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Structures for mine shafts —

Part 7:
Rope guides

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 82, *Mining*.

A list of all parts in the ISO 19426 series can be found on the ISO website.

Introduction

Many mining companies, and many of the engineering companies which provide designs for mines, operate globally so ISO 19426 was developed in response to a desire for a unified global approach to the safe and robust design of structures for mine shafts. The characteristics of ore bodies, such as their depth and shape, vary in different areas so different design approaches have been developed and proven with use over time in different countries. Bringing these approaches together in ISO 19426 will facilitate improved safety and operational reliability.

The majority of the material in ISO 19426 deals with the loads to be applied in the design of structures for mine shafts. Some principles for structural design are given, but for the most part it is assumed that local standards will be used for the structural design.

Structures for mine shafts —

Part 7:
Rope guides

1 Scope

1.1 General

This document specifies the design loads and the design procedures for the design of rope guides and rubbing ropes used for guiding conveyances and preventing collisions in vertical mine shafts for permanent operations. This standard covers personnel and material hoisting, as well as rock hoisting installations. There are no fundamental limitations placed on the size of conveyances, the hoisting speeds, shaft layout configurations, or the shaft depth.

This standard may be applicable under certain conditions to shaft sinking operations.

There are many reasons, based on technical, timing, and cost factors why rope guides may, or may not be selected for a particular application, and these require careful assessment at feasibility stage of any project where rope guides are considered. This standard provides some comments regarding the advantages and disadvantages of using rope guides compared to rigid guides, and specific design aspects to be considered when using rope guides. However, this standard is primarily intended to provide the technical information required to ensure good engineering of shafts where rope guided hoisting is the chosen solution.

1.2 Applications not covered

This document does not cover matters of operational safety.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12385-6, *Steel wire ropes. Safety. Part 6: Stranded ropes for mine shafts*

EN 12385-7, *Steel wire ropes. Safety. Part 7: Locked coil ropes for mine shafts*

ISO 19426-1, *Structures for mine shafts — Part 1: Vocabulary*

SANS 10293, *Condition assessment of steel wire ropes on mine winders*

ISO 19426-2, *Structures for mine shafts — Part 2: Headframe structures*

ISO 19426-5, *Structures for mine shafts — Part 5: Shaft system structures*

3 Terms and definitions

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

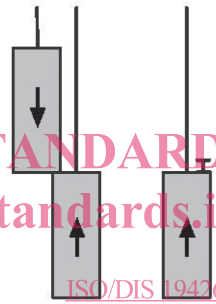
— IEC Electropedia: available at http://www.electropedia.org

For the purposes of this document, the terms and definitions given in ISO 19426-1 and the following apply.

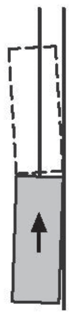
3.1
cheese weight
a stack of weights, usually steel castings, suspended from the bottom of a rope guide forming a dead weight tensioning system

3.2
collision
direct collision
A direct collision is an event in which a conveyance strikes another conveyance, or some other surface which is essentially transverse to the direction of travel of the conveyance, as shown in Figure 1 a).

3.3
oblique collision
An oblique collision is an event in which a conveyance strikes a shaft side wall, or some other surface which is oriented essentially parallel with the direction of travel of the conveyance, as shown in Figure 1 a) and Figure 1 b).



a) Direct Collision



b) Oblique Collision

Figure 1 — Schematic of Possible Collision Types

3.4
design clearance
(static clearance)
the nominal distance between different conveyances, or between conveyances and fixed objects, in the shaft, as shown on the design drawings

3.5
design location
the intended location of elements of the rope guided hoisting installation, as shown on the design drawings.

3.6
displacement multiplier
a factor by which the predicted conveyance lateral displacement is multiplied to make statistical allowance for inaccuracies in simulation and aerodynamic coefficients and construction tolerances

3.7
dynamic clearance
the minimum distance between different conveyances, or between conveyances and fixed objects, in the shaft during hoisting in the shaft, which is equal to the design clearance less the maximum dynamic displacement

3.8
dynamic displacement
the lateral dynamic displacement of conveyances while travelling in the shaft

3.9
design dynamic displacement
the lateral dynamic displacement of conveyances while travelling in the shaft multiplied by the displacement multiplier, which makes provision for simulation uncertainties and construction inaccuracies

3.10
reduced dynamic clearance
the minimum distance between different conveyances, or between conveyances and fixed objects, in the shaft during hoisting in the shaft, which is equal to the design clearance less the design dynamic displacement

3.11
entry point
position at which a conveyance enters fixed guides at the top and bottom ends of the hoisting cycle, and at any intermediate stations

3.12
entry speed
the speed at which conveyances enter the fixed guides at the top and bottom ends of the hoisting cycle, and at any intermediate stations

3.13
guide block
(guide bush)
(guide slipper)
the attachment of a conveyance to the rope guides. The guide block is usually made in two halves to bolt around the rope guide, and it has a guide block liner forming the rubbing surface on the rope guide

3.14
intermediate loading stations
any loading stations between bank level or a tipping station at the top of the shaft and a loading station at the bottom of the shaft, or any loading stations located more than 100 m below the top anchor point of the rope guides or more than 100 m above the bottom anchor point of the rope guides

3.15
operating clearance
the distance between different conveyances, or between conveyances and fixed objects, in the shaft during operation of the installation, which is equivalent to the design clearance reduced by the lateral displacement of conveyances while travelling in the shaft, and reduced by anticipated misalignments and tolerances

3.16
rope guide shoe
the mounting to secure the guide block through which the rope guide passes

3.17
rubbing block
(fixed guide slippers)
the contact point between a conveyance and the fixed guides at top and bottom of wind, which can run within or outside the fixed guide, and where the fixed guides are located close to the rope guides can also serve the purpose of the rope guide shoe

3.18
rubbing plate
a plate, or surface, mounted on the conveyances to provide a surface to rub against the rubbing ropes, which shall be provided when rubbing ropes are used

3.19
rubbing ropes
ropes located between conveyances running on rope guides, intended to deflect conveyances away from each other, thereby reducing the severity of a possible collision

3.20
vertical shaft cylinder
the maximum circular cylinder, clear of any obstructions, that will fit within the excavated mine shaft and constructed infrastructure

3.21
winder emergency braking
(winder trip-out)
braking of the winder under emergency conditions, such as loss of electrical power, detection of over-tension or under-tension on the hoist ropes, or accident to shaft signal

4 Symbols

For the purposes of this document, the following symbols apply.

a	Conveyance acceleration, m/s^2
A_C	Area of side of conveyance, m^2
A_R	Cross sectional steel area of a single head rope, m^2
A_1 , A_2	Area of specified portions of shaft cross-section, m^2
b	Thickness of skip stiffeners, m
B_E	Distance between conveyance centre of gravity and geometrical centre of the set of rope guides, guiding that conveyance m
B_X, B_Z	Plan dimensions of conveyance, m
C	Eccentricity of eccentric weight with respect to head rope attachment point, m
C_{BX} , C_{BZ}	Basic aerodynamic lateral force coefficient in appropriate direction, taken as 0,018
C_L	Aerodynamic force coefficient
C_{LX}, C_{LZ}	Aerodynamic lateral force coefficient in appropriate direction
C_{LP}	Conveyance passing buffeting force coefficient
C_Q	Torque factor applied to head ropes

C_T Coefficient of thermal expansion of the rope guide, $^{\circ}C^{-1}$

d Shaft diameter, m

D Rope diameter, m (Note that this is usually given in mm in hoist rope catalogues)

D_A Lateral conveyance displacement due to steady state aerodynamic force, m

D_B Lateral conveyance displacement due to buffeting forces, m

D_C Lateral conveyance displacement due to Coriolis force, m

D_{EB} Lateral conveyance displacement at the bottom of the conveyance due to conveyance eccentricity with respect to head rope attachment point, m

D_{EC} Lateral conveyance displacement at the centre of gravity of the conveyance due to conveyance eccentricity with respect to head rope attachment point, m

D_{ET} Lateral conveyance displacement at the top of the conveyance due to conveyance eccentricity with respect to head rope attachment point, m

D_G General lateral displacement of the centre of gravity of a conveyance in a shaft, m

D_G' General lateral displacement of the geometric centre of the set of rope guides guiding one conveyance in a shaft, m

D_I Amplitude of initial rope guide motion prior to hoisting of conveyance, m

D_M Nominal design movement allowance between conveyance and other objects in a shaft, m

D_N Nominal design clearance between conveyance and other objects in a shaft, m

D_O Minimum dynamic clearance, m

D_P Total combined lateral displacement of conveyance, m

D_R Lateral conveyance displacement due to initial rope guide motion, m

D_X Recommended tolerance allowance, m

D_Y Lateral displacement due to yaw rotation of conveyance in the shaft, m

E_S Elastic modulus of the head rope or the rope guide, Pa

F_A Steady state aerodynamic force acting on conveyance, N

F_C Coriolis force acting on conveyance, N

F_P Peak force during buffeting of conveyance, N

F_X General lateral force applied to a conveyance, N

F_Y General moment applied about the centre of gravity of a conveyance, Nm

g Acceleration due to gravity, m/s^2

h_1 Body height of conveyance, m

h_2 Ventilation opening height on cage, m

H Overall height of conveyance, m

H_C	Height from conveyance centre of gravity to top of conveyance, m
H_{Xi}	X dimensions from conveyance centre of gravity to head ropes, m
H_{Zi}	Z dimensions from conveyance centre of gravity to head ropes, m
I_C	Mass moment of inertia of conveyance about vertical centroidal axis, kgm^2
K_H	Lateral stiffness at conveyance elevation, of a single head rope, N/m
K_L	Lateral stiffness at conveyance elevation, of the set of ropes attached to one conveyance, N/m. (This includes the rope guides, the head ropes, and where applicable the tail ropes)
K_R	Lateral stiffness at conveyance elevation, of a single rope guide, N/m
K_T	Lateral stiffness at conveyance elevation, of a single tail rope, N/m
K_θ	Rotational stiffness at conveyance elevation of the set of ropes attached to one conveyance, Nm/rad
L	Overall length of the rope guides, m
L_H	Head rope length between the conveyance and the sheave, m
L_T	Tail rope length between the conveyance and the bottom sheave, m
L_1	Rope guide length between the top of conveyance and the top anchor point, m
L_2	Rope guide length between the bottom of conveyance and the bottom anchor point, m
m_C	Conveyance mass, including mass of rope attachments and payload, kg
m_H	Mass per unit length of a single head rope, kg/m
m_P	Payload mass, kg
m_R	Mass per unit length of a single rope guide, kg/m
m_T	Mass per unit length of a single tail rope, kg/m
M_O	Overturning moment due to eccentric loading, Nm
n	An integer greater than 1
n_H	Number of head ropes for a single conveyance
n_R	Number of rope guides guiding a single conveyance
n_T	Number of tail ropes for a single conveyance
Q	Rope torque applied to conveyance, Nm
Q_i	Rope torque from rope i applied to conveyance, Nm
r_t	Ratio of acceleration time to natural period
R	Ratio of first force peak to second force peak used for buffeting as two conveyances pass each other, taken as 1,5
R_B	Blockage ratio for two conveyances in a shaft

R_G	Gap ratio between conveyances in a shaft
R_{Xi},R_{Zi}	Dimensions from conveyance centre of gravity to rope guides, m
R_D,R_W	Distance and width ratios for air inflow and outflow buffeting
R_R	Distance of the rope guides from centre of gravity of conveyance, m
R_S	Shape factor for air inflow and outflow buffeting
S_A	Conveyance size factor
S_{PX}, S_{PZ}	Sidewall proximity factors
S_{SX}, S_{SZ}	Conveyance shape factors in X- and Z-directions
t	Time, sec
T	Tension in a rope, N
T_{BOT}	Rope guide tension at the bottom anchor point, N
T_H	Head rope tension at conveyance, N
T'_H	Increased head rope tension at conveyance, N
T_L	Rope guide tension at conveyance elevation in the shaft, N
T_M	Rope guide tension at mid-depth of the shaft, N
T_P	Time taken for two conveyances to pass each other in a shaft, m
T_T	Tail rope tension at conveyance, N
T_{TOP}	Rope guide tension at the top anchor point, N
T_{Xi}	X dimensions from conveyance centre of gravity to tail ropes, m
T_{Zi}	Z dimensions from conveyance centre of gravity to tail ropes, m
U_i	Horizontal dimensions of air inflow or outflow duct, m
v_D	Horizontal component of airflow velocity in station or side duct, m/s
v_H	Hoisting speed of conveyance, m/s
v_R	Velocity of conveyance relative to ventilation airflow speed, m/s
W	Total eccentric payload applied to a conveyance, N
w	Width of the skip stiffener, m
x_C, z_C	Design location of conveyance centre of gravity from shaft centre line, m
x_P, z_P	Horizontal distance between payload centre of gravity and centre of hoist rope attachment, m
Y_i	Vertical dimensions of air inflow or outflow duct, m
α	A dynamic magnification factor
α_T	Winder emergency braking magnification factor for torque and eccentricity

β	Tilt angle of a conveyance subjected to an eccentric payload, radian
β_1, β_2	Angles of the top or bottom of skip, radian
Δ_C	Change in ambient temperature, °C
Δ_T	Change in rope guide tension, N
θ	General yaw rotation of the conveyance in the shaft, radian
ρ	Air density, kg/m^3
γ_R	Displacement multiplier
ϕ	Latitude of the mine shaft site, positive north and south of the equator, degrees
ϕ_A	Angle of air inflow or outflow duct, radian
ω_E	Radial rotation velocity of the earth, $7{,}27\text{x}10^{-5}$ radian/sec
ω_R	Fundamental radial frequency of oscillation of the rope guides, radian/second
ω_{RC}	Fundamental radial frequency of oscillation of the rope guides with the conveyance, radian/second
ω_{RCY}	Fundamental radial frequency of yaw rotation of the rope guides with the conveyance, radian/second
ω_{VT}	Fundamental natural frequency of vertical motion of the conveyance suspended from the head ropes, radian/second

5 Materials

The materials used for rope guides and rubbing ropes shall be materials having guaranteed mechanical properties. It is most common to use high strength steel wire ropes complying with EN 12385-6 and EN 12385-7.

6 Disturbing actions

6.1 Coriolis force

The Coriolis force always acts in a westerly direction for an ascending conveyance, and in an easterly direction for a descending conveyance. The Coriolis force acts on all the moving masses, that is the mass of the conveyance and the head and tail ropes.

The Coriolis force results from the rotation of the earth and masses moving in a vertical direction. The Coriolis force F_C is may be taken as:

$$F_C = 2(m_C + n_H m_H \frac{L_H}{3} + n_T m_T \frac{L_T}{3}) v_H \omega_E \cos\phi$$

where

L_H is the head rope length between the conveyance and the sheave

L_T is the tail rope length below the conveyance

m_C is the conveyance mass, including mass of rope attachments and payload

m_H is the hoist rope unit mass

m_T is the tail rope length

n_H in the number of hoist ropes

n_T is the number of tail ropes

v_H is the hoisting speed of conveyance

ω_E is the radial rotation velocity of the earth, 7,27x10^{-5} radian/sec

ϕ is the latitude of the mine shaft site, positive north and south of the equator

6.2 Aerodynamic loads

6.2.1 Steady state

The steady state aerodynamic force acting on a conveyance F_A is defined as:

$$F_A = \frac{1}{2} C_L \rho v_R^2 A_C$$

where

C_L is the aerodynamic lateral coefficient, but not less than 0,02

ρ is the air density, which may be approximated using the values in Table 1

v_R is the conveyance velocity relative to the ventilation airflow

A_C is the area of the relevant side of the conveyance.

Values of C_L should be obtained from an appropriate level of accuracy of computational fluid dynamics analysis. However, for preliminary design only, the values may be obtained from Annex C. When C_L exceeds 0,02 it shall be taken to act in a specific direction arising from the aerodynamic flow around the conveyance. When C_L is taken as 0,02 it shall be taken to act in either direction.

Note that different values of F_A act on a conveyance in each of the two horizontal directions.

6.2.2 Buffeting

6.2.2.1 Buffeting force when two conveyances pass each other

The amplitude and time variation of the buffeting force when two conveyances pass each other in the shaft should be obtained from computational fluid dynamics analysis.

The amplitude of the buffeting force may be taken as:

$$F_P = \frac{1}{2} C_{LP} \rho v_H^2 A_C$$

where

C_{LP} is the buffeting force coefficient (see Annex C)

v_H is the relative passing speed