BS EN 12930:2015

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# Safety requirements for cableway installations designed to carry persons — Calculations

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**National foreword**

This British Standard is the UK implementation of EN 12930:2015. It supersedes BS EN 12930:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/20, Aerial ropeways.

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

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# Safety requirements for cableway installations designed to carry persons - Calculations

Prescriptions de sécurité pour les installations à câbles destinées au transport de personne - Calculs

Sicherheitsanforderungen an Seilbahnen für den Personenverkehr - Berechnungen

This European Standard was approved by CEN on 8 November 2014.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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EUROPÄISCHES KOMITEE FÜR NORMUNG

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# Foreword

This document (EN 12930:2015) has been prepared by Technical Committee CEN/TC 242 “Safety requirements for cableway systems for passenger transportation”, the secretariat of which is held by AFNOR.

This European Standard shall maintain the status of a National Standard, either with the publication of an identical text or by recognition up to July 2015, and any opposing National Standards shall be withdrawn by July 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document is intended to replace EN 12930:2004.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of the EU Directive 2000/9/EC.

For the relationship with the EU Directive 2000/9/EC, see informative Annex ZA, which is an integral part of this document.

The following main changes have been made to EN 12930:2004:

— In Clause 3 the term and definition “curvature ratio” has been replaced with the term “diameter ratio” and is defined in EN 1907.

— In Clause 3 the term and definition “safety component” has been removed, as the term and definition is defined in EN 1907 and/or in the Directive 2009/9/EC.

— In 5.2.2, 6.2 b) and 7.4.1 a) for the combinations of actions, the reference to their compatibility has been included.

— In 6.2 the requirement on calculation methods with regard to precision has been added.

— In 6.5 the wind force and the dynamic pressure are shown in simplified form and the possible deviation as a result of cableway-specific circumstances has been added.

— In 6.5 the usually assumed minimum dynamic pressure out of operation has been specified as 1,20 kN/m².

— In 6.5 consistency with EN 12929-1 has been achieved with regard to the reduction coefficient.

— In 6.5.5.3 the requirements for the ice load dependent on the nominal rope diameter have been changed, whereby provisions of international and national Standards (ISO 12494, EN 50341) have been taken into account.

— In 7.1.1 the non-essential details concerning the precision of the calculation of rope angles have been removed and the information concerning the step size for the calculation of longitudinal profile has been simplified with concentrated loads.

— In 7.1.4 due to the technical development of calculation programmes, the use of simplified calculation methods has been restricted.

— In 7.1.5 consistency with EN 1908 has been achieved.

— In 7.1.6 requirements to avoid rope spans which are too long and a too heavy concentration of carriers has been explained in more detail. The requirements for uni-directional aerial ropeways which are also operated with individual carriers have been compared with the requirements for group ropeways and cableways with carrier groups.

— In 7.2.3 the assumed friction coefficients for the line and rope calculations have been added.

— In 7.2.4 the reduction factor for the wind force in the "out of operation" load case has been added to the requirements.

— In 7.3 consistency with series EN 12927 has been achieved.

— In 7.4.1 b) the technically unfounded restriction on track ropes with fixed ends has been removed.

— 7.4.4 has been revised in order to clarify the previous requirements.

— In 7.5.2 the restriction of the smallest permissible tension safety factor whilst taking into consideration the wind and ice out of operation and in the case of cord tension as a result of differing groove diameters of multi-grooved drive sheaves has been added.

— In 7.5.2 c) and 7.6.2 c) the maximum tension safety factor on the long splicing has been restricted.

— In 7.5.4 the requirements concerning the verification of safe support of moving ropes in the case of suspended haul rope supports have been added.

— In 7.6.1 b) the partially incomplete specifications with regard to load positions for the approximation methods have been removed.

— In 7.6.2 the restriction of the smallest permissible tension safety factor whilst taking into consideration the wind and ice out of operation has been added.

— In 7.7.4 the technically unfounded requirement of the smallest bearing force for compression line support structures in the area of the loading area of ski-tows has been removed.

— The former 7.9.2 regarding the limit profile of the ropes of evacuation railways has been moved to EN 12929-1 to the remaining specifications with regard to the limit profile.

— In 7.9.2 a) the smallest permissible tension safety factor for endless evacuation ropes has been amended.

— The identification of the smallest nominal diameter of endless evacuation ropes has been moved to the new 7.9.3.

— The former 7.10.1 regarding the limit profile of the conductor, restraint and marker ropes has been moved to EN 12929-1 to the remaining specifications with regard to the limit profile.

— In 8.2.1 the list of the permissible friction values on the drive sheaves in the case of a complete loss of pressure in the hydraulic tensioning devices has been added.

— In 10.9.3 and 10.9.4 the actions as a result of a derailment on the towing ropes has been restricted.

— In 10.9.5 the actions as a result of a complete deropement have been specified in more detail and simplified.

— 10.9.6 has been removed as an accidental action, as if with detachable cableways which have a garaging possibility, the empty carriers on the rope are subjected to a wind "out of operation", no further standardised specifications have been made.

— In Annex A the A-deviation for Germany has been removed.

— Annex ZA has been updated.

This European Standard forms part of a series of European Standards concerning safety requirements for cableway installations designed to carry persons. This series of Standards comprises the following parts:

EN 1907 – *Terminology*

EN 12929 (all parts) – *General requirements*

EN 12930 – *Calculations*

EN 12927 (all parts) – *Ropes*

EN 1908 – *Tensioning devices*

EN 13223 – *Drive systems and other mechanical equipment*

EN 13796 (all parts) – *Carriers*

EN 13243 – *Electrical equipment other than for drive systems*

EN 13107 – *Civil engineering works*

EN 1709 – *Precommissioning inspection, maintenance and operational inspection and checks*

EN 1909 – *Recovery and evacuation*

EN 12397 – *Operation*

EN 12408 – *Quality assurance*

Together these form a series of Standards regarding design, manufacture, erection, maintenance and operation of all cableway installations designed to carry persons.

In respect of ski-tows, the drafting of this document has been guided by the works of the International Organisation for Transportation by Rope (OITAF).

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Belgium, Bulgaria, Denmark, Germany, the former Yugoslav Republic of Macedonia, Estonia, Finland, France, Greece, Ireland, Iceland, Italy, Croatia, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Norway, Austria, Poland, Portugal, Romania, Sweden, Switzerland, Slovakia, Slovenia, Spain, Czech Republic, Turkey, Hungary, United Kingdom and Cyprus.

## 1 Scope

This European Standard specifies the general safety requirements applicable to the calculations for cableway installations designed to carry persons. This document is applicable to the various types of cableway installations and takes into account their environment.

It contains:

- general requirements for calculations and their presentation;
- general requirements relating to the actions that shall be taken into account in the calculation of components as a basis for the requirements of the standards EN 13223, EN 13107, EN 12927 (all parts) and EN 1908;
- requirements relating to verification of ropes by calculation;
- requirements relating to the determination of the drive power;
- requirements for the actions of the ropes and carriers on the support structures and for the deformations of these support structures.

It does not apply to installations for the transportation of goods nor to lifts.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1709, *Safety requirements for cableway installations designed to carry persons — Precommissioning inspection, maintenance, operational inspection and checks*

EN 1907, *Safety requirements for cableway installations designed to carry persons — Terminology*

EN 1908, *Safety requirements for cableway installations designed to carry persons — Tensioning devices*

EN 1909, *Safety requirements for cableway installations designed to carry persons — Recovery and evacuation*

EN 1990, *Eurocode: Basis of structural design*

EN 1991-1-1, Eurocode 1: *Actions on structures — Part 1-1: General actions — Densities, self-weight and imposed loads for buildings*

EN 1991-1-4, Eurocode 1: *Actions on structures — Part 1-4: General actions — Wind actions*

EN 12397, *Safety requirements for cableway installations designed to carry persons — Operation*

EN 12408, *Safety requirements for cableway installations designed to carry persons — Quality control*

EN 12927 (all parts), *Safety requirements for cableway installations designed to carry persons — Ropes*

EN 12929 (all parts), *Safety requirements for cableway installations designed to carry persons — General requirements*

EN 13107, *Safety requirements for cableway installations designed to carry persons — Civil engineering works*

EN 13223, *Safety requirements for cableway installations designed to carry persons — Drive systems and other mechanical equipment*

EN 13243, *Safety requirements for cableway installations designed to carry persons — Electrical equipment other than for drive systems*

EN 13796 (all parts), *Safety requirements for cableway installations designed to carry persons — Carriers*

# 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1907 and the following apply.

**3.1**
**rope calculation**
calculation for designing the ropes on the basis of the tension forces determined from the calculation of the longitudinal profile

**3.2**
**calculation of longitudinal profile**
calculation to determine the tension forces in the rope and their actions on the rope supports and rope anchorages

**3.3**
**empty rope**
track rope or towing rope without carriers

**3.4**
**unloaded rope**
track rope or towing rope only carrying empty carriers at the required carrier pitch

**3.5**
**loaded rope**
track rope or towing rope carrying fully laden carriers at the required carrier pitch

**3.6**
**angle of deflection of rope**
angle through which a rope is deflected, measured between the tangent to the rope at the start of the deflection and the tangent to the rope at the end of the deflection in the same plane as the deflected rope

# 4 Symbols and abbreviations

Symbols and abbreviations are explained with the formula to which they apply throughout this document.

# 5 General requirements

## 5.1 Application of this Standard

The requirements of this document, together with those of EN 1709, EN 1908, EN 1909, EN 12397, EN 12408, EN 12927 (all parts), EN 12929 (all parts), EN 13107, EN 13223, EN 13243 and EN 13796 (all parts) apply to all cableway installations.

## 5.2 Safety principles

### 5.2.1 General

The safety principles set out in EN 12929-1 apply.

In addition, the following hazard scenarios and safety requirements relative to the scope of this document are also applicable:

#### 5.2.2 Hazard scenarios

The following events may lead to hazardous situations, which may be avoided or limited by the requirements of this document:

a) lack of or incorrect assessment of the actions on the individual components of the installation;

b) use of inappropriate calculation methods or formulae;

c) lack of or inadequate consideration of dynamic effects and fatigue effects on individual components;

d) lack of or incorrect assessment of the most unfavourable combinations of actions on each other when dimensioning and carrying out calculations;

e) erroneous assumptions in the calculations.

#### 5.2.3 Safety measures

This document stipulates the necessary general requirements for minimising the hazard scenarios listed in 5.2.2 when carrying out verification by calculation and when designing the complete installation as well as individual components, in particular when calculating the longitudinal profile and the rope, and for avoiding hazardous situations.

## 6 General requirements for calculations

### 6.1 General comments

The calculations to be submitted shall demonstrate that the safety requirements for cableways defined in this document and those in the other standards listed in 5.1 are fulfilled. In doing so, the anticipated operating conditions of the installation shall be taken into account.

The safety components of the installation shall be verified by calculations, where necessary with respect to static stresses, fatigue stresses, stability and suitability for use.

### 6.2 Calculation methods

All methods used in the calculations shall either be indicated directly or be explained by precise bibliographic references.

Methods of approximation and calculation models shall provide results which are sufficiently precise and conservative.

The following shall always apply:

a) in any calculation of a mechanical system, structure or component, it shall be clear from the documentation what the magnitudes and directions of the actions are assumed to be and which cross-sections have been examined;

b) the calculations shall be made taking into account the combinations of actions set out in the standards and other specifications. Should such information not be available, the most unfavourable interacting loading conditions shall be used as a basis and both the directions and magnitudes of the actions and their combinations shall be specified.

## 6.3 Presentation of calculations

The calculation documents shall be clear and perfectly comprehensible without any additional information. Their origin and date of production shall be stated.

The results of computer calculations shall be accompanied by a sheet on which the calculation model, the methods employed and the assumptions are described. Symbols and abbreviations used shall be explained. The version of the computer program used shall be stated. Input values and output values (results) shall be related to each other.

## 6.4 Verification by tests

Verification by tests alone may be carried out if this document or other Standards contain no indications concerning the calculation and calculation in accordance with recognised methods is not possible.

In exceptional cases, e.g. complex components or dynamic actions, additional verification by tests may be required to supplement calculations in order to verify the characteristics of safety components. The test programme and methods shall produce test conditions which are as close as possible to actual service conditions.

## 6.5 Actions

### 6.5.1 General

The following groups of actions shall be taken into account in the calculations:

— self weight and imposed loads;

— dynamic actions;

— actions resulting from tension forces in the ropes;

— actions due to climatic conditions;

— other actions (e.g. due to avalanches, earthquakes, installation conditions).

The combinations of actions applicable to each component are specified in the standards EN 1908, EN 13223, EN 13107 and EN 13796-1.

**6.5.2** The self-weight of components shall be assessed in accordance with EN 1991-1-1 or, if no Standard applies, according to information from the supplier.

With regard to the mass of a person to be adopted for the calculation of the longitudinal profile, 7.2.1 b) shall apply.

With regard to the mass of a person to be adopted for dimensioning the carriers, see EN 13796-1.

**6.5.3** The actions from the ropes shall be calculated in accordance with Clause 7. For the dimensioning of structures, Clause 10 and EN 1991-1-1 shall apply.

**6.5.4** Actions from wind shall be defined by the resultant wind force $F_w$ in accordance with the following provisions:

The resultant wind force shall generally be calculated in accordance with EN 1991-1-4 on the basis of formula (1):

$$F_\mathrm{w} = q \times c_\mathrm{f} \times A_\mathrm{ref} \tag{1}$$

Where:

| | |
|---|---|
| $q$ | dynamic pressure; |
| $c_f$ | force coefficient; |
| $A_{ref}$ | reference area for $c_f$ |

The values specified in the EN 1991-1-4 and in the national construction standards can differ in accordance with cableway-specific circumstances.

Provided no other regulations have been specified in EN 1709, EN 1908, EN 1909, EN 12397, EN 12408, EN 12927 (all parts), EN 12929 (all parts), EN13107, EN 13223, EN 13243 and EN 13796 (all parts), the following dynamic pressure values shall apply:

a) in operation, a minimum value for dynamic pressure $q$ = 0,25 kN/m$^2$ shall be used. For specific cableways a higher value may be necessary.

b) out of operation, the minimum value for dynamic pressure is $q$ = 1,20 kN/m$^2$, provided that particular local installation circumstances of the cableway or national cableway-specific provisions or directives do not stipulate other values.

c) the dynamic pressure acts as a uniformly distributed load over the total slope length $l^*$. Out of operation, the dynamic pressure may be reduced in accordance with equation (2).

$$q_{red} = \beta \times q \quad (2)$$

Where:

| | |
|---|---|
| $q_{red}$ | reduced dynamic pressure acting on the slope length $l^*$ of the span; |
| $\beta$ | reduction coefficient; |
| $q$ | dynamic pressure. |

The reduction coefficient $\beta$ is:

1) 1,00 at $l^*$ = 0 m;

2) 0,65 at $l^*$ = 600 m;

3) 0,50 at $l^* \geq$ 2 000 m.

With a slope field length $l^*$ between 0 m and 600 m or between 600 m and 2 000 m, $\beta$ shall be established by linear interpolation.

For the determination of lateral deflections of the ropes, see EN 12929-1.

**6.5.5** Other actions

**6.5.5.1** Other actions, in particular those of ice and snow, are defined in 7.2 and Clause 10, as well as in EN 13107.

**6.5.5.2** Actions due to ice on the ropes shall be taken into account, unless particularly favourable climatic conditions exist, in which case different sections of the cableway shall be investigated individually as required.

**6.5.5.3** An ice load on the rope shall be taken into account if the ice curtain cannot be removed in good time by moving or driving the rope in another manner.

Where an expert opinion establishes no other ice load on the rope, an ice sheet with a density of 600 kg/m$^3$ and an ice thickness of

— 20 mm for ropes with a nominal rope diameter ≤ 10 mm;

— 25 mm for ropes with a nominal rope diameter ≥ 100 mm;

shall be assumed.

With a nominal rope diameter between 10 mm (corresponding to an ice load of 11,1 N/m) and 100 mm (corresponding to an ice load of 57,8 N/m), the ice load shall be established by means of linear interpolation.

If required by local climatic conditions, a greater ice thickness or greater density shall be assumed. In the case of favourable climatic conditions, lower values may also be taken.

# 7 Verification by calculation for ropes

## 7.1 General

**7.1.1** The following shall be verified for ropes:

a) the extreme rope tension forces and the corresponding rope angles at supports and anchorage points;

b) the extreme tensile safety factors;

c) the extreme support forces acting on the line support structures (magnitude and direction of the force);

d) in the case of aerial ropeways, the extreme sag in the centre of the spans and at other points as required for verification of clearance.

Unless otherwise required, the ropes shall be assumed to be at rest or in uniform movement.

If, when calculating the longitudinal profile with individual loads, a stepped movement of the load is assumed, the step size shall be specified as max. 2,00 m.

**7.1.2** The following shall be taken into account, in particular when calculating the tension forces in the ropes:

a) the friction resistance of the tensioning device and the inaccuracy of the mass of the counterweight. These may be neglected if their combined effect on the tension force in the rope without taking into account the inertia forces from the counterweight does not exceed ± 3 %;

b) the working range of controlled tensioning devices if the effect on the tension force in the rope exceeds ± 3 %;

c) a breakdown or total oil loss in the hydraulic system of a controlled tensioning device;

d) the friction resistance on the rope supports and rope deflection components, over which the rope moves, in both directions of movement;

e) the power requirements of mechanical equipment driven by the rope;

f) the influence of changes in the ambient temperature (see 7.1.3);

g) additional influences, such as for example from wind and ice, if their influence on the tension forces in the rope exceeds ± 3 % (see 7.2.4).

**7.1.3** The temperature influence in accordance with 7.1.2 f) shall generally take into account a temperature difference of at least 60°C; the actual temperature limits are to be stated. Deviations from this value may be assumed if this is justified by local climatic conditions.

If there is equipment for adjusting the tension force in the rope or for the tensioning system travel, a temperature difference of 30°C may be taken into account.

**7.1.4** In the case of uni-directional aerial ropeways where the carriers are evenly distributed across the rope and fitted to the rope with fixed grips, the tension forces in the ropes with distributed load may be calculated up to a carrier pitch of 40 m.

**7.1.5** In the case of cableway tensioning devices, the necessary travel shall be verified, taking into account the influence of the following factors (the influence of each of these factors shall be quantified):

a) operational changes in sag and elastic elongation of the rope;

b) temperature change;

c) reserve for movement during starting and braking;

d) reserve for permanent elongation of the rope;

e) distance between stop position switch and buffer.

In addition, for the calculation of the tensioning system travel as well as the end buffer of the tensioning carriage, an ice load in accordance with 6.5.5.3 out of operation shall be taken into account.

In the case of tensioning devices for ski-tows, verification in accordance with influences a), b) and d) is adequate.

For the magnitudes (numerical values) of the influence of b) and d), reference is made to EN 1908.

For the elastic modulus of carrying-hauling ropes and haul ropes, a value of 100 kN/mm$^2$ shall be assumed.

**7.1.6** Rope spans which are too long shall be avoided in the case of continuous movement aerial ropeways with an equal distribution of carriers on both ropes. The change in the inclination of the tangents at the ends of the span between the unloaded rope and the loaded rope shall not be greater than 0,15 rad, with the load condition on the other rope spans remaining the same. If, in the case of a continuous movement aerial ropeway with a standard equal distribution of carriers on both ropes, an operating mode is also implemented with individual carriers and unequal distribution of the carriers, the requirements for cableway installations with carrier groups shall be applied.

An excessively high concentration of carriers shall be avoided in the case of group ropeways and cableway installations with carrier groups. The change to the inclination of the tangents at the ends of the span between the unloaded rope and loaded rope with any load position of the carrier may not exceed 0,225 rad.

NOTE Usually the critical case, which should be assessed first, is the downhill end of the span and with the minimum rope tension.

## 7.2 Actions to be taken into account when calculating the longitudinal profile and rope

### 7.2.1 Self weight and imposed loads

a) The self weights of ropes and carriers shall be taken in accordance with information from the suppliers.

In the case of aerial ropeways, the accuracy of the information shall be verified before the installation is brought into operation. If the actual self-weights differ by more than ± 3 % from the values taken into account in the calculations, the rope and longitudinal profile calculation shall be repeated, taking into account the actual values.

b) The average mass of a person shall be assumed to be 75 kg. In the case of cableway installations which transport persons plus their winter sports equipment, as well as for ski-tows, the average mass of a person shall be assumed to be 80 kg.

### 7.2.2 Dynamic effects

a) The starting acceleration shall be assumed to be at least 0,15 m/s$^2$.

b) The following values shall be assumed for deceleration:

   1) the minimum deceleration to be assumed when braking with the drive motor is 0,4 m/s$^2$;

   2) in the case of mechanical braking, the maximum deceleration occurring during normal operation of the drive brakes shall be taken into account.

   This maximum value shall be determined taking into consideration the following hazards:

   i. injury to people in the carriers or falling of people from the carriers;

   ii. lifting of ropes from their supports due to large oscillations in sag;

   iii. lifting of the bogies or carrier trucks from the rails or track ropes.

c) In exceptional operating cases, the following dynamic effects shall be investigated:

   1) in the case of an installation having two or more haul ropes, the dynamic effects due to the rupture of one haul rope;

   2) in the case of an installation with on-board brakes, the dynamic effects following application of the on-board brake with the haul rope still intact.

### 7.2.3 Friction coefficients

The friction coefficients below, expressed as percentages of the bearing forces, with the bending resistance of the ropes included in the friction resistance, shall be assumed for the calculation of longitudinal profile and ropes:

| | |
|---|---|
| — rubber-lined rollers | 3,0 %; |
| — plastic-lined rollers | 2,0 %; |
| — sheaves with roller bearings | 0,3 %; |
| — sheaves with journal bearings | 1,0 %; |
| — ropes on track rope shoes | 10,0 %; |
| — track rope roller chains with roller bearings | 0,5 %; |
| — track rope roller chains with journal bearings | 1,0 %; |
| — steel wheels on carriers for funicular railways without eccentric haul rope connection | 1,0 %; |
| — steel wheels on carriers for funicular railways in the case of horizontal bends or eccentric haul rope connection | 2,0 %; |
| — pneumatic tyres on carriers for funicular railways on concrete or steel girders without eccentric haul rope connection | 1,5 %; |

| | | |
|---|---|---|
| — | pneumatic tyres on carriers for funicular railways in the case of horizontal bends or eccentric haul rope connection | 2,5 %; |
| — | carrier truck rollers on aerial ropeway carriers | 2,0 %; |
| — | steel rollers on steel surfaces | 1,0 %; |
| — | skis on ski-tow tow-tracks | 10,0 %. |

#### 7.2.4 Actions from wind and ice

The following cases with simultaneous action from wind and ice shall be assumed:

a) in operation:

1) wind force in accordance with 6.5.4, ice load at 40 % of the value in accordance with 6.5.5.3, and;

2) wind force at 80 % of the value in accordance with 6.5.4, ice load in accordance with 6.5.5.3;

b) out of operation:

1) wind force at 65 % of the value in accordance with 6.5.4, ice load at 40 % of the value in accordance with 6.5.5.3, and;

2) wind force at 40 % of the value in accordance with 6.5.4, ice load in accordance with 6.5.5.3.

### 7.3 Tension safety factor – General

For the calculation of the tension safety factor, the test breaking force may be used in place of the minimum breaking force.

### 7.4 Track ropes

#### 7.4.1 Tension forces in the rope and sag

a) The calculation shall be made taking into account the most unfavourable loads, load positions and friction forces for empty rope and for loaded rope with individual loads.

b) In the case of track ropes, the influence of temperature in accordance with 7.1.3 and the actions of wind and ice in accordance with 7.2.4 shall also be taken into account in the calculation.

#### 7.4.2 Tension safety factor

The tension safety factor under normal operating conditions shall not be less than 3,15.

Taking into account the effect of any carrier track brake, the tension safety factor shall not be less than 2,7.

Taking into account the actions of wind and ice whilst out of operation in accordance with 7.2.4 b), the tension safety factor shall not be less than 2,25.

#### 7.4.3 Bending stress

a) Carrier cross loads:

In addition to the weight of the carriers, the actions of the moving rope on the carrier shall also be taken into account:

1) the transverse force factor shall not be less than the following values:

i. 10 for track ropes tensioned by means of weights or hydraulic devices;

ii. 8 for track ropes with fixed ends.

2) The transverse force factor applied to individual rollers in accordance with EN 12927 (all parts) shall not be less than 80 when using a roller lining material with a modulus of elasticity $E > 5\,000$ N/mm$^2$ or 60 if the modulus of elasticity is $E \leq 5\,000$ N/mm$^2$.

For the maximum permissible load on the carrier truck rollers, refer to EN 13796-1;

b) for diameter ratios, refer to EN 12927 (all parts).

NOTE Examples of values of modulus E:

1) rubber $E$ = 80 N/mm$^2$;

2) plastic $E$ = 200 to 5 000 N/mm$^2$;

3) bronze $E$ = 100 000 to 120 000 N/mm$^2$.

### 7.4.4 Minimum bearing forces

a) The track rope shall not lift off its supports, if:

1) at support towers, the maximum tension force in the rope, without any action of wind or ice, is increased by 40 %;

2) at compression line support structures (e.g. in stations), the minimum tension force in the rope is reduced by 40 %.

b) The angle of deflection of the empty track rope in the vertical plane shall be at least 0,02 rad.

c) The minimum bearing force on supports shall be greater than the resultant of the effects of an upward vertical wind acting on half the slope length of each adjacent rope span or, if applicable, half the slope lengths of equivalent adjacent rope spans in accordance with EN 12929-1, with a wind pressure q = 0,5 kN/m$^2$. For the calculation of the minimum bearing forces, the influence of the clamps shall not be taken into account.

d) The bearing safety of the track rope on its shoes shall be verified by determining the critical dynamic pressure $q_{krit}$ for each end of the track rope shoe using equation (3) in d), where the following conditions shall be met:

1) for the load case in operation $q_{krit} \geq 250$ N/m$^2$;

2) for the load case out of operation $q_{krit} \geq 1\,000$ N/m$^2$;

The critical dynamic pressure out of operation can be between 250 N/m$^2$ and 1 000 N/m$^2$, if further measures are used to combat derailment (for example: applying anti-derailers).

Refer to EN 13223.

The critical dynamic pressure shall be calculated according to equation (3) below:

$$q_{\text{krit}} = \sqrt{\frac{d}{R}} \times \sqrt{(1 - \sin\alpha)} \times \frac{\Sigma T}{\Sigma (c_{\text{f}} A_{\text{ref}})} \left[\text{N/m}^2\right] \tag{3}$$

Where:

$d$ is the nominal diameter of the track rope [m];

$R$ is the radius of curvature of the track rope shoe [m];

$\alpha$ is equal to 90° minus half the wrap angle on the shoe;

$\Sigma T$ is the sum of minimum track rope tension force and if necessary the minimum haul rope tension force; see following Paragraph [N];

$c_f$ are the respective force factors for the ropes and the carrier;

$A_{ref}$ are the respective areas struck by the wind [m$^2$].

The tension force in the haul rope shall be taken into account when calculating ΣT if the actions from the haul and ballast ropes and from the carrier are transmitted to the track rope (e.g. via the haul rope hangers or the carrier). In doing so, a carrier is assumed to be immediately adjacent to the support when in operation; out of operation the empty ropes shall be taken into account.

For calculating $\Sigma(c_f A_{ref})$, the actions of the moving ropes and/or the carrier shall be taken into account in the same way as the requirements of the above Paragraph.

The rope length of half the slope length of the span immediately adjacent to the support, or, if applicable, half the equivalent slope length of that span according to EN 12929-1 shall be taken into account.

## 7.5 Haul and ballast ropes

### 7.5.1 Tension forces in the rope and sag

Calculations shall be made taking into account the most unfavourable loads and load positions with individual loads.

In the case of uni-directional aerial ropeways, if provision is made for operation with an empty haul rope, even if only over a single span, this shall be taken into account.

### 7.5.2 Tension safety factor

a) The tension safety factor shall not be less than the following values, with dynamic effects in accordance with b) taken into account, for:

   1) funicular railways 4,2;

   2) reversible aerial ropeways with track rope brake 3,8;

   3) bi-cable uni-directional aerial ropeways 4,0.

b) The basic tensioning force is decisive for the calculation of the smallest tension safety factor. If the regulation of the basic tensioning force takes place only after a deviation of more than 5 % relating to the maximum rope tension force, the additional section shall be taken into consideration.

c) Dynamic effects in accordance with 7.2.2 a) and b) shall be taken into account approximately by considering the inertia of the masses moved by the rope as attached firmly to the rope and distributed uniformly along it.

d) The tension safety factor shall not exceed 20 for spliced ropes, with dynamic effects not being taken into account.

e) In the case of funicular railways and bi-cable reversible aerial ropeways, the minimum tension force in the haul rope shall be sufficient that the on-board brake is not released inadvertently under normal operating conditions.

f) Taking into account the dynamic effects provided for in 7.2.2 c), the tension safety factor shall not be less than 1,5.

g) Taking into account the actions of wind and ice whilst out of operation in accordance with 7.2.4 b), the tension safety factor shall not be less than 2,25.

h) In the case of multi-grooved drive sheaves, the safety of the rope, when taking into consideration the additional tension safety factors which arise due to the differing groove diameters, calculated with 1,3 times the minimum required friction coefficient, shall not exceed the value 2,5.

#### 7.5.3 Bending stress

a) For the transverse force factor, the regulations of EN 12927 (all parts) shall be taken into account.

b) With regard to the diameter ratios, refer to EN 12927 (all parts).

#### 7.5.4 Bearing safety

The moving rope shall not lift off its supports, except when a carrier travels past:

a) in the case of funicular railways, it shall be verified by calculation that the moving rope does not lift from the rollers in areas with concave line profiles, taking into account dynamic effects on the tension in the rope in these areas in accordance with 7.2.2 a) and b). Exception: see EN 12929-1.

b) in the case of aerial ropeways, it shall be verified by calculation that the rope does not lift off the rollers if the maximum tension in the rope during uniform movement is increased by 40 %.

   In the case of rollers of haul rope supports, this height does not need to be taken into account if an incorrect position of the rope has itself triggered the cableway to come to a standstill.

### 7.6 Carrying-hauling ropes of aerial ropeways

#### 7.6.1 Tension forces in the rope and sag

a) Exact method:

   The calculation shall be made taking into account the most unfavourable loads and most unfavourable load positions with individual loads.

   (This represents a basic requirement. In order to determine tension forces in the ropes, bearing forces on the ropes and sag at every point on the installation, the most unfavourable load conditions should be determined for the entire ropeway. This method is generally used for mono-cable reversible aerial ropeways, group ropeways or cableways with considerable individual loads and long carrier pitch.)

   Should provision be made for operation with an empty carrying-hauling rope, even if only over certain spans, this shall be taken into account when calculating tension forces in the ropes, the sag and the bearing forces from the ropes.

b) Approximate methods:

   If the conditions of 7.1.4 are fulfilled, bearing forces in the ropes and the sag can be calculated approximately in the following manner: the minimum and maximum tension forces in the rope at each support shall be combined respectively with the minimum and maximum loads in the relevant span.

   Should provision be made for operation with an empty carrying-hauling rope, even if only over certain spans, this shall be taken into account when calculating tension forces in the ropes, the sag and the bearing forces from the ropes.

If other approximation methods are used (e.g. assumption of evenly distributed loads, loads not uphill and downhill from the support), it shall be verified that the assumptions are conservative for each value obtained (sag, bearing force in rope, rope angle, etc.).

c) For carrying-hauling ropes with fixed drive and return sheaves, the influence of the temperature shall also be taken into consideration in accordance with 7.1.3 and the actions of wind and ice in accordance with 7.2.4.

### 7.6.2 Tension safety factor

a) The tension safety factor shall not be less than 4,0, with dynamic effects in accordance with b) taken into account.

b) Dynamic effects in accordance with 7.2.2 a) and b) shall be taken into account approximately by considering the inertia of the masses moved by the rope to be attached firmly to the rope and distributed uniformly along it.

c) The tension safety factor shall not exceed 20 for long splicing, with dynamic effects not being taken into account.

d) Taking into account the actions of wind and ice whilst out of operation in accordance with 7.2.4 b), the tension safety factor shall not be less than 2,25.

e) The basic tensioning force is decisive for the calculation of the smallest tension safety factor. If the regulation of the basic tensioning force takes place only after a deviation of more than 5 % relating to the maximum rope tension force, the additional section shall be taken into consideration.

### 7.6.3 Bending stress

a) The transverse force factor shall respect the requirements of EN 12927 (all parts).

b) For diameter ratios, refer to EN 12927 (all parts).

### 7.6.4 Minimum bearing forces

a) The minimum bearing force on a bearing support shall:

1) in operation, with uniform movement, correspond to at least 1,5 times the wind force resulting from the effect of the dynamic pressure $q$ of 0,25 kN/m$^2$ on the empty or unloaded rope over the length of the longest adjacent span;

2) out of operation, correspond at least to the wind force resulting from a dynamic pressure $q$ of 0,80 kN/m$^2$ over half the sum of the lengths of the chords of the adjacent spans on the empty rope or, if the carriers remain on the rope when the installation is out of operation, on the unloaded rope.

b) The minimum bearing force at a compression support with uniform movement shall correspond to at least 1,5 times the resultant wind force; the wind force shall be determined in accordance with a), but instead of the empty rope or unloaded rope, the loaded rope shall be taken into account.

c) The carrying-hauling rope shall not lift off at bearing supports when the maximum tension force in the rope in accordance with 7.1.2 is increased by 40 % on the spans adjacent to the support under investigation.

d) The carrying-hauling rope shall not lift off at compression supports when the minimum tension force in the rope in accordance with 7.1.2 is reduced by 20 % and there is a simultaneous increase of 25 % in the imposed load on the rope spans adjacent to the support.

e) With a complete pressure loss of the hydraulic system, in the case of compression line support structures and taking into consideration the individual load in the most unfavourable of load cases, a minimum rolling load of the towing rope of 200 N shall not be exceeded.

f) Where the carrying-hauling rope moves uniformly, the minimum load on the rollers shall be at least 500 N and correspond to equation.

$$A \geq 500 + 50\left[d - \left(D_1 - D_2\right)\right] \tag{4}$$

Where:

$A$ is the minimum roller pressure [N];

$d$ is the nominal rope diameter [mm];

$D_1$ is the diameter of the outer cheek of the roller [mm], and;

$D_2$ is the diameter at the bottom of the groove of a new bearing liner [mm].

In the case of loads where no passengers are being carried (exceptional loads, e.g. loading the installation, journeys with an empty rope, etc.), the value expressed by the above condition may be halved.

For the design and construction of rollers, refer to EN 13223.

g) Support-compression roller batteries shall be installed in such a way that in the neutral position of the carrying-hauling rope (bearing force in rope = zero) on the rollers and the minimum roller pressure in accordance with Paragraph f) is maintained. For all other load cases, the rollers with the lower roller pressure shall not leave the rope.

## 7.7 Haul ropes of ski-tows

### 7.7.1 Tension forces in the rope and sag

The bearing forces and sag may be determined approximately by assuming that the individual loads are evenly distributed on the haul rope. The calculation shall be made for uniform movement and for the installation at rest.

### 7.7.2 Tension safety factor

a) The tension safety factor shall not be less than 4,0.

b) The basic tensioning force is decisive for the calculation of the smallest tension safety factor. If the regulation of the basic tensioning force takes place only after a deviation of more than 5 % relating to the maximum rope tension force, the additional section shall be taken into consideration.

c) The tension safety factor shall not exceed 20.

### 7.7.3 Bending stress

For diameter ratios, refer to EN 1908, EN 12927 (all parts) and EN 13223.

### 7.7.4 Minimum bearing forces

a) The minimum bearing force on the haul rope rollers of a roller battery in the most unfavourable load case shall not exceed the following values:

1) for support rollers 500 N;

2) for compression rollers 900 N.

These values may not be fallen short of for guide rollers, support-compressed roller batteries and roller batteries in the area of the loading area.

b) The sheave load on line support structures in the most unfavourable load case shall not exceed the following values:

1) for support sheaves 1 000 N;

2) for compression sheaves 1 800 N.

These values may not be fallen short of for guide sheaves, support-compression sheaves and the rope sheaves adjacent to the loading areas.

## 7.8 Tension ropes

### 7.8.1 Tension forces in the ropes

The tension forces in the ropes shall be taken from the calculation of the longitudinal profile with uniform movement.

### 7.8.2 Tension safety factor

The tension safety factor shall not be less than 5,0.

If load equilibrium cannot be assumed between two or more parallel tension ropes, the tension safety factor of each rope shall not be less than 6,0.

### 7.8.3 Bending stress

For diameter ratios, refer to EN 12927 (all parts).

## 7.9 Evacuation ropes

### 7.9.1 Tension forces in the ropes, sag, bearing forces, bending stress

The calculation of the tension forces in the ropes, bearing forces, sag and bending stresses shall be carried out as indicated in 7.5 or 7.6.

### 7.9.2 Tension safety factor

a) For endless evacuation ropes:

1) The tension safety factor shall not be less than 2,9

2) The basic tensioning force is decisive for the calculation of the smallest tension safety factor. If the regulation of the basic tensioning force takes place only after a deviation of more than 5 % relating to the maximum rope tension force, the additional section shall be taken into consideration.

3) Taking into account the actions of wind out of operation in accordance with 6.5.4, the tension safety factor shall not be less than 2,75.

4) Taking into account the actions of wind and/or ice whilst out of operation in accordance with 7.2.4 b), the tension safety factor shall not be less than 2,0.

b) The tension safety factor for endless evacuation ropes shall not be less than 5,0.

#### 7.9.3 Smallest nominal diameter of endless evacuation ropes

Endless evacuation ropes shall have a nominal diameter of at least 15 mm.

### 7.10 Conductor, restraint and marker ropes

#### 7.10.1 Tension safety factor

The tension safety factor may not be less than a value of

a) in operation:

   1) without taking into account the actions of ice 3,0;

   2) taking into account the actions of ice 2,5;

b) out of operation and taking account the requirements of wind and ice according to 7.2.4 b) 2,0;

#### 7.10.2 Bending stress

For diameter ratios, refer to EN 12927 (all parts).

## 8 Load transmission on the drive sheave

### 8.1 Safe transmission of tangential force

The safe transmission of the tangential force to the drive sheave, or to each drive sheave in the case of multiple drive sheaves, shall be verified. This verification shall be considered satisfactory if the permissible friction coefficient $\mu_{zul}$ at the drive sheave, for all loadings, taking dynamic effects also into account, is greater than or equal to the necessary friction coefficient $\mu_{erf}$ which is calculated according to formula (5) below:

$$\mu_{\text{zul}} \geq \mu_{\text{erf}} = \frac{1}{\alpha} \times \ln \frac{T_{\max}}{T_{\min}} \quad (5)$$

Where:

| | |
|---|---|
| $\alpha$ | is the angle of contact with the drive sheave [rad]; |
| $T_{max}$ or $T_{min}$ | greatest or smallest in each case with the tension force of the rope occurring for the same load case on the drive sheave; |
| $\mu_{erf}$ | required friction coefficient on the drive sheave. |

The dynamic effects shall be taken into account:

a) in accordance with 7.2.2 a) and b) (normal operation of drive brakes), and;

b) taking into account the maximum possible deceleration occurring in the event of defective operation of the drive brakes (refer to EN 13223).

If the requirements of 7.1.4 are complied with, the same approximation method may be used for calculating the maximum and minimum tension forces in the rope.

For ski-tows, the dynamic effects as indicated in 7.2.2 a) need not be taken into account.

### 8.2 Permissible friction coefficients at the drive sheave

**8.2.1** In the case of cableway installations aerial ropeways, the permissible friction coefficient $\boldsymbol{\mu_{zul}}$ at the drive sheave shall be calculated as a function of the friction coefficient $\boldsymbol{\mu}$, corresponding to realistic conditions (e.g. wet rope, lubricated rope at + 40°C) in accordance with the following conditions:

— In taking account of the dynamic effects in 8.1 a): $\mu_{zul}$ = 0,67 $\mu$; $\mu_{zul}$ = 0

— In taking account of the dynamic effects in 8.1 a), the permissible friction coefficient is $\mu_{zul}$ 2/3 of $\mu$: $\mu_{zul}$ = 0,73 $\mu$; $\mu_{zul}$ = 0

— In taking account of the dynamic effects in 8.1 b) and in order to take into account pressure losses in hydraulic tensioning systems in accordance with EN 1908, the permissible friction coefficient is 80 % of $\mu$: $\mu_{zul}$ = 0,80 $\mu$. $\mu_{zul}$ = 0

For rubber, a minimum coefficient $\mu$ = 0,30 may be assumed.

For other materials, the actual friction coefficient shall be determined by testing.

**8.2.2** In the case of ski-tows with rubber-lined drive sheaves, the permissible friction coefficient is $\boldsymbol{\mu_{zul}}$:

— 0,22 if grips without rope twist equalisation (fixed grips) are used;

— 0,25 for a haul rope of diameter up to 18 mm if grips without rope twist equalisation (fixed grips) are used;

— 0,30 if the grips allow rope twist equalisation (detachable bushes). This value may be increased by up to 40 % subject to verification by testing.

### 8.3 Load cases

In the case of detachable systems where the carriers can be garaged, the most unfavourable loading conditions shall be taken into account, which are usually:

— occupied carriers up, empty rope down, or;

— empty rope up, occupied carriers down.

If the most unfavourable load cases listed are not possible (e.g. because of counting mechanisms, monitoring of the torque at the drive sheave or preventive operational measures), only those loading conditions which actually occur need be considered.

## 9 Calculation of drive power

### 9.1 General

The power of drive systems shall be determined taking into account all the characteristics of the cableway or the ski-tow which are relevant to the system and its operation.

For the purposes of calculation, the characteristic force and speed shall be those at the rim of the drive sheave (at the axis of the rope) and the characteristic power shall be that at the shaft of the drive motor at nominal speed.

### 9.2 Continuous power for cableway installations in non-continuous operation

**9.2.1** For cableway installations

— which have set changes of speed for operating purposes or due to requirements on the line or at the stations (e.g. electrical starting and stopping on the line, arrival at normal stopping points in stations), and/or;

— in which for other reasons operation of the drive system is not continuous;

the continuous power shall be calculated for each load case on the basis of a time-tangential force diagram in which changes in tangential force due to acceleration (or deceleration) in accordance with 9.4 shall be taken into account. The diagram shall be produced for a complete travel cycle. It shall be used to calculate the mean square value which is the basis for the necessary continuous power.

**9.2.2** It shall be verified that (taking into account the altitude and temperature at the site of the installation) the permissible limit values for the drive system (e.g. peak torque, peak power, current load) are adequate when, in addition to the continuous power in accordance with 9.2.1, the extreme values figuring in the diagram are also taken into account (see EN 13223 and EN 13243).

NOTE The calculation method specified in 9.2 is generally applicable for funicular railways, reversible aerial ropeways and pulsed movement aerial ropeways.

### 9.3 Continuous power for cableway installations in continuous operation

**9.3.1** For cableway installations

— in which operation of the drive system is continuous, and;

— in which, apart from occasional changes of speed (e.g. for temporary reductions in travel speed, to stop the installation for operational reasons or to prevent danger) the speed of the drive system is uniform, and;

both tangential force and operating speed shall be considered as constant βwhen calculating the continuous power.

**9.3.2** For cableway installations, it shall be verified, taking into account the elevated position and temperature at the location, that the permissible limit values for the drive mechanisms (e.g. peak torque, peak power, current load) are adequate, taking into account not only the continuous power in accordance with 9.3.1 but also the acceleration power in accordance with 9.4.

NOTE The calculation method is generally employed for uni-directional aerial ropeways and for ski-tows.

### 9.4 Acceleration power

When determining the acceleration or deceleration power, it is permissible to assume that all translational masses and all rotational inertia of a cableway are subjected to a constant acceleration (or deceleration) from the drive system. The resulting inertia forces in the case of acceleration or deceleration shall be assumed to be constant.

## 10 Actions of ropes and carriers on civil engineering works

### 10.1 General

The dimensioning of mechanical devices is covered in EN 13223 and the dimensioning of support structures in EN 13107.

This Clause covers the actions of the ropes and carriers acting on the support structures.

The actions according to 10.2 to 10.8 are variable actions and the actions according to 10.9 are accidental actions as defined in EN 1990.

The requirements of EN 13107 apply to combinations of actions on the support structures.

## 10.2 Actions due to tension forces in the ropes

### 10.2.1 General

When dimensioning the civil engineering works, the nominal values from the calculation of the longitudinal profile are used as characteristic values for the actions (vector quantities) which result from the tension forces in the ropes.

In the case of variable actions, the characteristic value corresponds to:

— either an upper value which is not exceeded during a reference period with a given probability or a lower value which is not fallen below with a given probability;

— a nominal value which may be determined when there is no known probability distribution.

NOTE Because the statistical distribution is not known for the actions due to the tension forces in the ropes, a nominal value from the calculation of the longitudinal profile is used as the characteristic value.

**10.2.2** The characteristic value in operation is specified by a minimum value and a maximum value.

**10.2.3** The characteristic value out of operation is specified as a single value; if necessary, different values are given for different basic tension forces (see 7.1.2).

## 10.3 Wind forces on ropes and carriers

In the case of a static rope, the force resulting from a crosswind shall be assumed to act at the rope support entry point and, in the case of a moving rope, it is generally equally distributed over the outermost two rollers on the rope support.

The wind forces on the ropes and carriers shall be assumed in accordance with 6.5.4.

For systems with detachable carriers which do not normally remain on the line, the wind forces on the carriers when out of operation shall not be taken into account.

## 10.4 Friction forces of ropes on the civil engineering works

The friction forces shall be determined in accordance with 7.2.3.

## 10.5 Ice curtains on ropes

Account shall be taken of the actions of ice in accordance with 6.5.5; simultaneous wind and ice actions shall be taken into consideration in accordance with 7.2.4.

## 10.6 Starting and braking forces

For support structures in stations, dynamic effects in accordance with 7.2.2 shall be taken into account in determining the characteristic value of the tension force in the rope.

## 10.7 Dynamic effects during operation

The dynamic effects on support structures are covered in EN 13107.

## 10.8 Actions resulting from installation and maintenance work

**10.8.1** The support structures shall be calculated with eccentric loads which occur during installation or maintenance work, e.g. due to a rope being removed from its supports on one side of the cableway. The characteristic value is then the nominal value of the bearing force of the rope in accordance with the longitudinal profile calculation for the empty rope or unloaded rope remaining on the support (depending on type and use of the installation).

**10.8.2** For lifting the rope from the support or for anchoring the rope, the characteristic value is the nominal value of the bearing force of the rope or the tension force in the rope in accordance with the longitudinal profile calculation for the empty rope or the unloaded rope - depending on the type and use of the installation. A deviation angle of ± 0,09 rad (± 5°) from the direction of the bearing force of the rope or the tension force of the rope shall be taken into account.

## 10.9 Accidental actions

### 10.9.1 General

The characteristic value of an action is defined in 10.2. The design value of an accidental action results from the multiplication of its characteristic value by the partial coefficient, specified as follows for the different accidental actions.

### 10.9.2 Braking forces

a) Braking with the on-board brake: the characteristic value is the nominal value of the braking force, as indicated by the supplier, taking into account the maximum possible friction coefficient.

b) Unexpected operation of the service and/or safety brakes: for the support structures of stations, the design value is assumed to be 1,5 times the value of the braking force occurring in the event of defective operation of the drive brakes.

### 10.9.3 Actions due to derailment of rope onto the rope catcher

a) In operation, a rope derailment on one side onto the rope catchers shall be assumed taking into account the rope friction on the rope catchers, whereby between the rope and the rope catcher a friction coefficient of 0,20 shall be taken into account: the design value is 1,3 times the value of the largest rope bearing force resulting from the longitudinal profile calculation.

b) Out of operation, a rope derailment on one side onto the rope catchers shall be assumed: the design value is 1,3 times the value of the maximum rope bearing force resulting from the longitudinal profile calculation.

### 10.9.4 Actions due to derailment of rope onto the rope catcher arm of a compression support

a) In operation, the following shall be considered:

   1) a rope derailment, taking into account the rope friction on the rope catcher arm, assuming a friction coefficient of 0,30 between the rope and the rope catcher arm; the design value is twice the value of the maximum rope bearing force resulting from the longitudinal profile calculation;

   2) a rope derailment according to 1) together with the catching of a grip if the grips cannot pass over the rope catcher arm; the design values are then 1,1 times the value of the grip slipping force $F_{lab}$ according to EN 13796-1 and 1,1 times the value of the maximum rope bearing force and 1,1 times the value of the force due to rope friction on the rope catcher arm with a friction coefficient of 0,30.

b) Out of operation, the following shall be assumed: the design value is 2 times the value of the maximum rope bearing force resulting from the longitudinal profile calculation.

#### 10.9.5 Actions due to a complete deropement of a moving rope on one side

For all installations, only a moving rope deroped on one side of the track shall be assumed. This applies for load cases “in operation” and “out of operation”.

For installations with a moving rope on each track side, the design value of the remaining rope on the affected line support structure shall be assumed to be 1,1 times the value of the greatest rope bearing force resulting from the longitudinal profile calculation.

#### 10.9.6 Breakage of a conductor cable anchored to a support structure

In order to take into account a break in a conductor rope, the design value shall be obtained by the tension force of the broken cable acting vectorially in the opposite direction.

The simultaneous breakage of two or more cables shall not be considered.

When taking into account the ice load in accordance with 6.5.5.3, to obtain the design value, only half of the tension force of the broken rope acting vectorially in the opposite direction shall be applied.

#### 10.9.7 Other accidental actions

For other accidental actions, see EN 13107.

## 11 Deformations of supports

In order for the rope to be guided safely, the supports shall be of adequate rigidity and their bending and torsional deflections shall be limited. See EN 13107 for the permissible values of deformations and their calculation.

## 12 Technical documents for the line profile

### 12.1 For funicular railways

Longitudinal profile calculation and calculation of the track superstructure and infrastructure; verification of the rope tension forces, of the bearing forces on the haul rope supports, of the transverse roller force factor and of the clearance profile; calculation of the counterweight travel, of the maximum drive power and of the necessary braking force, as well as the safe transmission of the tangential force to the drive sheave.

### 12.2 For aerial ropeways

**12.2.1** Longitudinal profile calculation; verification of the tension forces, of the rope inclination and of the bearing forces on supports, of the transverse force ratios on the line and on supports, as well as of the clearance profile; calculation of sag, of the counterweight travel, of the maximum drive power and of the necessary braking force, as well as the safe transmission of the tangential force to the drive sheave.

**12.2.2** Any necessary calculations for the transverse sections of the line.

**12.2.3** Where an auxiliary aerial ropeway for evacuation along the rope exists: longitudinal profile calculation for the recovery rope; verification of the rope tension forces, of the rope inclination and of the bearing forces on supports, of the distance between the recovery rope and the haul rope or carrying-hauling rope, if necessary, of the loading or unloading effects on the recovery cabin from the recovery rope and the haul rope, of the counterweight travel, of the maximum drive power and of the necessary braking force as well as the safe transmission of the tangential force to the drive sheave.

### 12.3 For ski-tows

Longitudinal profile calculation; verification of the tension forces, of the rope inclination and of the bearing forces on supports, of the transverse ratios, as well as of the clearance profile; calculation of sag, of the counterweight travel, of the maximum drive power and of the necessary braking force, as well as the safe transmission of the tangential force to the drive sheave.

# Annex ZA
(informative)

## Relationship between this European Standard and the essential requirements of the EU Directive 2000/9/EC relating to cableway installations designed to carry persons

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to essential requirements of the New Approach Directive 2000/9/EC relative to cableway installations designed to carry persons.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national Standard in at least one Member State, compliance with the Clauses of this Standard given in Table ZA.1 confers, within the limits of the scope of this Standard, a presumption of conformity with the corresponding essential requirements of that Directive and associated EFTA regulations.

**Table ZA.1 — Correspondence between this European Standard and Directive 2000/9/EC relating to cableway installations designed to carry persons**

| Clause(s)/sub-clause(s) of this European Standard | Essential requirements of Directive 2000/9/EC | Qualifying remarks/Notes |
|---|---|---|
| All Clauses/Subclauses of this EN | 2.4 | |
| 5.2 | 2.2 | |
| Clause 6 | 3.2.1 | |
| 6.5.4 | 2.3 | |
| 6.5.5 | 2.3 | |
| Clause 7 | 4.1 | |
| 7.1.2 to 7.1.4 | 2.3 | |
| Clause 8 | 3.2.1, 4.2.3.1 | |
| Clause 9 | 4.2.1, 4.2.2 | |
| 9.2.2 | 2.3 | |
| 9.3.2 | 2.3 | |
| Clause 10 | 4.1, 4.2.3.2 | |
| Clause 11 | 3.2.1 | |
| Clause 12 | 7.1 | |

**WARNING —** Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this Standard.

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