avalanche structure depends on a distance (separated structures) to the next neighbouring avalanche structure (Figure 1.1.1).

Load case 2: If the distances between separated structures (see Figure A.4) are not provided, the calculations shall be made for both cases:

a) $A > 2{,}0$ m

b) $A \leq 2{,}0$ m

The end-effect characteristic snow loads S_{Rk} are applied as supplementary distributed slope-parallel loads over length of ΔL:

$$S_{\mathrm{Rk}} = f_{\mathrm{R}} \cdot S_{\mathrm{Nk}} \qquad \text{(kN/m)} \qquad \text{(A.4)}$$

where f_{R} is the end-effect factor as follows:

$$f_{\mathrm{R}} = (0{,}92 + 0{,}65 \cdot N)\frac{A}{2} \leq (1{,}00 + 1{,}25 \cdot N) \qquad \text{(A.5)}$$

If the distances between separated structures A are not provided the following values are taken into account:

a) for A > 2,0 m: f_{R} = (1,00 + 1,25 · N)

b) for A ≤ 2,0 m: f_{R} according to formula (A.5) with A = 2,0 m

The length ΔL on which the increased end-effect characteristic snow load S_{Rk} acts is:

$$\Delta L = 0{,}60\frac{A}{2} \leq \frac{D_{\mathrm{K}}}{3} \qquad \text{(m)} \qquad \text{(A.6)}$$

If the distance between separated structures A is not provided the following values apply:

a) for A > 2,0 m ΔL = D_{K}/3 (m)

b) for A ≤ 2,0 m ΔL according to formula (A.6) with A = 2,0.

The increased snow load S_{Rk} and length ΔL is calculated from the assumption that the resultants of actual course of snow load and simplified course of snow load are equal.

The load distribution in longitudinal direction of kit in **load case 2** is depicted in Figure A.4

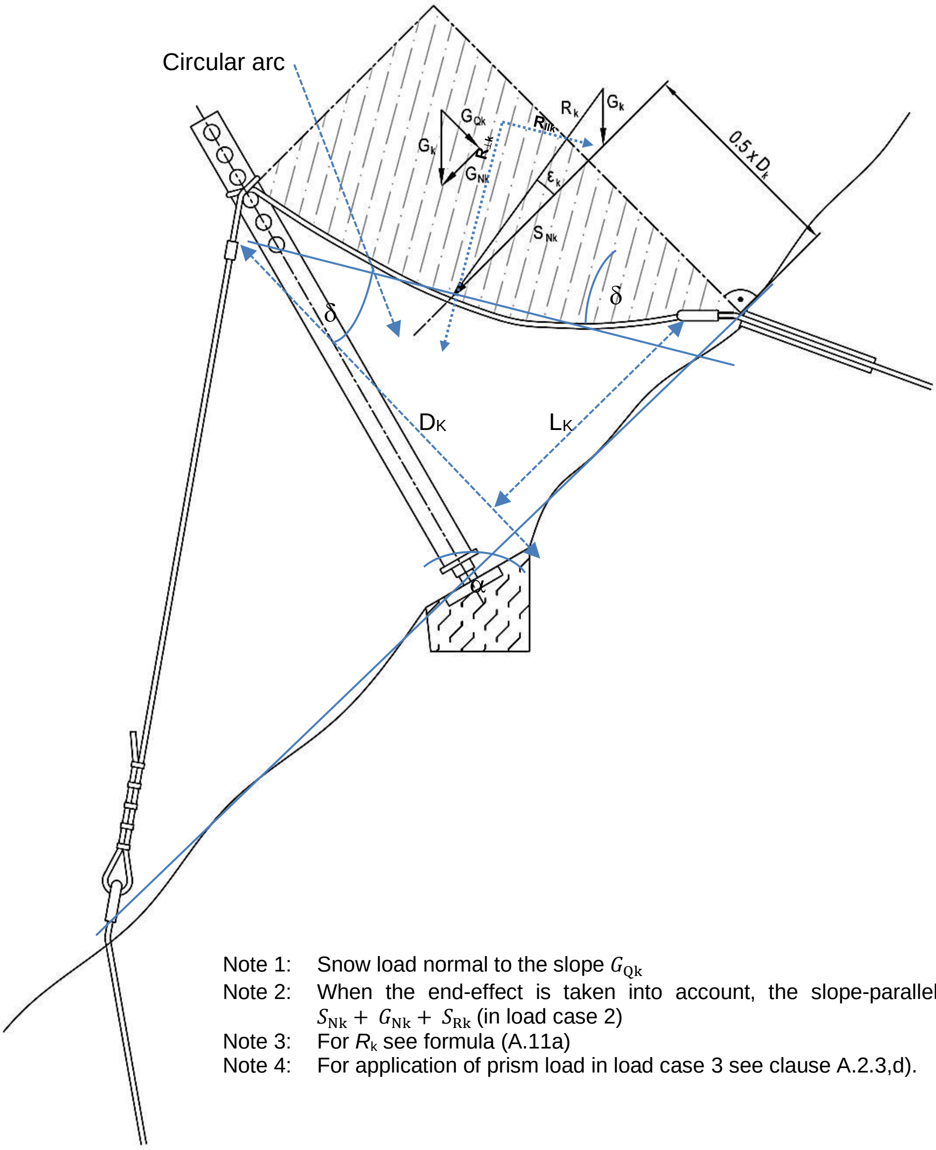
In certain cases, a symmetrical distribution of snow load shall be applied despite non-equal loading of the two ends of the structure, taking into account the greater value of the two end-effect loads. This concerns in particular the case of shorter structures at their unprotected ends when there is an increased risk of dynamic loads.

Load case 3: The load distribution in longitudinal direction of kit in load case 3 is depicted in Figure A.5.

i) The characteristic quasi-permanent end-effect load $S_{\mathrm{k}\perp}(7)$ = $S_{\mathrm{k}\perp}(4)$ · f_{R}, where $S_{\mathrm{k}\perp}(4)$ is calculated according to clause A.2.3,c2),i) and f_{R} is calculated according to formula (A.5). If the distance between separated structures is not provided, use A = 1,60 m. The distance A is to be given in ETA within the product description.

ii) The characteristic variable end-effect load $S_{\mathrm{k}\perp}(8)$ = $S_{\mathrm{k}\perp}(5)$ · f_{R}, where $S_{\mathrm{k}\perp}(5)$ is calculated according to clause A.2.3,c2),ii) and f_{R} is calculated according to formula (A.5). If the distance between separated structures is not provided, use A = 1,60 m. The distance A is to be given in ETA within the product description.

iii) The effective length of application of load with end-effect is according to formula (A.6).



Note 1: Snow load normal to the slope G_{Qk}

Note 2: When the end-effect is taken into account, the slope-parallel force is $S_{\mathrm{Nk}} + G_{\mathrm{Nk}} + S_{\mathrm{Rk}}$ (in load case 2)

Note 3: For R_{k} see formula (A.11a)

Note 4: For application of prism load in load case 3 see clause A.2.3,d).

Figure A.3 – Snow loads on supporting surface

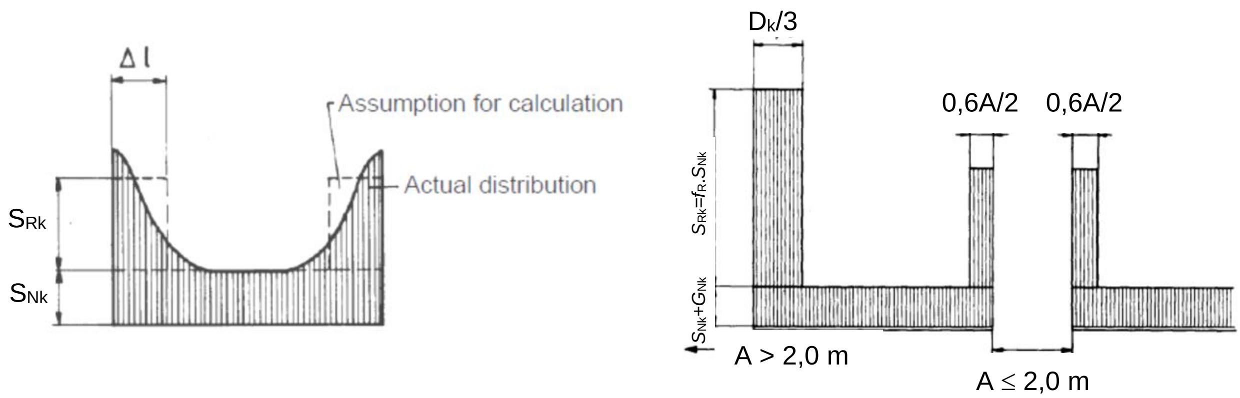
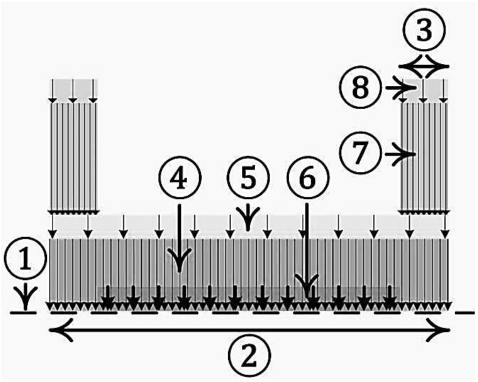


Figure A.4 – Distribution of slope-parallel snow load with end-effect in longitudinal direction, load case 2



① : Level line of average ground plane
② : Ground length of single module
③ : Length of application of end-effect load ΔL
④ : Quasi -permanent load $S_{k\perp}(4)$
⑤ : Variable load $S_{k\perp}(5)$
⑥ : Quasi-permanent load $S_{k\perp}(6)$ on the bottom part of net
⑦ : Quasi-permanent end-effect load $S_{k\perp}(7)$
⑧ : Variable end-effect load $S_{k\perp}(8)$

Figure A.5 – Distribution of slope-parallel snow load with end-effect in longitudinal direction, load case 3

f) Calculate the magnitude and direction of characteristic snow load resultant, **load case 2**

For infinite structure:

Characteristic slope-parallel load component:

$$R_{\mathrm{Nk}} = S_{\mathrm{Nk}} + G_{\mathrm{Nk}} \qquad \text{(kN/m)} \qquad \text{(A.7)}$$

Characteristic load component orthogonally to the slope:

$$R_{\mathrm{Qk}} = G_{\mathrm{Qk}} \qquad \text{(kN/m)} \qquad \text{(A.8)}$$

For structure with end-effect the end-effect loads S_{Rk} are added to the characteristic slope-parallel load component:

$$R_{\mathrm{Nk,end}} = S_{\mathrm{Nk}} + G_{\mathrm{Nk}} + S_{\mathrm{Rk}} \qquad \text{(kN/m)} \qquad \text{(A.9)}$$

For structure with end-effect the characetirstic load component orthogonally to the slope remains unchanged:

$$R_{\mathrm{Qk,end}} = G_{\mathrm{Qk}} \qquad \text{(kN/m)} \qquad \text{(A.10)}$$

The magnitude of characteristic resultant R_{k} is a vectorial sum of load components (in Figure A.3, in case of end-effect loads, the symbol R_{k} is to be changed to $R_{\mathrm{k,end}}$):

$$R_{\mathrm{k}} = \sqrt{{R_{\mathrm{Nk}}}^2 + {R_{\mathrm{Qk}}}^2} \qquad \text{(kN/m)} \qquad \text{(A.11a)}$$

$$R_{\mathrm{k,end}} = \sqrt{{R_{\mathrm{Nk,end}}}^2 + {R_{\mathrm{Qk,end}}}^2} \qquad \text{(kN/m)} \qquad \text{(A.11b)}$$

The direction ε_{k} of characteristic resultant from the idealised slope (in Figure A.3, in case of end-effect loads, the symbol ε_{k} is to be changed to $\varepsilon_{\mathrm{k,end}}$):

$$\varepsilon_{\mathrm{k}} = \arctan\left(\frac{R_{\mathrm{Qk}}}{R_{\mathrm{Nk}}}\right) \qquad \text{(A.12a)}$$

$$\varepsilon_{\mathrm{k,end}} = \arctan\left(\frac{R_{\mathrm{Qk,end}}}{R_{\mathrm{Nk,end}}}\right) \qquad \text{(A.12b)}$$

The point (line in longitudinal direction) of resultant application is assumed in the centre line of height H_{K} of structure.

If the angle δ is not provided, it is calculated from geometry of kit as δ = arctan ($L_{\mathrm{k}}/D_{\mathrm{k}}$).

The characteristic component of resultant R_{k} orthogonally to the net chord in load case 2 (in Figure A.3, in case of end-effect loads, the symbol $R_{\mathrm{k}\perp}$ is to be changed to $R_{\mathrm{k}\perp,\mathrm{end}}$):

$$R_{k\perp} = R_k \cdot \cos(\delta - \varepsilon_k) \quad \text{(kN/m)} \qquad \text{(A.13a)}$$

$$R_{k\perp,end} = R_{k,end} \cdot \cos(\delta - \varepsilon_{k,end}) \quad \text{(kN/m)} \qquad \text{(A.13b)}$$

The characteristic component of resultant R_k parallel to the net chord (in Figure A.3, in case of end-effect loads, the symbol R_{kII} is to be changed to $R_{kII,end}$):

$$R_{kII} = \sqrt{(R_k^2 - R_{k\perp}^2)} \quad \text{(kN/m)} \qquad \text{(A.14a)}$$

$$R_{kII,end} = \sqrt{\left(R_{k,end}^2 - R_{k\perp,end}^2\right)} \quad \text{(kN/m)} \qquad \text{(A.14b)}$$

g) Calculate the characteristic snow load resultant (direction of load orthogonally to the net chord) in **load case 3** (see Figure A.2 and the input values in formulas (A.15) to (A.19) are given in clauses A.2.3, c2) and d))

For infinite structure (middle spans):

$$R_{k\perp}(4) = S_{k\perp}(4) + G_{k\perp}(4) \quad \text{(kN/m)} \qquad \text{(A.15)}$$

$$R_{k\perp}(5) = S_{k\perp}(5) + G_{k\perp}(5) \quad \text{(kN/m)} \qquad \text{(A.16)}$$

$$R_{k\perp}(6) = S_{k\perp}(6) \quad \text{(kN/m)} \qquad \text{(A.17)}$$

For structure with end-effect loads (end spans):

$$R_{k\perp,end}(4) = S_{k\perp}(4) + G_{k\perp}(4) + S_{k\perp}(7) \quad \text{(kN/m)} \qquad \text{(A.18)}$$

$$R_{k\perp,end}(5) = S_{k\perp}(5) + G_{k\perp}(5) + S_{k\perp}(8) \quad \text{(kN/m)} \qquad \text{(A.19)}$$

h) Calculate the characteristic direct, transversal snow load on ropes and posts (Figure A.6) (**load case 2** and **load case 3**), if relevant

Lateral, guy ropes and/or posts in specific cases, when they are not protected by the net surface, are subject to full, increased snow load as follows:

$$q_{Nk,R} = \eta_k \cdot S_{Nk} \frac{relevant\ rope\ diameter}{length\ of\ rope} \sin(\alpha) \quad \text{(kN/m)} \qquad \text{(A.20a)}$$

$$q_{Nk,P} = \eta_k \cdot S_{Nk} \frac{post\ dimension\ subject\ to\ load}{length\ of\ post} \sin(\alpha) \quad \text{(kN/m)} \qquad \text{(A.20b)}$$

where

$q_{Nk,R}$ characteristic transversal load on rope

$q_{Nk,P}$ characteristic transversal load on post

α angle between the rope or post (as relevant) and the surface of the ground

S_{Nk} characteristic slope-parallel snow load component according to formula (A.2) for **load case 2** and **load case 3** as well

η_k influence factor taken as η_k = 50 for ropes, η_k = 5,0 for post with direct snow load (otherwise η_k = 1,0)

NOTE 1 – In **load case 2** it is possible to calculate the effects of loads (internal forces and moments) using the characteristic snow load.

NOTE 2 – In **load case 3** the maximum snow loads shall be considered with two different values in calculations of effects of loads (internal forces and moments), due to the division of snow load to quasi-permanent and variable loads (see Figure A.2).

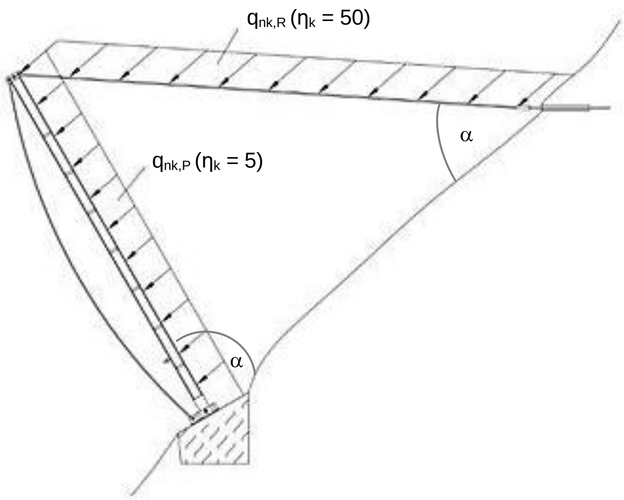


Figure A.6 – Influence factor on post and ropes subject to direct snow load

A.2.4 Resistance check of net

Load case 2

a) The resistance check of net is performed in the middle spans of net.

For resistance check of net, the load width equal to 1,0 m is considered.

The length of net chord:

$$L = \sqrt{D_K^2 + L_K^2} \quad \text{(m)} \tag{A.21}$$

For assessment of net, consider the snow load according to load case 2 acting on full height of kit H_K. The net boundary conditions are idealized as simple supports (Figure A.7). The net is loaded by distributed transversal load, obtained from resultant calculated according to formula (A.11a) without end-effect load S_{Rk}.

The distributed characteristic load acting on net of width of 1,0 m:

$$q_k = \frac{R_k}{0{,}77 \cdot L} \quad \text{(kN/m)} \tag{A.22}$$

b) Calculate the horizontal H and vertical V reactions and their resultant P_{Ek}:

$$H = \frac{q_k \cdot L^2}{8 \cdot f} \quad \text{(kN)} \tag{A.23}$$

$$V = \frac{q_k \cdot L}{2} \quad \text{(kN)} \tag{A.24}$$

$$P_{Ek} = \sqrt{V^2 + H^2} \quad \text{(kN)} \tag{A.25}$$

where

f (m) initial sag of net, if not provided, the value of $0{,}15 \cdot L$ is to be applied, see Figure A.8

L (m) length of net chord

c) Calculate the utilization of net:

$$U = \frac{P_{Ek} \cdot \gamma_Q}{P_{Rk} \cdot 1{,}0 / \gamma_{net}} \tag{A.26}$$

where

$P_{Rk}.1{,}0$ (kN) characteristic tension resistance of net multiplied by 1,0 m.

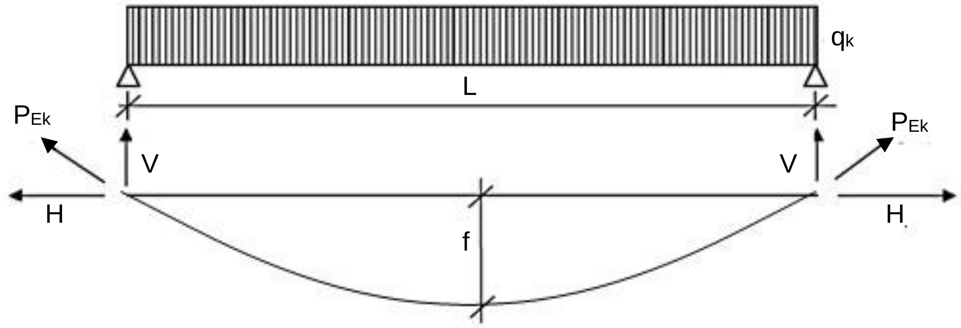


Figure A.7 – Calculation scheme for net, load case 2

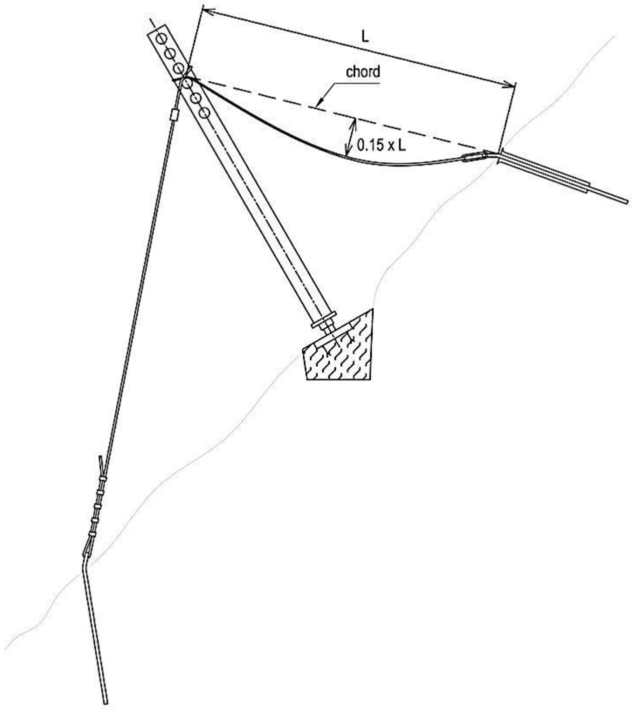


Figure A.8 – Initial sag of net

If the utilization of net U > 1,0, go to step 1, select another value of snow density and repeat the calculations.

If the utilization $U \leq$ 1,0, continue with assessment of ropes.

Load case 3

d) The resistance check of net is performed in the middle spans of net with $L=H_{K.}\cos(\psi)/\cos(\delta)$, length of net chord

Characteristic snow loads distributed on net of width of 1,0 m:

$$q_{\mathrm{k}}(4) = R_{\mathrm{k}\perp}(4) \quad \text{(kN/m)} \tag{A.27}$$

$$q_{\mathrm{k}}(5) = R_{\mathrm{k}\perp}(5) \quad \text{(kN/m)} \tag{A.28}$$

$$q_{\mathrm{k}}(6) = R_{\mathrm{k}\perp}(6) \quad \text{(kN/m)} \tag{A.29}$$

Maximum snow load distributed on net (Figure A.2 and Figure A.9) of width of 1,0 m applied in resistance check (for γ_{Q} and $\gamma_{Q(S)}$ see Table A.1):

$$q_{\mathrm{d}}(4) = q_{\mathrm{k}}(4) \cdot \gamma_{\mathrm{Q(S)}} \qquad \text{(kN/m)} \qquad \text{(A.30)}$$

$$q_{\mathrm{d}}(5) = q_{\mathrm{k}}(5) \cdot \gamma_{\mathrm{Q}} \qquad \text{(kN/m)} \qquad \text{(A.31)}$$

$$q_{\mathrm{d}}(6) = q_{\mathrm{k}}(6) \cdot \gamma_{\mathrm{Q(S)}} \qquad \text{(kN/m)} \qquad \text{(A.32)}$$

e) Calculate the horizontal H and vertical V reactions and their resultant P_{Ed}. The horizontal reaction is calculated as the horizontal reaction on arch as:

$$H = \frac{M_{\mathrm{Ed,max}}}{f} \qquad \text{(kN)} \qquad \text{(A.33)}$$

where

$M_{\mathrm{Ed,max}}$ (kNm) maximum bending moment.

f (m) initial sag of net, if not provided, the value of 0,15·L is to be applied, see Figure A.9

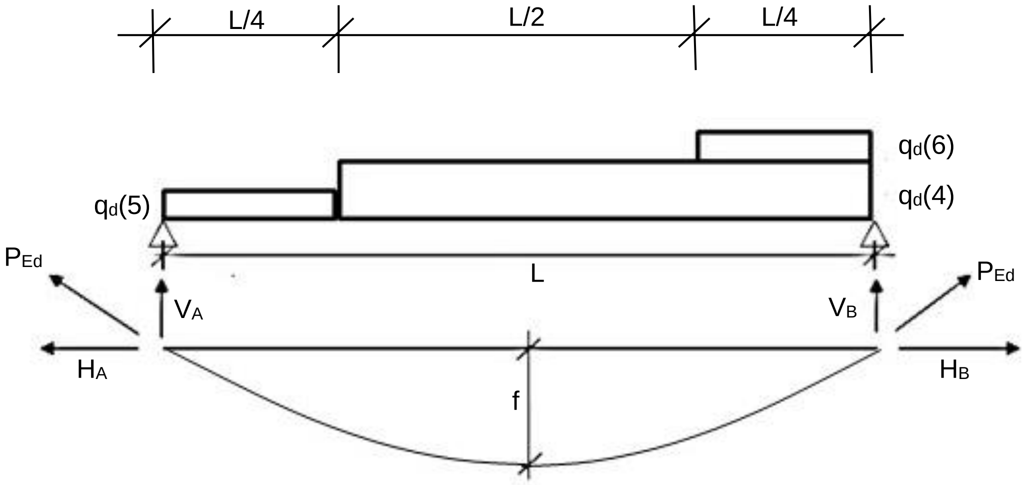


Figure A.9 – Calculation scheme for net, load case 3

f) Calculate the utilization of net:

$$U = \frac{P_{\mathrm{Ed}}}{P_{\mathrm{Rk}} \cdot 1{,}0/\gamma_{\mathrm{net}}} \qquad \text{(A.34)}$$

where

P_{Rk}.1,0 (kN) characteristic tension resistance of net multiplied by 1,0 m.

If the utilization of net U > 1,0, go to step 1, select another value of snow density and repeat the calculations.

If the utilization U ≤ 1,0, continue with assessment of ropes.

A.2.5 Resistance check of ropes

The ropes are divided into five groups:

1) Ropes in the middle spans – without end-effect load
2) Ropes in the end spans – with end-effect load for A ≤ 2,0 m
3) Ropes in the end spans – with end-effect load for A > 2,0 m
4) Ropes not covered by net surface
5) Guy ropes

A.2.5.1 Load distribution on ropes

The snow load shall be distributed to ropes so that the entire load is transferred by ropes. The general scheme of load distribution in longitudinal direction for the most common (triangular) net rope set-up is shown in Figure A.10b.

In load cases 2 and 3, the resultant component orthogonally to the plane of net chord shall be distributed to upper, lower and net ropes.

The length of net rope is:

$$L_\mathrm{N} = \sqrt{\left(\frac{B}{2}\right)^2 + L^2} \qquad \text{(m)} \qquad \text{(A.35)}$$

The length of upper and lower rope (L_R) is the distance between the posts (B).

In **load case 3**, the maximum loads in middle spans, applied in resistance checks ($q_\mathrm{d}(4)$, $q_\mathrm{d}(5)$, $q_\mathrm{d}(6)$, see formulas (A.30), (A.31) and (A.32) and Figure A.9 shall be used, due to the divison of snow load to variable and quasi-permanent loads, see Figures A.2 and A.5.

In load case 3, the loads parallel to plane chord are not taken into account.

In load case 3 without end-effect loads the non-uniform distribution of maximum loads $q_\mathrm{d}(4)$, $q_\mathrm{d}(5)$ and $q_\mathrm{d}(6)$ over the net chord may be transformed to average uniformly distributed maximum load Q_d (formula (A.36)) instead of considering the non-uniform load model. The resultant of average uniformly distributed load Q_d shall be equal to the resultant of non-uniform load model:

$$Q_\mathrm{d} = \frac{q_\mathrm{d}(4)\cdot\frac{3}{4}\cdot L + q_\mathrm{d}(5)\cdot\frac{1}{4}\cdot L + q_\mathrm{d}(6)\cdot\frac{1}{4}\cdot L}{L} \qquad \text{(kN/m)} \qquad \text{(A.36)}$$

In load case 3 in end spans the maximum loads with end-effect are:

$$q_\mathrm{d,end}(4) = R_\mathrm{k\perp,end}(4) \cdot \gamma_\mathrm{Q(S)} \qquad \text{(kN/m)} \qquad \text{(A.37)}$$

$$q_\mathrm{d,end}(5) = R_\mathrm{k\perp,end}(5) \cdot \gamma_\mathrm{Q} \qquad \text{(kN/m)} \qquad \text{(A.38)}$$

In load case 3 with end-effect loads the non-uniform distribution of maximum loads over the net chord $q_\mathrm{d,end}(4)$ and, $q_\mathrm{d,end}(5)$ (with end-effect) may be transformed over the net chord to average distributed load $Q_\mathrm{d,end}$ (formula (A.39)). The resultant of average uniformly distributed load shall be equal to the resultant of non-uniform load model.

$$Q_\mathrm{d,end} = \frac{q_\mathrm{d,end}(4)\cdot\frac{3}{4}\cdot L + q_\mathrm{d,end}(5)\cdot\frac{1}{4}\cdot L}{L} \qquad \text{(kN/m)} \qquad \text{(A.39)}$$

NOTE – The possibility "may be transformed to average uniformly distributed load" is introduced to simplify the hand calculations. The final results of forces and assessments of limit states of ropes and the performance of kit are not influenced by this simplification, because the resultant of loads remains unchanged, moreover, the applied method for rope assessment includes this negligible model uncertainty (see Figure C.3, EN 1990).

The load distribution on ropes shall be calculated for two options. The unfavourable one shall then be taken into account for calculations in Clause A.2.5.2.

For the given load case, the unfavourable option is that for which the maximum uniformly distributed (or average uniformly) snow load is greater by 5 % for at least one rope (net, lower, upper) in any span (middle or end span). In case the maximum uniformly distributed (or average uniformly) snow loads vary by less than 5 % in all ropes, the two options are considered to be equivalent.

A.2.5.1.1 Option "a" of load distribution on ropes, load case 2

Middle span

Calculate the factors of overall load attributed to the concerned ropes separately for both middle (for $F_{1,\mathrm{m}}$, $F_{2,\mathrm{m}}$ and $F_{3,\mathrm{m}}$ see Figure A.10a) and end spans (for $F_{1,\mathrm{e}}$, $F_{2,\mathrm{e}}$ and $F_{3,\mathrm{e}}$ see Figure A.10a):

For net rope:

$$n_{1,\mathrm{m}} = \frac{F_{1,m}}{B\cdot L} \qquad \text{(A.40)}$$

$$n_{1,\mathrm{e}} = \frac{F_{1,e}}{\frac{3}{4}B \cdot L} \qquad \text{(A.41)}$$

For lower rope:

$$n_{2,\mathrm{m}} = \frac{F_{2,m}}{B \cdot L} \qquad \text{(A.42)}$$

$$n_{2,\mathrm{e}} = \frac{F_{2,e}}{\frac{3}{4}B \cdot L} \qquad \text{(A.43)}$$

For upper rope:

$$n_{3,\mathrm{m}} = \frac{F_{3,m}}{B \cdot L} \qquad \text{(A.44)}$$

$$n_{3,\mathrm{e}} = \frac{F_{3,e}}{\frac{3}{4}B \cdot L} \qquad \text{(A.45)}$$

Uniformly distributed characteristic snow load on net rope:

$$q_{\mathrm{k,mnr2,a}} = n_{1,\mathrm{m}} \cdot \frac{R_{\mathrm{k}\perp} \cdot B}{0{,}77 \cdot L_{\mathrm{N}}} \quad \text{(kN/m)} \qquad \text{(A.46)}$$

Uniformly distributed characteristic snow load on lower rope:

$$q_{\mathrm{k,mlr2,a}} = n_{2,\mathrm{m}} \cdot \frac{R_{\mathrm{k}\perp} \cdot B}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \qquad \text{(A.47)}$$

Uniformly distributed characteristic snow load on upper rope:

In upper ropes, the resultant component parallel to the plane of chord R_{kII} (formula A.14a) shall be added to the distributed part of component acting orthogonally to the plane of chord according to formula (A.50):

$$q_{\mathrm{k}\perp\mathrm{,mur2,a}} = n_{3,\mathrm{m}} \cdot \frac{R_{\mathrm{k}\perp} \cdot B}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \qquad \text{(A.48)}$$

$$q_{\mathrm{kII,mur2}} = R_{\mathrm{kII}} \quad \text{(kN/m)} \qquad \text{(A.49)}$$

$$q_{\mathrm{k,mur2,a}} = \sqrt{{q_{\mathrm{k}\perp\mathrm{,mur2,a}}}^2 + {q_{\mathrm{kII,mur2}}}^2} \quad \text{(kN/m)} \qquad \text{(A.50)}$$

Uniformly distributed maximum snow load applied in resistance check of each rope is:

$$q_{\mathrm{d,mnr2,a}} = q_{\mathrm{k,mnr2,a}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \qquad \text{(A.51)}$$

$$q_{\mathrm{d,mlr2,a}} = q_{\mathrm{k,mlr2,a}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \qquad \text{(A.52)}$$

$$q_{\mathrm{d,mur2,a}} = q_{\mathrm{k,mur2,a}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \qquad \text{(A.53)}$$

End span

For internal and lateral net ropes in end span, see Figure 1.1.1.

Uniformly distributed characteristic snow load on lateral net rope for both cases *A* ≤ 2 m and *A* > 2 m:

$$q_{\mathrm{k,enr2,a,l}} = \frac{1}{2} n_{1,\mathrm{e}} \frac{R_{\mathrm{k}\perp\mathrm{,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot R_{\mathrm{k}\perp}}{0{,}77 \cdot L_{\mathrm{N}}} \quad \text{(kN/m)} \qquad \text{(A.54)}$$

Uniformly distributed characteristic snow load on internal net rope (in end span, if the rope is different from the lateral rope) for both cases *A* ≤ 2 m and *A* > 2 m:

$$q_{\mathrm{k,enr2,a,i}} = \frac{1}{2} n_{1,\mathrm{e}} \frac{R_{\mathrm{k}\perp\mathrm{,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot R_{\mathrm{k}\perp}}{0{,}77 \cdot L_{\mathrm{N}}} \quad \text{(kN/m)} \qquad \text{(A.55)}$$

Uniformly distributed characteristic snow load on lower rope for both cases *A* ≤ 2 m and *A* > 2 m:

$$q_{\mathrm{k,elr2,a}} = n_{2,\mathrm{e}} \frac{R_{\mathrm{k}\perp\mathrm{,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot R_{\mathrm{k}\perp}}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \qquad \text{(A.56)}$$

Uniformly distributed characteristic snow load on upper rope for both cases *A* ≤ 2 m and *A* > 2 m:

In upper ropes, the resultant component parallel to the plane of chord R_{kII} (formula A.14a) and $R_{\mathrm{kII,end}}$ (formula A.14b) shall be added to the distributed part of component acting orthogonally to the plane of chord according to formula (A.59):

$$q_{\mathrm{k\perp,eur2,a}} = n_{3,\mathrm{e}} \frac{R_{\mathrm{k\perp,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot R_{\mathrm{k\perp}}}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \qquad \text{(A.57)}$$

$$q_{\mathrm{kII,eur2}} = (R_{\mathrm{kII,end}} \cdot \Delta L + (B - \Delta L) \cdot R_{\mathrm{kII}})/L_{\mathrm{R}} \quad \text{(kN/m)} \qquad \text{(A.58)}$$

$$q_{\mathrm{k,eur2,a}} = \sqrt{{q_{\mathrm{k\perp,eur2,a}}}^2 + {q_{\mathrm{kII,eur2}}}^2} \quad \text{(kN/m)} \qquad \text{(A.59)}$$

Uniformly distributed maximum snow load applied in resistance check of each rope is:

$$q_{\mathrm{d,enr2,a}} = q_{\mathrm{k,enr2,a}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \qquad \text{(A.60)}$$

$$q_{\mathrm{d,elr2,a}} = q_{\mathrm{k,elr2,a}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \qquad \text{(A.61)}$$

$$q_{\mathrm{d,eur2,a}} = q_{\mathrm{k,eur2,a}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \qquad \text{(A.62)}$$

A.2.5.1.2 Option “a” of load distribution on ropes, load case 3

Middle span

Uniformly distributed maximum snow load on net rope:

$$q_{\mathrm{d,mnr3,a}} = n_{1,\mathrm{m}} \cdot \frac{Q_{\mathrm{d}} \cdot B}{L_{\mathrm{N}}} \quad \text{(kN/m)} \qquad \text{(A.63)}$$

Uniformly distributed maximum snow load on lower rope:

$$q_{\mathrm{d,mlr3,a}} = n_{2,\mathrm{m}} \cdot \frac{Q_{\mathrm{d}} \cdot B}{L_{\mathrm{R}}} \quad \text{(kN/m)} \qquad \text{(A.64)}$$

Uniformly distributed maximum snow load on upper rope:

$$q_{\mathrm{d,mur3,a}} = n_{3,\mathrm{m}} \cdot \frac{Q_{\mathrm{d}} \cdot B}{L_{\mathrm{R}}} \quad \text{(kN/m)} \qquad \text{(A.65)}$$

End span

Uniformly distributed maximum snow load on lateral net rope for both cases $A \leq 2$ m and $A > 2$ m:

$$q_{\mathrm{d,enr3,a,l}} = \frac{1}{2} n_{1,\mathrm{e}} \frac{Q_{\mathrm{d,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot Q_{\mathrm{d}}}{L_{\mathrm{N}}} \quad \text{(kN/m)} \qquad \text{(A.66)}$$

Uniformly distributed maximum snow load on internal net rope in end span, if the rope is different from the lateral rope, for both cases $A \leq 2$ and $A > 2$:

$$q_{\mathrm{d,enr3,a,i}} = \frac{1}{2} n_{1,\mathrm{e}} \frac{Q_{\mathrm{d,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot Q_{\mathrm{d}}}{L_{\mathrm{N}}} \quad \text{(kN/m)} \qquad \text{(A.67)}$$

Uniformly distributed maximum snow load on lower rope for both cases $A \leq 2$ m and $A > 2$ m:

$$q_{\mathrm{d,elr3,a}} = n_{2,\mathrm{e}} \frac{Q_{\mathrm{d,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot Q_{\mathrm{d}}}{L_{\mathrm{R}}} \qquad \text{(A.68)}$$

Uniformly distributed maximum snow load on upper rope for both cases $A \leq 2$ m and $A > 2$ m:

$$q_{\mathrm{d,eur3,a}} = n_{3,\mathrm{e}} \frac{Q_{\mathrm{d,end}} \cdot \Delta L + (\frac{3}{4}B - \Delta L) \cdot Q_{\mathrm{d}}}{L_{\mathrm{R}}} \quad \text{(kN/m)} \qquad \text{(A.69)}$$

A.2.5.1.3 Option “b” of load distribution on ropes, load case 2

Middle span

Uniformly distributed characteristic snow load on net rope:

$$q_{\mathrm{k,mnr2,b}} = 0{,}26 \cdot \frac{R_{\mathrm{k}\perp} \cdot B}{0{,}77 \cdot L_{\mathrm{N}}} \quad \text{(kN/m)} \tag{A.70}$$

Uniformly distributed characteristic snow load on lower rope:

$$q_{\mathrm{k,mlr2,b}} = 0{,}22 \cdot \frac{R_{\mathrm{k}\perp} \cdot B}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.71}$$

Uniformly distributed characteristic snow load on upper rope:

In upper ropes, the resultant component parallel to the plane of chord R_{kII} (formula A.14a) shall be added to the distributed part of component acting orthogonally to the plane of chord according to formula (A.74):

$$q_{\mathrm{k}\perp\mathrm{,mur2,b}} = 0{,}22 \cdot \frac{R_{\mathrm{k}\perp} \cdot B}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.72}$$

$$q_{\mathrm{kII,mur2}} = R_{\mathrm{kII}} \quad \text{(kN/m)} \tag{A.73}$$

$$q_{\mathrm{k,mur2,b}} = \sqrt{{q_{\mathrm{k}\perp\mathrm{,mur2,b}}}^2 + {q_{\mathrm{kII,mur2}}}^2} \quad \text{(kN/m)} \tag{A.74}$$

Uniformly distributed maximum snow load applied in resistance check of each rope is:

$$q_{\mathrm{d,mnr2,b}} = q_{\mathrm{k,mnr2,b}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.75}$$

$$q_{\mathrm{d,mlr2,b}} = q_{\mathrm{k,mlr2,b}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.76}$$

$$q_{\mathrm{d,mur2,b}} = q_{\mathrm{k,mur2,b}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.77}$$

NOTE – The missing 4% of snow load orthogonally to the chord of net, acting on supporting surface, are to be transfered by the adjacent quy ropes.

End span, distance between separated structures *A* ≤ 2 m

Uniformly distributed characteristic snow load on lateral net rope (applied on both separate net ropes):

$$q_{\mathrm{k,enr2,b,A\leq 2}} = 0{,}33 \cdot \frac{R_{\mathrm{k}\perp\mathrm{,end}} \cdot \Delta L + (B - \Delta L) \cdot R_{\mathrm{k}\perp}}{0{,}77 \cdot L_{\mathrm{N}}} \quad \text{(kN/m)} \tag{A.78}$$

Uniformly distributed characteristic snow load on lower rope:

$$q_{\mathrm{k,elr2,b,A\leq 2}} = 0{,}17 \cdot \frac{R_{\mathrm{k}\perp\mathrm{,end}} \cdot \Delta L + (B - \Delta L) \cdot R_{\mathrm{k}\perp}}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.79}$$

Uniformly distributed characteristic snow load on upper rope:

In upper ropes, the resultant component parallel to the plane of chord R_{kII} (formula A.14a) and $R_{\mathrm{kII,end}}$ (formula A.14b) shall be added to the distributed part of component acting orthogonally to the plane of chord according to formula (A.82):

$$q_{\mathrm{k}\perp\mathrm{,eur2,b,A\leq 2}} = 0{,}17 \cdot \frac{R_{\mathrm{k}\perp\mathrm{,end}} \cdot \Delta L + (B - \Delta L) \cdot R_{\mathrm{k}\perp}}{0{,}77 \cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.80}$$

$$q_{\mathrm{kII,eur2}} = (R_{\mathrm{kII,end}} \cdot \Delta L + (B - \Delta L) \cdot R_{\mathrm{kII}}) / L_{\mathrm{R}} \quad \text{(kN/m)} \tag{A.81}$$

$$q_{\mathrm{k,eur2,b,A\leq 2}} = \sqrt{{q_{\mathrm{k}\perp\mathrm{,eur2,b,A\leq 2}}}^2 + {q_{\mathrm{kII,eur2}}}^2} \quad \text{(kN/m)} \tag{A.82}$$

Uniformly distributed maximum snow load applied in resistance check of each rope is:

$$q_{\mathrm{d,enr2,b,A\leq 2}} = q_{\mathrm{k,enr2,b,A\leq 2}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.83}$$

$$q_{\mathrm{d,elr2,b,A\leq 2}} = q_{\mathrm{k,elr2,b,A\leq 2}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.84}$$

$$q_{\mathrm{d,eur2,b,A\leq 2}} = q_{\mathrm{k,eur2,b,A\leq 2}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.85}$$

End span, distance between separated structures *A* > 2 m

Uniformly distributed characteristic snow load on lateral and internal net rope in end span:

$$q_{\mathrm{k,enr2,b,A>2}} = \frac{R_{\mathrm{k}\perp\mathrm{,end}} \cdot \Delta L}{2 \cdot 0{,}77 \cdot L_{\mathrm{N}}} \quad \text{(kN/m)} \tag{A.86}$$

Uniformly distributed characteristic snow load on lower rope:

$$q_{\mathrm{k,nlr2,b,A>2}} = 0{,}6 \cdot \frac{(\frac{3}{4}B-\Delta L)\cdot R_{\mathrm{k}\perp}}{0{,}77\cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.87}$$

Uniformly distributed characteristic snow load on upper rope:

In upper ropes, the resultant component parallel to the plane of chord R_{kII} (formula A.14a) and $R_{\mathrm{kII,end}}$ (formula A.14b) shall be added to the distributed part of component acting orthogonally to the plane of chord according to formula (A.90):

$$q_{\mathrm{k\perp,eur2,b,A>2}} = 0{,}4 \cdot \frac{(\frac{3}{4}B-\Delta L)\cdot R_{\mathrm{k}\perp}}{0{,}77\cdot L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.88}$$

$$q_{\mathrm{kII,eur2}} = (R_{\mathrm{kII,end}} \cdot \Delta L + (B-\Delta L)\cdot R_{\mathrm{kII}})/L_{\mathrm{R}} \quad \text{(kN/m)} \tag{A.89}$$

$$q_{\mathrm{k,eur2,b,A>2}} = \sqrt{{q_{\mathrm{k\perp,eur2,b,A>2}}}^2 + {q_{\mathrm{kII,eur2}}}^2} \quad \text{(kN/m)} \tag{A.90}$$

Uniformly distributed maximum snow load applied in resistance check of each rope is:

$$q_{\mathrm{d,enr2,b,A>2}} = q_{\mathrm{k,enr2,b,A>2}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.91}$$

$$q_{\mathrm{d,elr2,b,A>2}} = q_{\mathrm{k,elr2,b,A>2}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.92}$$

$$q_{\mathrm{d,eur2,b,A>2}} = q_{\mathrm{k,eur2,b,A>2}} \cdot \gamma_{\mathrm{Q}} \quad \text{(kN/m)} \tag{A.93}$$

A.2.5.1.4 Option “b” of load distribution on ropes, load case 3

Middle span

Uniformly distributed maximum snow load on net rope:

$$q_{\mathrm{d,mnr3,b}} = 0{,}26 \cdot \frac{Q_{\mathrm{d}}\cdot B}{L_{\mathrm{N}}} \quad \text{(kN/m)} \tag{A.94}$$

Uniformly distributed maximum snow load on lower rope:

$$q_{\mathrm{d,mlr3,b}} = 0{,}22 \cdot \frac{Q_{\mathrm{d}}\cdot B}{L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.95}$$

Uniformly distributed maximum snow load on upper rope:

$$q_{\mathrm{d,mur3,b}} = 0{,}22 \cdot \frac{Q_{\mathrm{d}}\cdot B}{L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.96}$$

NOTE – The missing 4% of snow load orthogonally to the chord of net, acting on supporting surface, are to be transfered by the adjacent quy ropes.

End span, distance between separated structures *A* ≤ 2 m

Uniformly distributed maximum snow load on lateral net rope (applied on both separate net ropes):

$$q_{\mathrm{d,enr3,b,A\leq2}} = 0{,}33 \cdot \frac{Q_{\mathrm{d,end}}\cdot\Delta L+(B-\Delta L)\cdot Q_{\mathrm{d}}}{L_{\mathrm{N}}} \quad \text{(kN/m)} \tag{A.97}$$

Uniformly distributed maximum snow load on lower rope:

$$q_{\mathrm{d,elr3,b,A\leq2}} = 0{,}17 \cdot \frac{Q_{\mathrm{d,end}}\cdot\Delta L+(B-\Delta L)\cdot Q_{\mathrm{d}}}{L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.98}$$

Uniformly distributed maximum snow load on upper rope:

$$q_{\mathrm{k\perp,eur3,b,A\leq2}} = 0{,}17 \cdot \frac{Q_{\mathrm{d,end}}\cdot\Delta L+(B-\Delta L)\cdot Q_{\mathrm{d}}}{L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.99}$$

End span, distance between separated structures *A* > 2 m

Uniformly distributed maximum snow load on lateral and internal net rope in end span:

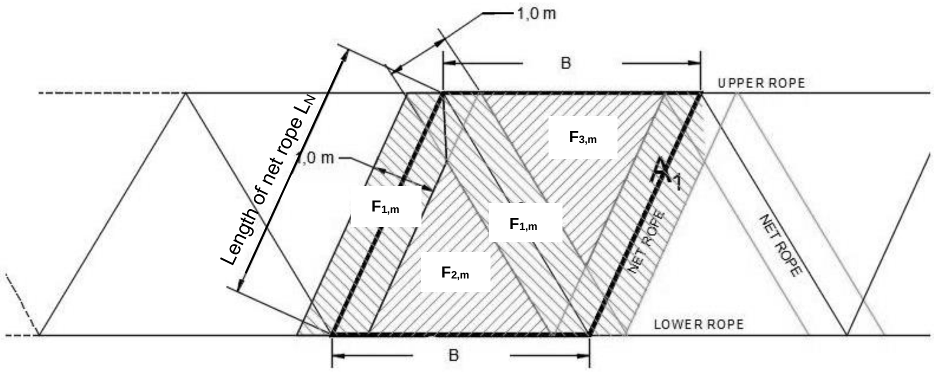
$$q_{\mathrm{d,enr3,b,A>2}} = \frac{Q_{\mathrm{d,end}}\cdot\Delta L}{2\cdot L_{\mathrm{N}}} \quad \text{(kN/m)} \tag{A.100}$$

Uniformly distributed maximum snow load on lower rope:

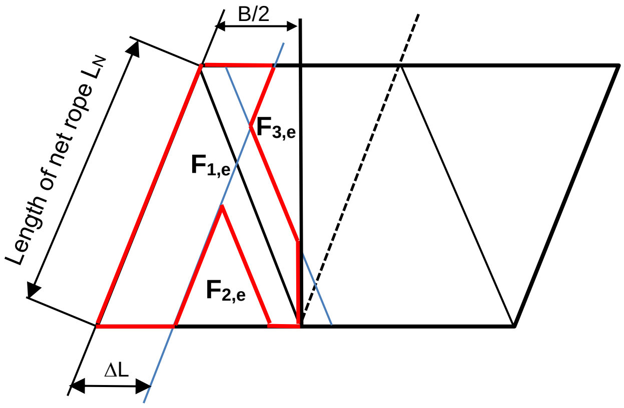
$$q_{\mathrm{d,elr3,b,A>2}} = 0{,}6 \cdot \frac{(\frac{3}{4}B - \Delta L) \cdot Q_{\mathrm{d}}}{L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.101}$$

Uniformly distributed maximum snow load on upper rope:

$$q_{\mathrm{d,eur3,b,A>2}} = 0{,}4 \cdot \frac{(\frac{3}{4}B - \Delta L) \cdot Q_{\mathrm{d}}}{L_{\mathrm{R}}} \quad \text{(kN/m)} \tag{A.102}$$



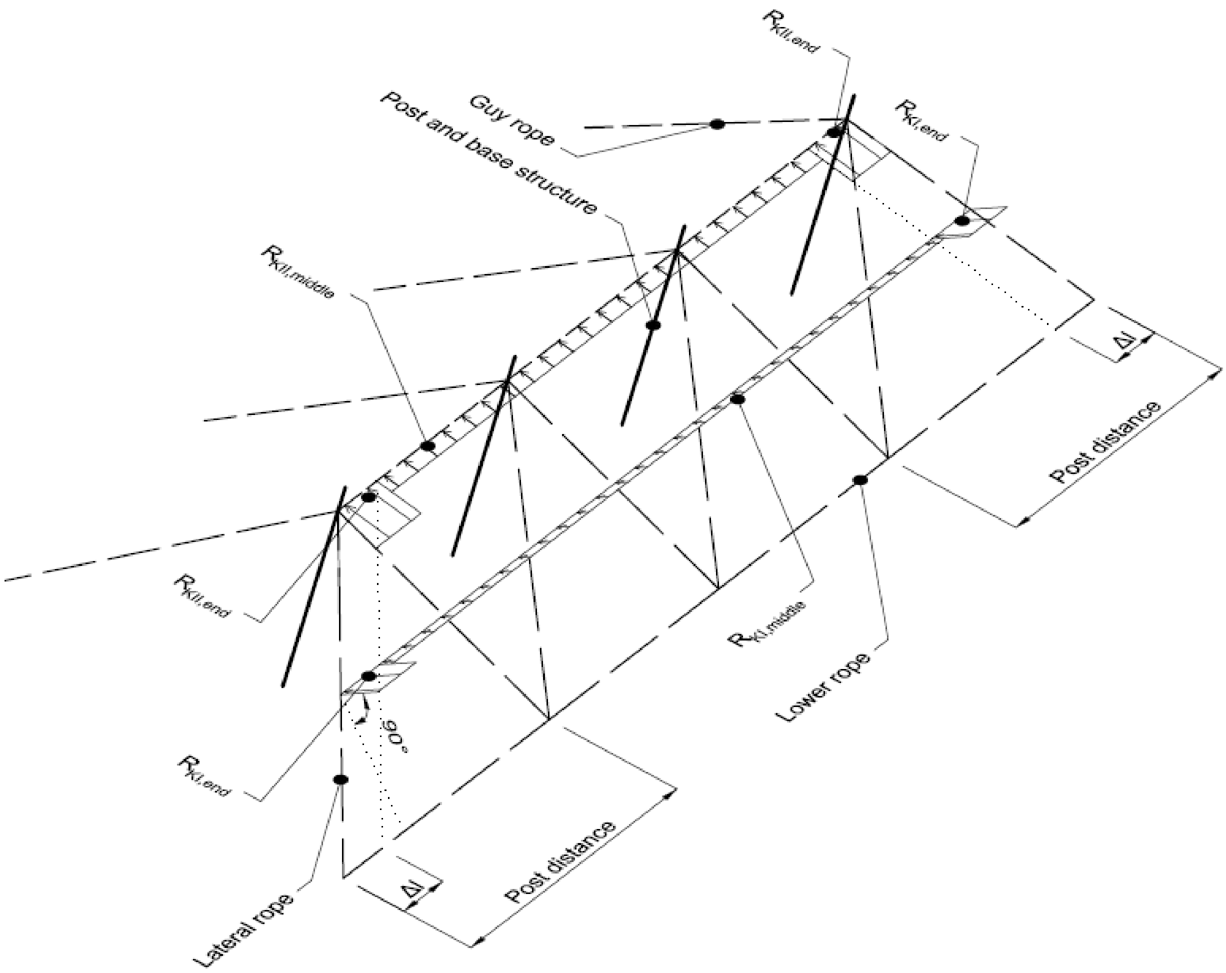
Attributed areas in the middle span



$F_{1,m}$ and $F_{1,e}$: attributed area for net ropes
NOTE – the boundary lines of area $F_{1,e}$ are in red
$F_{2,m}$ and $F_{2,e}$: attributed area for lower rope
$F_{3,m}$ and $F_{3,e}$: attributed area for upper rope

Attributed areas in the end span

Figure A.10a – Distribution of snow load to ropes



In load cases 1 and 2: $R_{k\parallel}$ and $R_{k\parallel,end}$ transmitted: by upper ropes
In load cases 1 and 2: $R_{k\perp}$ and $R_{k\perp,end}$ transmitted by: upper, lower and net ropes
In load case 3: apply Q_d instead of $R_{k\perp}$: transmitted by: upper, lower and net ropes
In load case 3: apply $Q_{d,end}$ instead of $R_{k\perp,end}$: transmitted by: upper, lower and net ropes

Figure A.10b – Distribution of snow load to ropes in longitudinal direction

A.2.5.1.5 Ropes not covered by net surface - direct snow load on rope

The uniformly distributed characteristic load $q_{\mathrm{Nk,R}}$ on rope directly subject to snow load (Figure A.6) shall be taken according to formula (A.20a) for both load case 2 and load case 3.

The uniformly distributed maximum snow load is:

$$q_{\mathrm{Nd,R}} = q_{\mathrm{Nk,R}} \cdot \gamma_{\mathrm{Q}} \qquad \text{(kN/m)} \qquad \text{(A.103)}$$

A.2.5.1.6 Tension force in guy ropes

The maximum tension force in guy rope $P_{Ed} = Z_{C,d}$ ($Z_{C,d,end}$). For $Z_{C,d}$ ($Z_{C,d,end}$) see Figure A.12. The maximum forces in guy ropes adjacent to middle and end spans shall be calculated.

A.2.5.2 Resistance check of ropes

The tension force P_{Ed} in net supporting, upper, lower ropes and ropes not covered by net surface (if exist) shall be calculated using the second order linear-elastic analysis as shown in Figure A.11.

The resistance check shall be done as follows:

a) Calculate the vertical reaction V (in N), horizontal reaction H (in N) (according to formula in Figure A.11) and their resultant P_{Ed}.

$$H^3 + H^2 + EA_\mathrm{m}\left(1 - \frac{l_R}{S_0}\right) = \frac{EA_\mathrm{m} \cdot q_\mathrm{d} \cdot l_R^3}{24 \cdot S_0}$$

For net rope: $l_R = L_N$

For upper and lower ropes: $l_R = B$

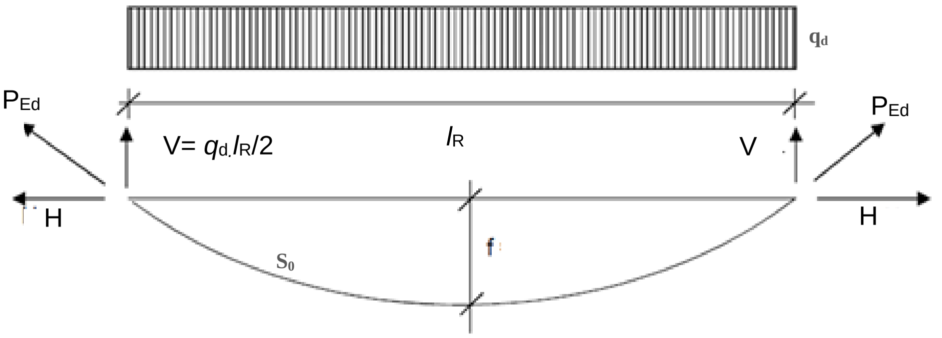


Figure A.11 – Calculation scheme of rope tension force

Symbols in Figure A.11 are:

l_R (mm) length of concerned (net supporting, lower, upper, directly loaded) rope

E $= E_Q$ (N/mm²) modulus of elasticity of concerned rope according to EN 1993-1-11, clause 3.2, Table 3.1

A_m (mm²) cross-sectional area of concerned rope according to clause 2.3.1 of EN 1993-1-11

f (mm) initial rope sag (max. 15 % of length of concerned rope)

S_0 (mm) length of rope with sag

q_d (kN/m) uniformly distributed snow load applied in resistance check. Depending on the assessed rope (net, lower, upper, not covered by net surface), unfavourable distritbution option (option 1 or option 2), location of rope in the kit (middle span, lateral span) and load case (load case 2 or 3), the relevant uniformly distributed snow load calculated in clauses A.2.5.1.1, A.2.5.1.2, A.2.5.1.3, A.2.5.1.4 and A.2.5.1.5 shall be taken into account. For example, for resistance check of net rope in middle span in case of unfavourable distribution option 2 and for load case 2: $q_d = q_{d,mnr2,b}$ according to formula (A.75)

$$P_\mathrm{Ed} = \frac{1}{1000}\sqrt{V^2 + H^2} \qquad \text{(kN)}$$

(A.104)

Calculate the utilization of concerned rope

$U = P_{Ed} / P_{Rd}$

(A.105)

where

P_{Ed} (kN) maximum tension force in rope

P_{Rd} (kN) calculated according to formula (6.2) of EN 1993-1-11, taking into account the characteristic value F_{uk} of the breaking strength calculated in accordance with formulas (6.4) and (6.5) of EN 1993-1-11.

NOTE – For ropes commonly used in kit the minimum value from formula (6.2) of EN 1993-1-11 is related to characteristic value F_{uk} of the breaking strength as obtained e.g., from EN 12385-4 (or similar) for given type of rope.

A.2.6 Iteration process

If within the current iteration step the utilization of net is U < 0,95 and the utilization of at least one rope U is from interval $\langle 0{,}95; 1{,}0\rangle$ and the utilizations of all other ropes are U < 0,95, continue with resistance check of posts, base structure/s and connection components based on characteristic snow load.

If within the current iteration step the utilization of net is from interval $\langle 0{,}95; 1{,}0\rangle$ and the utilizations of all ropes are $U \leq 1{,}0$, continue with resistance check of posts, base structure/s and connection components based on characteristic snow load.

If within the current iteration step the utilization of net is from interval $\langle 0{,}95; 1{,}0\rangle$, but the utilization of any rope is U > 1,0, go to step in clause A.2.3,a), select another value of snow density and repeat the calculations.

If within the current iteration step the utilization of net is U < 0,95 and the utilizations of all ropes are U < 0,95, go to step in clause A.2.3,a), select another value of snow density and repeat the calculations.

A.2.7 Resistance check of posts

In both load cases, use the results from the last iteration step. The cross section of post shall be of maximally class 3 when classified according to clause 5.5 of EN 1993-1-1 for steel or clause 5.2 of EN 1993-1-4 for stainless steel. This calculation method applies for posts with **boundary conditions** which are considered as column **pinned at both ends**.

If as the result of the given eccentric loading of the pin support occurs, the compression force shall be applied with the maximum eccentricity.

a) In load case 3, calculate the slope-parallel component Q_{Nd} and the component Q_{Qd} orthogonally to the slope of uniformly distributed snow load Q_d (formula (A.36)) in middle span:

$$Q_{\mathrm{Nd}} = Q_{\mathrm{d}} \cdot \cos(\delta) \qquad \text{(kN/m)} \qquad \text{(A.106)}$$

$$Q_{\mathrm{Qd}} = \sqrt{{Q_{\mathrm{d}}}^2 - {Q_{\mathrm{Nd}}}^2} \qquad \text{(kN/m)} \qquad \text{(A.107)}$$

b) In load case 3, calculate the slope-parallel component $Q_{Nd,end}$ and the component $Q_{Qd,end}$ orthogonally to the slope of uniformly distributed snow load $Q_{d,end}$ (formula (A.39)) in lateral span:

$$Q_{\mathrm{Nd,end}} = Q_{\mathrm{d,end}} \cdot \cos(\delta) \qquad \text{(kN/m)} \qquad \text{(A.108)}$$

$$Q_{\mathrm{Qd,end}} = \sqrt{{Q_{\mathrm{d,end}}}^2 - {Q_{\mathrm{Nd,end}}}^2} \qquad \text{(kN/m)} \qquad \text{(A.109)}$$

c) The calculation of maximum compression force is according to the formulas and geometry gicen in Figure A.12.

d) Calculate the direct transversal uniformly distributed load (for both load case 2 and load case 3) $q_{\mathrm{Nk,P}}$ according to formula (A.20b) and Figure A.6.

NOTE - At sites with low snow glide (N < 1,6 or effective snow glide protection), this transversal load is allowed to be neglected.

e) Determine the effects of loads for the length of post L_P considered in calculations as follows:

$$L_{\mathrm{P}} = (D_{\mathrm{K}} + 0{,}5)/\sin\alpha \qquad \text{(m)} \qquad \text{(A.110)}$$

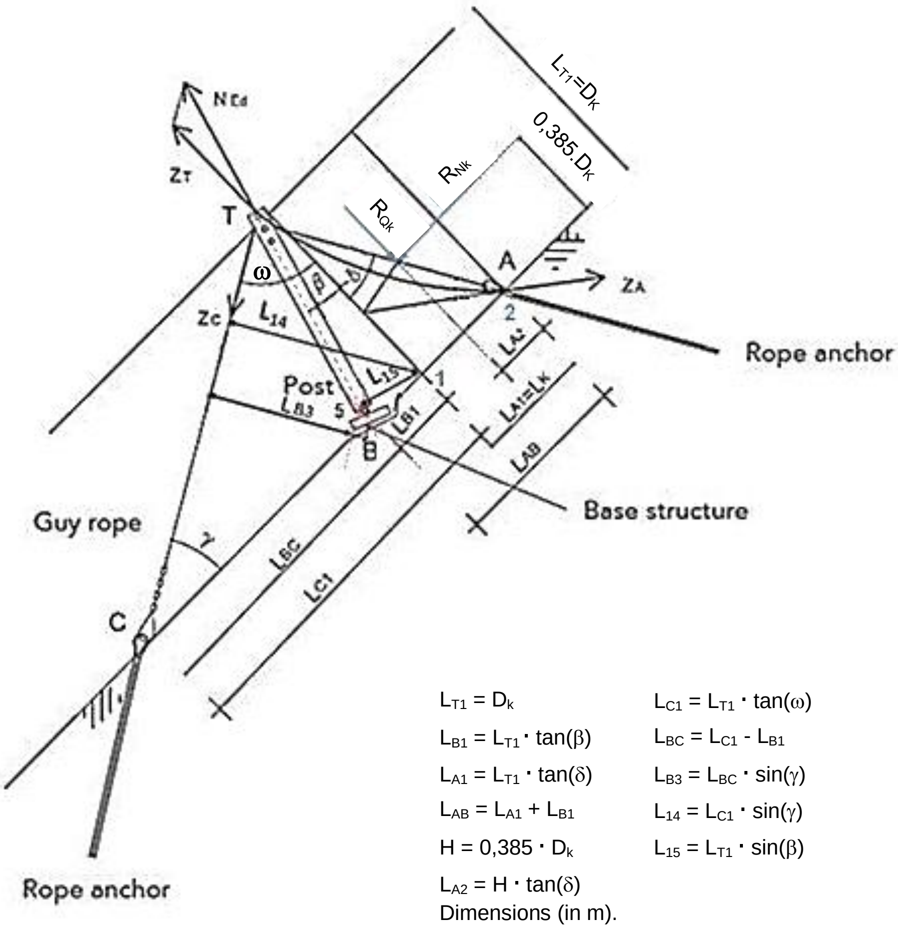
Maximum bending moment:

$$M_{\mathrm{Ed}} = \frac{q_{\mathrm{Nk,P}} \cdot L_{\mathrm{P}}^2}{8} \cdot \gamma_{\mathrm{Q}} \qquad \text{(kNm)} \qquad \text{(A.111)}$$

Maximum shear force:

$$V_{\mathrm{Ed}} = \frac{q_{\mathrm{Nk,P}} \cdot L_{\mathrm{P}}}{2} \cdot \gamma_{\mathrm{Q}} \qquad \text{(kN)} \qquad \text{(A.112)}$$

f) The resistance check of post for bending and axial force as individual single span member (post) with boundary conditions corresponding to post connections (normally pin – pin boundary conditions) shall be carried out according to clause 6.3.3 of EN 1993-1-1 for steel or according to clause 5.5, formulas (5.13) and (5.14) of EN 1993-1-4 for stainless steel post.



$L_{T1} = D_k$ $\quad L_{C1} = L_{T1} \cdot \tan(\omega)$

$L_{B1} = L_{T1} \cdot \tan(\beta)$ $\quad L_{BC} = L_{C1} - L_{B1}$

$L_{A1} = L_{T1} \cdot \tan(\delta)$ $\quad L_{B3} = L_{BC} \cdot \sin(\gamma)$

$L_{AB} = L_{A1} + L_{B1}$ $\quad L_{14} = L_{C1} \cdot \sin(\gamma)$

$H = 0{,}385 \cdot D_k$ $\quad L_{15} = L_{T1} \cdot \sin(\beta)$

$L_{A2} = H \cdot \tan(\delta)$

Dimensions (in m).

Calculation of compression force (kN) in post and tension force in guy rope (kN), load case 2

$Z_T = (R_{Nk} \cdot H \cdot B + R_{Qk} \cdot L_{A2} \cdot B) / L_{A1}$

$Z_{T,end} = (R_{Nk} \cdot H \cdot (B-\Delta L) + R_{Nk,end} \cdot H \cdot \Delta L + R_{Qk} \cdot L_{A2} \cdot B) / L_{A1}$

$Z_{Cd} = \gamma_Q \cdot Z_T \cdot L_{B1} / L_{B3}$

$Z_{Cd,end} = \gamma_Q \cdot Z_{T,end} \cdot L_{B1} / L_{B3}$

$N_{Ed} = \gamma_Q \cdot Z_C \cdot L_{14} / L_{15}$

$N_{Ed,end} = \gamma_Q \cdot Z_{C,end} \cdot L_{14} / L_{15}$

Calculation of compression force (kN) in post and tension force in guy rope (kN), load case 3

$Z_T = (Q_{Nd} \cdot H \cdot B + Q_{Qd} \cdot L_{A2} \cdot B) / L_{A1}$

$Z_{T,end}=(Q_{Nd} \cdot H \cdot (B-\Delta L)+Q_{Nd,end} \cdot H \cdot \Delta L+Q_{Qd} \cdot (B - \Delta L) \cdot L_{A2} \cdot B+Q_{Qd,end} \cdot \Delta L \cdot L_{A2} \cdot B)/L_{A1}$

$Z_{Cd} = Z_T \cdot L_{B1} / L_{B3}$

$Z_{Cd,end} = Z_{T,end} \cdot L_{B1} / L_{B3}$

$N_{Ed} = Z_C \cdot L_{14} / L_{15}$

$N_{Ed,end} = Z_{C,end} \cdot L_{14} / L_{15}$

NOTE – In Figure Q_{Nd} replaces R_{Nk} and Q_{Qd} replaces R_{Qk}

Figure A.12 – Calculation of force in post and in guy rope

g) The resistance check of post for shear force shall be carried out according to clause 6.2.6 of EN 1993-1-1. For pin – pin boundary conditions the resistance check is to be omitted, because of the negligible influence of shear force.

h) The resistance of transversal members, to which the ropes are connected (see Figure A.13) shall be checked as follows:

$$\frac{N_{\mathrm{Ed}}}{2} \leq V_{\mathrm{c,Rd}} \qquad \text{(A.113)}$$

where

$V_{\mathrm{c,Rd}}$ (kN) shear resistance of transversal members according to clause 6.2.6 of EN 1993-1-1 for steel or clause 5.6 of EN 1993-1-4 for stainless steel.

i) The actions on foundations and anchor forces shall be calculated according to procedure given in Figure A.14.

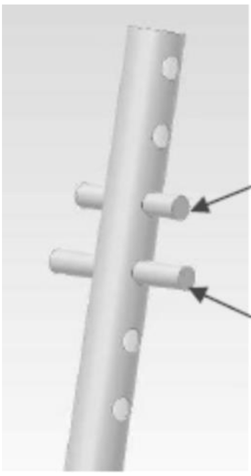


Figure A.13 – Transversal members in post

A.2.8 Resistance check of base structure

The design calculations according to Eurocodes listed below in this Clause are completely out of the scope of the EAD and their correctness is not at all covered by CE marking (including the whole „chain“ of EAD-ETA-DoP-CE mark).

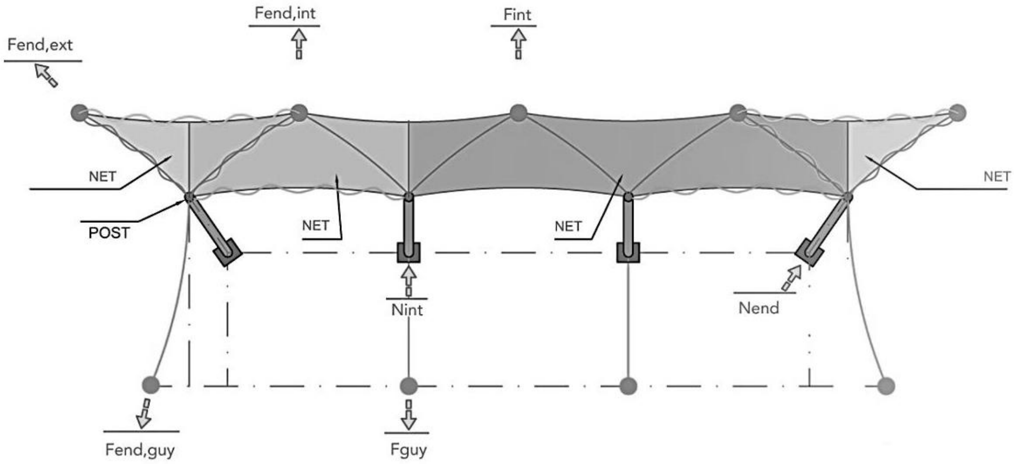
In case, the forces are transferred directly to foundations, the base structure resistance check is not required.

The ETA may include alternative types of base structures for the same kit depending on ground conditions. When the base structure is in direct contact with the subsoil, the resistance assessment for all structural components may be provided. In such a case, the value of "the minimum required bearing capacity *p* (kN/m^2) of considered subsoil" need to be presented within the product description identified as a "supporting informative value".

When the base structure is in direct contact with the subsoil, the resistance check of base structure is based on rigid-plastic model. The base structure is divided into fields supported by rigid members (stiffeners of base structure, post, etc.). The resistance check then is based on plastic bending moment resistances (clause 6.2.5 (2) of EN 1993-1-1) of rigid members and the following shall be valid for each field-rigid member:

$$M_{\mathrm{Ed}} \leq M_{\mathrm{pl,Rd}} \qquad \text{(A.114)}$$

The resistance check of post to base structure joint, for example welded joints clause 4 of EN 1993-1-8 or pins clause 3.13 of EN 1993-1-8 may be carried out. In case of use of structural bearings, EN 1337-1 applies.



Characteristic forces (kN) on foundations and anchors in load case 2

$N_{int} = N_{Ed} / \gamma_Q$

$N_{end} = N_{Ed,end} / \gamma_Q$

$F_{guy} = Z_{Cd} / \gamma_Q$

$F_{end,guy} = Z_{C,end} / \gamma_Q$

$F_{int} = [(R_{Nk} \cdot B)^2 + (Z_T - R_{Qk} \cdot B)^2]^{0,5}$

$F_{end,int} = \{[R_{Nk,end} \cdot \Delta L + R_{Nk} \cdot (B - \Delta L)]^2 + (Z_{T,end} - R_{Qk} \cdot B)^2\}^{0,5}/2 + F_{int} /2$

$F_{end,ext} = \{[R_{Nk,end} \cdot \Delta L + R_{Nk} \cdot (B - \Delta L)]^2 + (Z_{T,end} - R_{Qk} \cdot B)^2\}^{0,5}/2$

Maximum forces (kN) on foundations and anchors in load case 3

$N_{int} = N_{Ed}$

$N_{end} = N_{Ed,end}$

$F_{guy} = Z_{Cd}$

$F_{end,guy} = Z_{Cd,end}$

$F_{int} = [(Q_{Nd} \cdot B)^2 + (Z_T - Q_{Qd} \cdot B)^2]^{0,5}$

$F_{end,int} = \{[Q_{Nd,end} \cdot \Delta L + Q_{Nd} \cdot (B - \Delta L)]^2 + [(Z_{T,end} - Q_{Qd} \cdot ((B - \Delta L) - Q_{Qd,end} \cdot \Delta L)]^2\}^{0,5}/2 + F_{int} /2$

$F_{end,ext} = \{[Q_{Nd,end} \cdot \Delta L + Q_{Nd} \cdot (B - \Delta L)]^2 + [(Z_{T,end} - Q_{Qd} \cdot ((B - \Delta L) - Q_{Qd,end} \cdot \Delta L)]^2\}^{0,5}/2$

Figure A.14 – Calculation of forces on foundations and anchors

A.2.9 Resistance check of connection components

The wire clips, U-bolt wire rope grips and similar connection components creating the rope connections and terminations, are assessed according to the relevant standard with requested number, distance, torque moment, etc.

Connection components that connect the net panels together, the net panels to the ropes, the ropes to the anchors (for example, clips, shackles, ropes) are assessed to the resistance of connected components (net, ropes). If no characteristic values of connection components are available, the working load limits (WLL) are considered to be a resistance.