
Structures for mine shafts —

Part 5: Shaft system structures

Structures de puits de mine —

Partie 5: Structures des réseaux de puits

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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. It is also recognized that typical equipment varies from country to country, so the clauses in ISO 19426 do not specify application of the principles to specific equipment. However, in some cases examples demonstrating the application of the principles to specific equipment are provided in informative Annexes.

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Structures for mine shafts —

Part 5: Shaft system structures

1 Scope

This document specifies the loads, the load combinations and the design procedures for the design of shaft system structures in both vertical and decline shafts. The shaft system structures covered by this document include buntons, guides and rails, station structures, rock loading structures, brattice walls, conveyance and vehicle arresting structures and dropsets, services supports, rope guide anchor supports and box fronts.

Rock support is excluded from the scope of this document.

This document does not cover matters of operational safety, or layout of the shaft system structures

This document adopts a limit states design philosophy.

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.

ISO 19338, *Performance and assessment requirements for design standards on structural concrete*

ISO 22111, *Bases for design of structures — General requirements*

ISO 10721-1, *Steel structures — Part 1: Materials and design*

ISO 2394, *General principles on reliability for structures*

ISO 3010, *Bases for design of structures — Seismic actions on structures*

ISO 12122, *Timber structures — Determination of characteristic values*

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

ISO 19426-4, *Structures for mine shafts — Part 4: Conveyances.*

3 Terms and definitions

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

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>

4 Symbols

A	frontal area of the conveyance (m^2)
a	gap at a joint in a rail (m) (see Table B.2)
B_f and B_w	two sides of the section in Table 3, for aspect 3
b	height difference between two rails at a support to the rails (m) (see Table B.2)
D_n	self-weight of pipe including any lagging (N/m)
d	vertical or lateral differential at a joint in a rail (m) (see Table B.2)
d_i	deformation of the relevant structural component (m).
d_s	depth of the conveyance guide shoe (m)
E_r	emergency rope load
E_p	emergency load on a protective platform
e	maximum moving beam misalignment of the guide (m) (see Table B.1)
e'	modified moving beam misalignment of the guide (m)
F	design load or load effect (N , Nm)
F_B	dynamic load on the platform (kN)
F_F	load on station footwall structures (N , N/m^2)
F_p	load on personnel loading and access platform structures (N , N/m^2)
F_v	vertical load (N)
G_1 and G_2	permanent loads or load effects (N , Nm)
G_b	permanent load applied to brow beams (N , N/m^2)
G_c	conveyance self-weight load (N)
G_p	permanent load applied to pipe supports (N)
G_s	permanent load applied to sidewall support structure (N)
G_y	permanent load on conveyor supports (N)
g	acceleration due to gravity (m/s^2)
H	lateral imposed load (N)
H_f	guide roller load (N)
H_s	lateral slipper plate load (N)
h	overall width or depth of the section or height of the bulk material (m)
h_1, h_2	lever arm distances of the relevant slipper plate loads with respect to the relevant centroidal axes (m)

h_b	height of the ore pass (m)
h_d	height through which the rock falls; to be taken as the depth of the rock pass (m)
I_l, I	mass moments of inertia of the conveyance about the centroidal axes perpendicular to the relevant direction of the slipper plate load (kgm ²)
K	conveyance holding device support load (N)
k_b	lateral stiffness of the steelwork at the guide to buntion connection (N/m)
$\overline{k_b}$	non-dimensional lateral steelwork stiffness at the guide to buntion connection
k_g	lateral stiffness of the steelwork at the guide midspan (N/m)
k_r	roller assembly stiffness (N/m)
L	guide span, buntion to buntion (m)
L_C	member length (m)
L_p	assessed length of pipe supported on the pipe support (m)
$\overline{M}$	guide bending moment coefficient (obtained from Figure 2)
M_g	maximum guide bending moment (Nm)
m_e	proportion of the conveyance mass effectively acting at a slipper plate (kg)
m_r	mass of the largest rock (kg)
m_s	mass of the conveyance (empty or full) including the compensating sheave mass, if applicable (kg)
n	number of wheels on the conveyance
p	surface pressure on the layer of girders (kN/m ²)
P_a	load on arresting structures (N)
$\overline{P_b}$	slipper plate load coefficient (obtained from Figure 1)
P_{d1}, P_{d2}, P_{d3}	loads on station dropsets (N)
p_h	hydrostatic pressure (N/m ²)
P_p	vertical impact load on penthouse structures (N)
Q	conveyance payload (N)
Q_1	dominant imposed load or load effect, or the applied load causing fatigue (N, Nm)
Q_2 to Q_n	additional independent imposed loads or load effects (N, Nm)
Q_e	emergency load or load effect (N, Nm)
R_i	single rock impact load on the box front (N)
r_k	steelwork stiffness ratio = k_b/k_g

r_u	rebound velocity ratio (obtained from Figure 5)
$r_{u.1}$	rebound velocity ratio on the stiffer side (obtained from Figure 5)
$r_{u.2}$	rebound velocity ratio on the less stiff side (obtained from Figure 5)
s	penetration depth into the bulk material (m)
S_f	frequency of guide roller load application (percentage of buntons passed deemed to cause guide roller load application) (see Table B.1)
S_r	frequency of rail impact load application (percentage of rail joints passed deemed to cause rail impact load application) (see Table B.2)
S_s	frequency of slipper plate load applications (obtained from Table B.1)
T	slinging load (N)
T_s	static load applied to slinging anchorage (N)
U	load due to underslung equipment (N)
U_p	impact energy on a protective platform (J)
v	winding velocity (m/s)
W_a	wheel impact load arising from rail joint irregularity (N)
W_l	lateral wheel load acting normal to the rail (N)
W_n	conveyance wheel load acting normal to the rail (N)
Z_i	impact energy of the falling rock (J)
α_a	conveyance impact factor
α_{d1}	conveyance loading impact factor
α_{d2}	rail impact factor due to rail irregularities
α_{d3}	shaft impact factor due to the change in direction from the decline shaft to the station dropset
α_f	hopper door opening impact factor
α_i	proportion of potential energy transferred into impact energy on the box front
α_l	lateral wheel load factor (see Table B.2)
α_n	nominal slipper plate impact factor
α_r	shaft condition factor (see Table B.1)
α_s	sling impact factor
α_w	wheel dynamic factor
α_H	wheel horizontal load factor
β	dynamic load coefficient

β_s	slipper load amplification factor
δ_s	conveyance displacement coefficient (obtained from Figure 3)
γ_e	partial load factor for emergency loads
γ_{f1} to γ_{fn}	partial load factors for imposed loads
γ_{g1} and γ_{g2}	partial load factors for permanent loads
ε_t	transverse rock strain, as defined by rock engineering analysis
μ	friction factor between the hopper payload and the door
ρ	bulk density of ore pass contents, or the bulk density of hopper payload (kg/m ³)
ψ_1 to ψ_n	load combination factors
$\varnothing_d$	angle between the horizontal and the shaft decline
$\varnothing_s$	angle between the dropset and the shaft decline
Δ	total lateral displacement of a conveyance (m)
Δ_c	specified clearance between slipper plate and guide (m)
Δ_e	sum of guide gauge and slipper gauge variations, or the rail gauge variations (m) (see Table B.1 and Table B.2)
Δ_{e1}	maximum allowable guide gauge variation (m) (see Table B.1)
Δ_g	lateral guide displacement (m)
Δ_o	overlap allowance (m) which shall be taken as not less than 0,003 m
Δ_w	slipper plate wear (m) (see Table B.1)

5 Materials

Materials used in the construction of shaft system structures should be as specified in EN 197-1 and EN 206-1 for concrete, ISO 10721-1 for structural steel and ISO 12122 for timber. All materials used shall be properly graded materials.

6 Nominal loads

6.1 Permanent loads

6.1.1 Self-weight

Self-weight loads shall be assessed in accordance with ISO 22111.

6.1.2 Brow beams and sidewall support structures

Where required, the permanent load, G_b , applied to brow beams shall be assessed considering the rock over-break but shall be not less than a uniformly distributed load of 20 000 N/m². Where fractured or weak rock conditions are encountered, loading shall be specified in consultation with the rock engineer.

The permanent load, G_s , applied to sidewall support structures shall be assessed considering the rock properties and over-break but shall be not less than a uniformly distributed load of 5 000 N/m². Where fractured or weak rock is encountered, loading shall be specified in consultation with the rock engineer.

6.1.3 Pipe supports

The permanent load, G_p , applied to pipe supports shall be obtained using the following Formula:

$$G_p = L_p D_n \quad (1)$$

where

L_p is the assessed length of pipe supported on the pipe support. In the absence of better information, the assessed length, for vertical pipes, shall be taken to be the length of pipe from the support below the one in question to the support above the one in question (m);

for horizontal or inclined pipes, the assessed length shall be taken as the length of pipe from the support to the left of the one in question to the support to the right of the one in question (m);

D_n is the self-weight of pipe including any connections and lagging (N/m).

6.1.4 Conveyor supports

The permanent load, G_y , on conveyor supports shall be assessed in accordance with normal conveyor design practice.

6.2 Imposed loads and load effects

6.2.1 General

Shaft system structures shall be designed to resist the imposed loads as assessed in accordance with ISO 22111. In addition, they shall be designed to resist the loads defined in 6.2.2 to 6.2.14.

6.2.2 Guide support structures

6.2.2.1 Fixed guides in vertical shafts in shaft zone A (see annex A)

6.2.2.1.1 Lateral imposed loads (H) and maximum guide bending moment (M_g)

It shall be assumed that only one of the loads defined in (a) and (b) below can act at any one time.

a) Guide roller load (H_f):

The load normal to the guide face or the guide sides shall be taken as

$$H_f = k_r \Delta_c \quad (2)$$

where

k_r is the roller assembly stiffness (N/m);

Δ_c is the specified clearance between slipper plate and guide (m).

b) Lateral slipper plate load (H_s):

Slipper plate loads shall be assessed in two directions, namely, normal to the face of the guide and normal to the sides of the guide. These loads shall be assessed for both full and empty conveyances and shall be applied to the guide in the vicinity of the connection to the bunton, considering the action of only one slipper at a time, i.e. it is assumed that the slipper plate load normal to the face of the guide and the slipper plate load normal to the sides of the guide cannot occur simultaneously.

The lateral load between any slipper plate and the guide, H_s (N), shall be taken as:

$$H_s = \alpha_n \left(\overline{P_b} \frac{400 m_e v^2 e}{L^2} \right) \quad (3)$$

The proportion of the conveyance mass effectively acting at a slipper plate, m_e (kg), is:

$$m_e = \frac{m_s I_1 I_2}{(I_1 I_2 + m_s h_2^2 I_1 + m_s h_1^2 I_2)} \quad (4)$$

The non-dimensional lateral steelwork stiffness at the guide to bunton connection, $\overline{k_b}$, is:

$$\overline{k_b} = \frac{k_b L^2}{m_e v^2} \quad (5)$$

The steelwork stiffness ratio, r_k , is:

$$r_k = \frac{k_b}{k_g} \quad (6)$$

Where, in Formulas (3) to (6),

α_n is the nominal slipper plate impact factor which in the absence of better information shall be taken as 2,0;

$\overline{P_b}$ is the slipper plate load coefficient (obtained from [Figure 2](#));

m_e is the proportion of the conveyance mass effectively acting at a slipper plate (kg);

v is the winding velocity (m/s) – see [Figure 1](#);

e is the maximum moving beam misalignment of the guide (see Table B.1) (m) – see [Figure 1](#);

L is the guide span, bunton to bunton (m) – see [Figure 1](#);

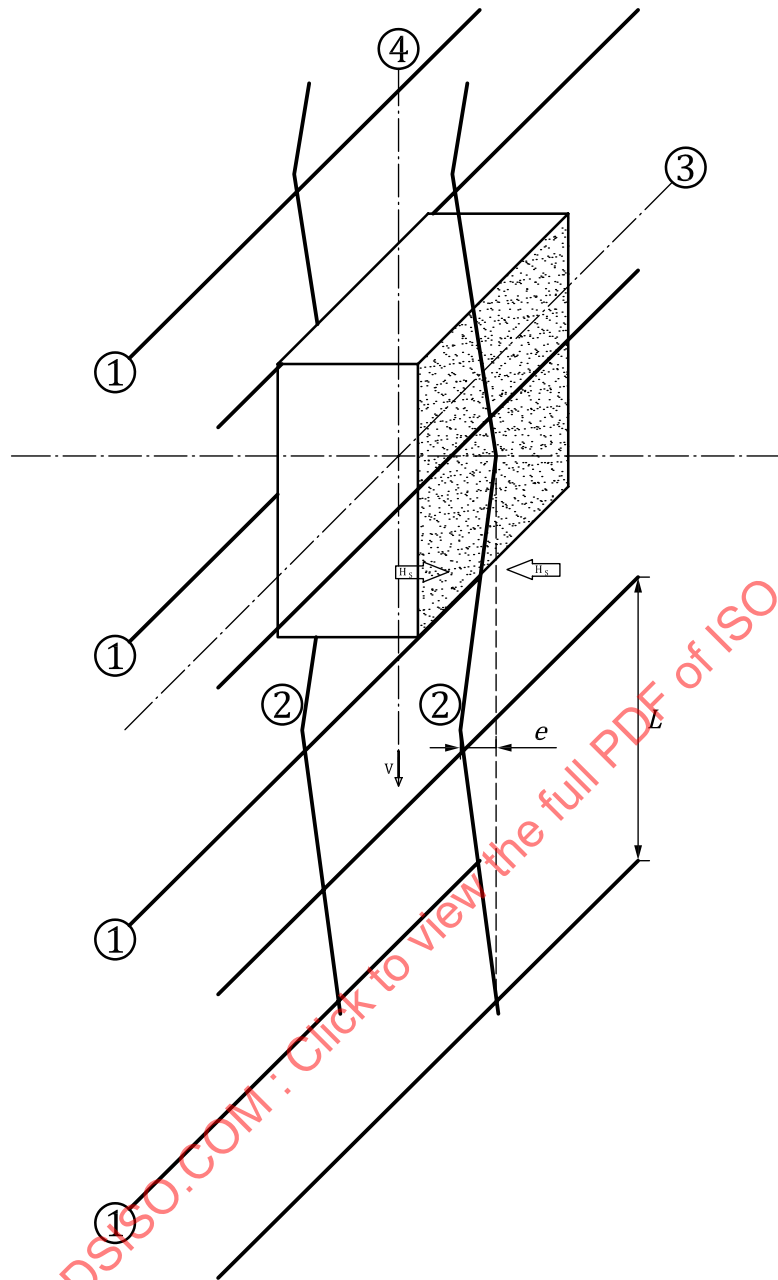
m_s is the mass of the conveyance (empty or full) including the compensating sheave mass, where applicable (kg);

I_1, I_2 mass moments of inertia of the conveyance about the centroidal axes perpendicular to the relevant direction of the slipper plate load (kg/m²);

k_b is the lateral stiffness of the steelwork at the guide to bunton connection (N/m);

NOTE See COMRO User Guide No. 21 for a method of incorporating the stiffness of the conveyance into the steelwork stiffness.

k_g is the lateral stiffness of the steelwork at the guide midspan (N/m).



Key

- | | | | |
|---|---------|---|--------|
| 1 | buntons | 3 | axis 1 |
| 2 | guides | 4 | axis 2 |

Figure 1 — Freebody diagram of lateral load

c) Maximum guide bending moment (M_g)

The maximum guide bending moment resulting from slipper plate action shall be assessed for both slipper plate load directions.

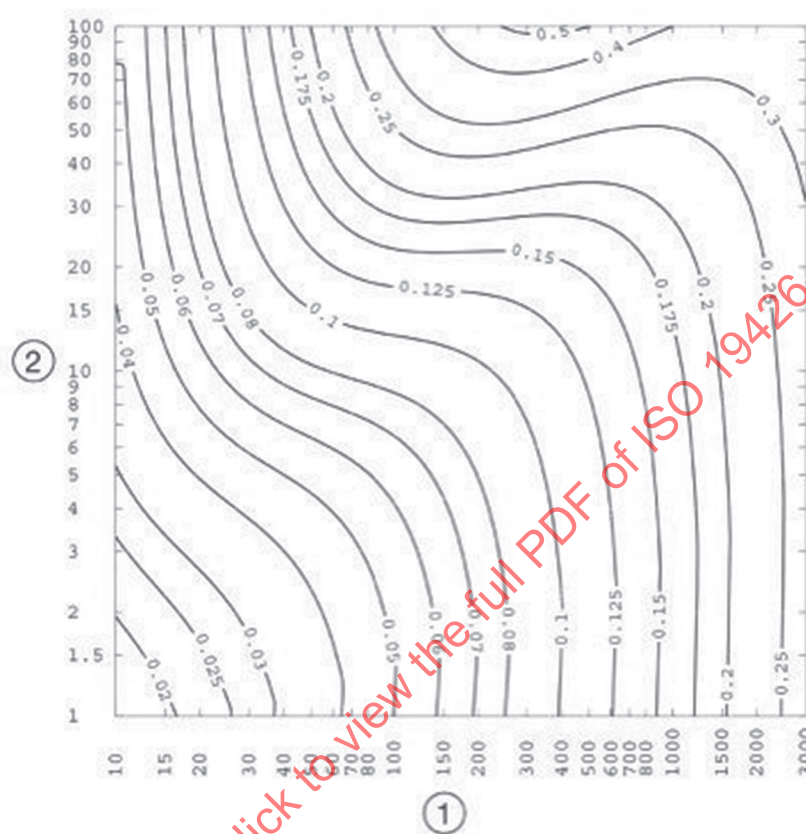
The maximum guide bending moment, M_g (Nm), shall be taken as:

$$M_g = \alpha_n \left(\frac{-400m_e v^2 e}{L} \right) \quad (7)$$

where

α_n , m_e , v , e , and L are as defined above;

$\bar{M}$ is the guide bending moment coefficient (obtained from Figure 3).



Key

- 1 non-dimensional lateral steelwork stiffness at guide to bunton connection $\bar{k}_b$
- 2 steelwork stiffness ratio r_k

Figure 2 — Contour plot of slipper plate load coefficient $\bar{P}_b$

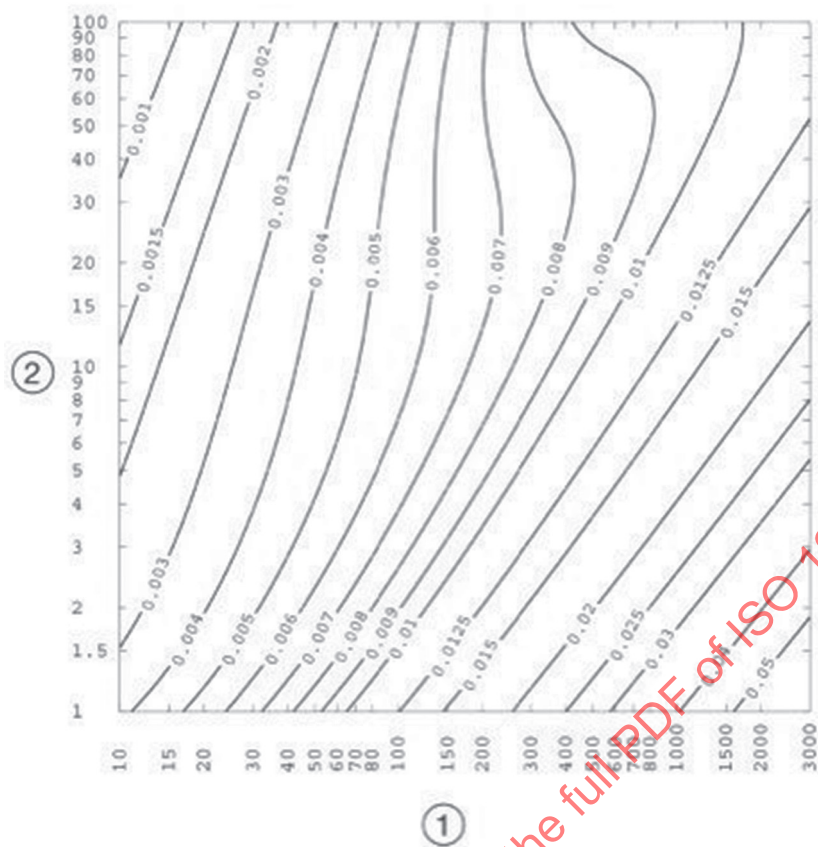
6.2.2.1.2 Vertical loads (F_V)

The vertical loads, F_V , shall be taken as follows.

- a) The friction induced vertical load, F_V (N), acting during slipper plate contact on each guide shall be taken as

$$F_V = 0,5H_s \quad (8)$$

- b) The vertical loads induced by the action of conveyance holding and braking devices shall be rationally assessed. The vertical loads due to conveyance holding devices shall be in accordance with ISO 19426-4.



Key

- 1 non-dimensional lateral steelwork stiffness at guide to bunton connection $\bar{k}_b$
- 2 steelwork stiffness ratio r_k

Figure 3 — Contour plot of guide bending moment coefficient $\bar{M}$

6.2.2.2 Fixed guides in vertical shafts in shaft zone B (see [Annex A](#))

6.2.2.2.1 Lateral loads (H) and maximum guide bending moment (M_g)

Where the shaft zone is B, the lateral loads and maximum guide bending moments are as defined for shaft zone A in [6.2.2.1.1](#), except that the maximum moving beam misalignment of the guide, e , shall be replaced by the modified moving beam misalignment, e' :

$$e' = e + 2\varepsilon_t L \quad (9)$$

where

e is the maximum moving beam misalignment of the guide (m);

ε_t is the transverse rock strain, as defined by the rock engineering analysis;

L is the guide span, bunton to bunton (m).

6.2.2.2.2 Vertical loads (F_V)

Where the shaft zone is B, the vertical loads are as defined for shaft zone A in [6.2.2.1.2](#).

6.2.2.3 Fixed guides in vertical shafts in shaft zones C and D (see [Annex A](#))

6.2.2.3.1 Lateral loads (H) and maximum guide bending moments (M_g)

Where the shaft zone is C or D, the lateral loads and maximum guide bending moments shall be rationally derived in accordance with the dynamic behaviour of the shaft steelwork and conveyances in these shaft zones.

6.2.2.3.2 Vertical loads (F_V)

Where the shaft zone is C or D, the vertical loads are as defined for shaft zone A in [6.2.2.1.2](#).

6.2.2.4 Fixed guides in conveyance loading zones

The loads on fixed guides in conveyance loading zones shall be as specified in ISO 19426-4.

6.2.2.5 Decline shaft wheel loads

6.2.2.5.1 Conveyance wheel load acting normal to the rail (W_n)

The wheel load, W_n (N), acting normal to the rail shall be taken as:

$$W_n = \frac{\alpha_w (G_c + Q) \cos \varnothing_d}{n} \quad \text{(Acting at every wheel)} \quad (10)$$

where

α_w is the wheel dynamic factor;

Q is the conveyance payload (N);

G_c is the conveyance self weight load (N);

$\varnothing_d$ is the angle between the horizontal and the shaft decline;

n is the number of wheels on the conveyance.

Where the rail misalignment falls within the tolerances defined in [Table B.2](#), the wheel dynamic factor, α_w , shall be taken as specified in [Table 1](#). Where a greater rail misalignment exists, the wheel dynamic factor shall be increased on a rational basis.

Table 1 — Wheel dynamic factor

Shaft condition	Wheel within rail length	Wheel at rail joint
Good	1,2	2,0
Average	1,2	2,5
Poor	1,2	3,5

The wheel impact load on each wheel, W_a (N), at rail joints shall be calculated by rational analysis. Alternatively, the impact factor on each wheel may be taken as specified in [Table 1](#).

6.2.2.5.2 Lateral conveyance wheel loads (W_l)

The lateral wheel load, W_l (N), acting at every wheel shall be taken as:

$$W_l = \alpha_l W_n \quad (11)$$

where

W_l is the lateral wheel load acting normal to the rail (N);

α_l is the lateral wheel load factor (see Table B.2).

6.2.3 Fixed flare guides

The loads on fixed flare guides, applicable to rope guide systems, shall be as specified in 6.2.2.1.

6.2.4 Station structures

6.2.4.1 Station footwall structures

The load on station footwall structures, F_F , shall be taken as any one of the following loads acting in isolation:

- a) uniformly distributed load of 5 000 N/m²;
- b) a concentrated load of 5 000 N applied anywhere over an area of 0,1 m × 0,1 m;
- c) the conveyance floor loads as specified in ISO 19426-4; or
- d) the loads that might arise from any equipment lowered down the shaft.

6.2.4.2 Platforms

The load on personnel access platforms, F_p , shall be taken as any one of the following loads acting in isolation:

- a) a uniformly distributed load of 5 000 N/m²; or
- b) a vertical impact point load equal to a static load of 5 000 N applied anywhere over an area of 0,1 m × 0,1 m.

6.2.4.3 Canopy structures

In the absence of better information, the vertical impact load on canopy structures, P_p , shall be taken as a vertical load of 20 000 N, applied anywhere on the penthouse over an area of 0,1 m × 0,1 m.

6.2.4.4 Conveyance holding device support

The conveyance holding device support load, K , shall be in accordance with ISO 19426-4.

Where the holding device clamps onto guides, the guides shall be capable of resisting the clamping force.

6.2.4.5 Brattice screens, screens and screen supports

In the absence of better information, all screens shall be designed to resist each of the following loads acting independently:

- a) a horizontal impact load of 5 000 N applied anywhere on the screen over an area of 0,1 m × 0,1 m;

- b) where screens are required to protect personnel during crowd personnel loading, a uniformly distributed horizontal line load of 2 000 N/m applied along a line 1,5 m above the footwall or platform level;
- c) where screens protect personnel remote from personnel loading locations, the load shall be as specified in ISO 22111.

6.2.4.6 Guard rails to stairs, landings and platforms

Guard rails to stairs, landings and platforms shall be designed to resist a uniformly distributed load as specified in ISO 22111, in any direction transverse to the handrail.

6.2.4.7 Slings anchorages

Slings anchorages shall be designed to resist a slinging load, T (N), using the following Formula:

$$T = \alpha_s T_s \quad (12)$$

where

α_s is the sling impact factor which in the absence of a rigorous analysis shall be taken as 1,5;

T_s is the resultant static load applied to the slinging anchorage (N).

6.2.4.8 Station buffers

Where conveyances enter horizontal stations in decline shafts, the buffers or conveyance stops shall be designed to resist a load calculated on the basis of energy principles. Unless better information is available, the impact velocity shall be taken as 1,0 m/s.

6.2.5 Rock loading structures

6.2.5.1 Surge and spillage bins

The loads applied to surge and spillage bins shall be assessed assuming that the bin is completely full. The pressures during filling and emptying shall be assessed using a recognized contained-material pressure theory.

6.2.5.2 Measuring flasks

Where relevant, the load applied to the flask shall be assessed assuming that the flask is completely full. The pressures during filling and emptying shall be as specified for skips in ISO 19426-4.

6.2.5.3 Rock loading station floors

Rock loading station floors shall be designed to resist a uniformly distributed load of 5 000 N/m². Where spillage can occur, this load shall be increased to 10 000 N/m².

6.2.5.4 Box fronts

The loads on box fronts shall be taken as the most severe of a pressure (a), or a concentrated load (b), see below. These two loads shall be assumed to act independently, and not in combination, in the following way.

- a) If it can be shown that dry, granular rock conditions will exist in the ore pass, rational analyses may be used to assess the loads on box fronts. If not, the load applied to box fronts shall be based on reference pressure, p_h (N/m²), using the following Formula:

$$p_h = \rho g h_b \quad (13)$$

where

ρ is the density of the ore pass contents (kg/m³);

g is the acceleration due to gravity (m/s²);

h_b is the height of the ore pass, for heights of up to 30 m, or equal to 30 m for ore passes of height in excess of 30 m (m).

This pressure shall be applied to all components of box fronts, including concrete in-fill areas, chutes and radial gates.

- b) All main structural components of box fronts shall be designed to resist a single rock impact load on the box front, R_i , which shall be based on energy considerations. The impact energy of the falling rock, Z_i (J), shall be taken as:

$$Z_i = \alpha_i h_d g m_r \quad (14)$$

where

α_i is the proportion of potential energy transferred into impact energy on the box front;

h_d is the height through which the rock falls; to be taken as the depth of the rock pass (m);

g is the acceleration due to gravity (m/s²);

m_r is the mass of the largest rock (kg).

The proportion of potential energy transferred into impact energy on the box front, α_i , shall be based on a rational assessment of energy losses in the rock pass, or it may be taken as:

- 1) 0,8, when the rock pass is inclined at more than 70° to the horizontal;
- 2) 0,6, when the rock pass is inclined at less than 70° to the horizontal;
- 3) 0,3, when there is a dogleg in the rock pass not more than 15 m above the box front.

The impact load shall be calculated assuming plastic deformation of the structural components of the box front, but shall be taken as not less than 100 000 N, and need not be taken as more than the point load strength of the rock. The single rock impact load on the box front, R_i (N), is obtained using the following Formula:

$$R_i = \frac{Z_i}{d_i} \quad (15)$$

where

Z_i is the impact energy of the falling rock (J);

d_i is the deformation of the relevant structural component (m).

This load shall be taken as acting in a direction parallel to the axis of the ore pass.

The mass of the rock may be based on a rock size limited by the physical constraints of the rock handling system, but the rock size shall not be taken as less than 0,02 m³.

The plastic deformation of the relevant structural component, d_i , shall be taken as being in the range from 2 % to 5 % of the span of the relevant structural component.

The beams surrounding the chute and the door of the box front may be designed using plastic design methods. The columns and other main steelwork shall be designed to remain elastic.

NOTE The main structural components include the columns, struts, beams and anchors, but exclude the chute and doors.

6.2.5.5 Skip tipping loads

Where relevant, the tipping loads shall be determined as given in ISO 19426-4.

6.2.6 Operational arresting structures

Operational arresting structures for conveyances can be used at end of wind positions in vertical shafts, or at stations in decline shafts, for the purpose of absorbing low speed impact energy. These structures shall be designed to resist the greater of the following loads:

$$P_a = \alpha (G_c + Q), \text{ or} \quad (16)$$

$$P_a = \alpha (G_c + U) \quad (17)$$

where

α is the conveyance impact factor;

G_c is the conveyance self-weight (N);

Q is the conveyance payload (N);

U is the load due to underslung equipment (N).

The impact factor, α , shall be assessed by the consideration of energy principles, assuming that impact occurs at 1,0 m/s, or at the specified creep speed of the winder, if available.

6.2.7 Station dropsets

6.2.7.1 The loads applied to station dropsets in decline shafts shall be evaluated on the basis of operational requirements. The most severe one of the following loads may be considered where relevant, using the following Formulas:

$$\text{a) } P_{d1} = G_c + \alpha_{d1} (Q) \quad (18)$$

applied at the station loading position where the conveyance is located on the station dropset during loading (N);

$$\text{b) } P_{d2} = \alpha_{d2} (G_c + Q) \quad (19)$$

applied anywhere along the station dropset (N);

$$\text{c) } P_{d3} = \alpha_{d3} (G_c + Q) \quad (20)$$

applied where the conveyance leaves the shaft rails and enters the station dropset (N);

where, in Formulas (18) to (20),

α_{d1} is the conveyance loading impact factor;

α_{d2} is the rail impact factor due to rail irregularities;

α_{d3} is the shaft impact factor due to the change in direction from the decline shaft to the station dropset;

G_c is the conveyance self-weight (N);

Q is the conveyance payload (N).

6.2.7.2 The proportion of these loads applied at each of the conveyance axles shall be considered.

6.2.7.3 The conveyance loading impact factor, α_{d1} , shall be obtained from ISO 19426-3.

6.2.7.4 The rail impact factor, α_{d2} , shall be taken as 1,0 where the rail on the dropset has no joints, otherwise it shall be taken as 1,5.

6.2.7.5 The shaft impact factor, α_{d3} , should be assessed from energy principles, or it may be taken as $(1,0 + 2,0 \sin \varnothing_s)$, where $\varnothing_s$ is the angle between the dropset and the shaft decline.

6.2.8 Pipe supports

Pipe supports, as appropriate, shall be designed to resist any of the following loads, or a combination of loads, using the assessed length, L_p , of pipe supported:

- a) the static loads arising from the weight and pressure of the contents of the pipe;
- b) the loads resulting from flow in the pipe, particularly at bends;
- c) the dynamic loads resulting from transient pressures (for example, water hammer) in the pipe;
- d) the loads resulting from thermal expansion or contraction of the pipe;
- e) a stability load acting in any direction transverse to the pipe, equal to 1 % of the maximum compression in the pipe wall in vertical shafts, or equal to 2,5 % of the maximum compression in the pipe wall in decline shafts or horizontal haulages;
- f) supports to ducksfoot support bends shall be designed for the loads obtained from the simultaneous application of vertical and horizontal pressure thrusts, including the effects of transient pressures; or
- g) the loads obtained by assuming the horizontal portions of all compressed air pipes to be half filled with water.

Pipe support loads should be determined using a pipe network flexibility analysis computer programme.

6.2.9 Rope guide and rubbing rope anchor supports

The loads applied to rope guide and rubbing rope anchor supports shall be rationally assessed. Cognizance shall be given to the method of applying the tension to the rope guides or rubbing ropes when considering thermal loads.

6.2.10 Brattice walls

6.2.10.1 Vertical loads

Brattice wall panels which rely on vertical wedge action for support shall be designed to support, in addition to their self-weight, the vertical load from two additional panels.

Brattice wall panels on a ledge support system shall be designed to support the weight of all panels for a height equivalent to twice the distance between the ledge supports.

6.2.10.2 Ventilation pressure and thermal loads

The load acting normal to the surface of a brattice wall panel shall be assessed taking into consideration the differential air pressures due to ventilation air flow. In addition, thermal load effects due to temperature differences between upcast and downcast airflow shall be considered.

6.2.11 Strain loading

6.2.11.1 Rock strain

The loads induced by rock strains shall be assessed. Where rock strains occur within the limits of shaft zone A, as specified in [Annex A](#), the rock strain induced loads may be ignored.

6.2.11.2 Thermal strain

Calculation of thermal strain loads shall be based on local conditions.

6.2.12 Ladderway loading

6.2.12.1 The load applied to rungs or steps shall be taken as 2 000 N.

6.2.12.2 The vertical load applied to the ladderway stringers on each side of the ladderway shall be taken as 1 200 N/m length of ladder.

6.2.12.3 Where handrails are fitted to ladderways, the load applied to the handrail shall be taken as 1 000 N/m acting in any direction transverse to the hand railing.

6.2.12.4 The intermediate platforms shall be designed for a minimum of 2 000 N/m².

6.2.13 Conveyance drop test loads

Where a drop test is performed within the mine shaft, the loads shall be as defined for dogging system loads in ISO 19426-4.

Provided the connections between adjoining guide lengths are adequate to transfer conveyance drop test loads, the conveyance drop test loads may be distributed over a maximum of five buntion levels.

6.2.14 Earthquake loads

Earthquake loads shall be determined in accordance with ISO 3010.

Where deemed necessary, underground structures shall be designed using a normal degree of importance.

Underground structures may be designed using the equivalent static method, except where the representative peak ground acceleration for the region exceeds 30 % of gravity acceleration, in which case the dynamic method shall be used.

6.3 Emergency loads

6.3.1 Emergency arresting structures

6.3.1.1 The emergency loads applied to conveyance emergency arresting structures in the shaft or vehicle emergency arresting structures at stations shall be assessed using energy principles. The assumed entry velocity in these calculations shall be one of the following.

- a) In the case of vertical shafts, 50 % of the maximum design velocity.
- b) In the case of decline shafts, the velocity achieved by a detached conveyance rolling freely down its rails, for whatever distance free travel is possible.
- c) In the case of horizontal rails at stations in decline shafts, the maximum design velocity.
- d) In the case of vehicles at stations, the maximum travelling speed.

6.3.1.2 The sum of the elastic and plastic strain energy capacity of the emergency arresting structure shall exceed 75 % of the impact energy of the conveyance or vehicle.

6.3.2 Emergency stopping devices

Where conveyances operating in vertical shafts are fitted with emergency stopping devices (dogs) or where conveyances in decline shafts are fitted with a braking system to stop the conveyance in the event of loss of tension in the rope or rope detachment, the resulting loads shall be as defined in ISO 19426-4. The resulting loads applied to the shaft guides or rails shall be treated as emergency loads.

The braking deceleration used for deriving the braking loads shall be taken as not less than $3,0 \text{ m/s}^2$.

6.3.3 Pipe supports

6.3.3.1 Where pipelines have been designed and equipped with devices to reduce the effects of transient pressures (for example, water hammer), the dynamic loads resulting from transient pressures, that could develop should devices fail to perform satisfactorily, shall be treated as emergency load.

6.3.3.2 The loads that arise from breaks in the pipeline shall be treated as emergency loads. Where multiple pipelines are supported on a common pipe support only one break need be considered.

6.3.3.3 Where a change in direction occurs in a pipeline, consideration should be given to providing a pipe anchor support on both sides of the direction change to accommodate a possible break in the pipeline.

6.3.3.4 The horizontal portions of all compressed air pipes shall be assumed to be filled with water as an emergency condition.

6.3.4 Spillage winch support and sheave support structures

The emergency rope load, E_r (N), shall be taken as the nominal aggregate rope breaking load or 1,15 times the estimated rope breaking load.

6.3.5 Brattice walls

Areas of brattice walls local to locations at which blasts or gas explosions can occur shall be designed to resist blast or explosion pressures of not less than $20\,000 \text{ N/m}^2$. This load shall be treated as a short duration, emergency load.

6.3.6 Impact load on protective platforms

The emergency load on a protective platform, E_p , shall be taken as the load resulting from impact energy on a protective platform, U_p (J), of:

$$U_p = \alpha_a P_P g H \quad (21)$$

where

P_P the mass of any object that can fall down the shaft (kg);

H the fall distance (m);

g gravity acceleration (9,8 m/s²);

α_a the air resistance factor, see [Table 2](#).

The mass of any object that can fall down the shaft, P_P (kg), shall be taken as not less than:

- 10 % of the maximum payload of the conveyance applied over an area of 0,5 m², where rock or material is carried in conveyances;
- the maximum mass of equipment applied over the area of the equipment, where equipment is slung below conveyances.

Table 2 — Air resistance factor, α_a

H (m)	200	300	400	500	600	700	800	900	1 000	1 100	1 200
α	0,96	0,95	0,93	0,92	0,90	0,89	0,87	0,86	0,85	0,84	0,83

The emergency load on a protective platform, E_p , shall be calculated on a rational basis from the impact energy, U_p .

7 Design procedures

7.1 Design loads

The nominal loads for operating and emergency conditions shall be obtained from [Clause 6](#). Structural reliability shall be ensured to the extent envisaged in ISO 2394. This can be achieved by the application of partial load factors and load combinations in accordance with ISO 22111 together with appropriate resistance factors.

See [Annex C](#) for additional guidance.

7.2 Design codes

The design of components of shaft system structures shall comply with the provisions of ISO 19338, ISO 10721-1, and ISO 12122.

7.3 Design of emergency arresting structures

Plastic deformation of emergency arresting structures under emergency loads is acceptable, provided the following applies:

- the deformation results from a ductile material;
- no buckling of components occurs;
- the maximum plastic strain does not exceed half the strain of the material at tensile failure;

- d) plastic deformation takes place in structural components or energy absorbers and not in connections;
- e) plastic deformation is limited to the extent that the impacting conveyance or vehicle cannot pass through or over the emergency arresting structure.

7.4 Design of emergency stopping device supports

Provided the connections between adjoining guide or rail lengths are adequate to transfer emergency stopping device loads, the emergency stopping device loads may be distributed over a maximum of five bunt or sill levels.

Plastic deformation of emergency stopping devices and the guides or rails on which they act shall not occur.

7.5 Special design requirements for shaft steelwork in different shaft zones

7.5.1 Shaft zones

Shaft zones are defined in [Annexes A](#) and [B](#).

7.5.2 Shaft steelwork within shaft zone A

No special precautions are required to accommodate the expected strains.

7.5.3 Shaft steelwork within shaft zone B

Suitable expansion joints or adjustable connections shall be provided to accommodate the strain of the shaft wall.

7.5.4 Shaft steelwork within shaft zone C

All shaft steelwork shall be either

- a) isolated from the shaft wall, or
- b) provided with connections, which are vertically and horizontally adjustable, at all points of attachment to the shaft wall.

Suitable expansion joints shall be provided.

7.5.5 Shaft steelwork within shaft zone D

7.5.5.1 All shaft steelwork shall be isolated from the shaft wall.

7.5.5.2 Suitable expansion joints shall be provided, including a closure joint of sufficient length to allow for the predicted closure at the reef intersection.

7.5.5.3 Suitable provision shall be made to accommodate the predicted lateral dislocation of the shaft at the reef intersection.

7.6 Additional limit states

7.6.1 Lateral displacement of conveyance

The total lateral displacement, Δ , of conveyances within the shaft system and an overlap allowance, Δ_0 , shall not exceed the depth of the conveyance guide shoe, d_s , so as to prevent disengagement of the

conveyance from the shaft guides. Calculate the lateral displacement of conveyance using the following Formula:

$$\Delta = \Delta_w + \Delta_g + \Delta_e + 2\Delta_c \quad (22)$$

$$\Delta + \Delta_o \leq d_s \quad (23)$$

where

Δ_w is the slipper plate wear (obtained from Table B.1) (m);

Δ_g is the lateral guide displacement [caused by the slipper plate load], which shall be taken as $\delta_s 800e$ (where δ_s is obtained from [Figure 4](#)) (m);

Δ_e is the sum of the guide gauge and slipper gauge variations (obtained from Table B.1) (m);

Δ_c is the specified clearance between the slipper plate and guide (m);

Δ_o is the overlap allowance (m), which shall be taken as not less than 0,003 m;

d_s is the depth of the conveyance guide shoe.

7.6.2 Fatigue

Members subject to fluctuating loads shall be assessed for fatigue damage. The combined effects of variable stress range cycles shall be assessed using a recognized method such as Miner's rule. In general, the number of cycles for fatigue loading shall be determined from the required shaft life.

The number of cycles for slipper plate action during travelling shall be based on the frequency of slipper plate load applications, S_s (obtained from [Table B.1](#)), for different shaft conditions. The number of cycles for guide roller action during travelling shall be based on the frequency of guide roller load application, S_f (obtained from Table B.1), for different shaft conditions.

A shaft condition classification is specified in [Annex B](#).

Fatigue does not require to be checked under emergency load conditions.

7.6.3 Rebound velocity ratio

In terms of good practice, the rebound velocity ratio, r_u , of conveyances, obtained from [Figure 4](#), should not exceed a value of 2,0.

7.6.4 Amplification of loads and load effects

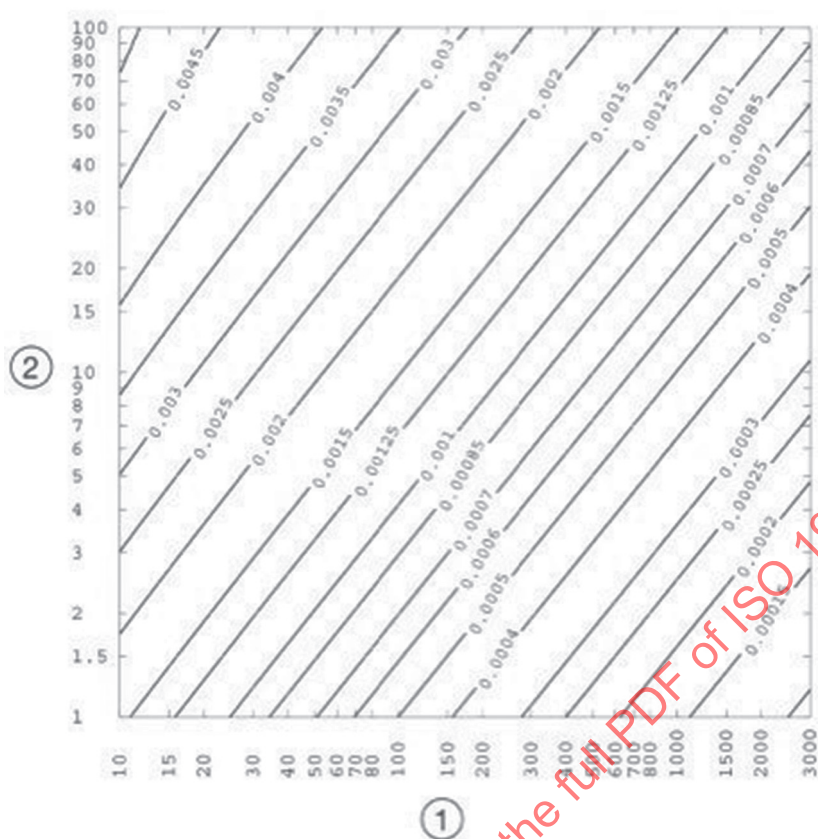
If the lateral steelwork stiffnesses on either side of a conveyance compartment are different, the slipper plate load, guide bending moment and conveyance displacement calculated for the less stiff side shall be increased by the following slipper plate load amplification factor, β_s :

$$\beta_s = \frac{r_{u,1}}{r_{u,2}} \quad (24)$$

where

$r_{u,1}$ is the rebound velocity ratio on the stiffer side (obtained from [Figure 5](#));

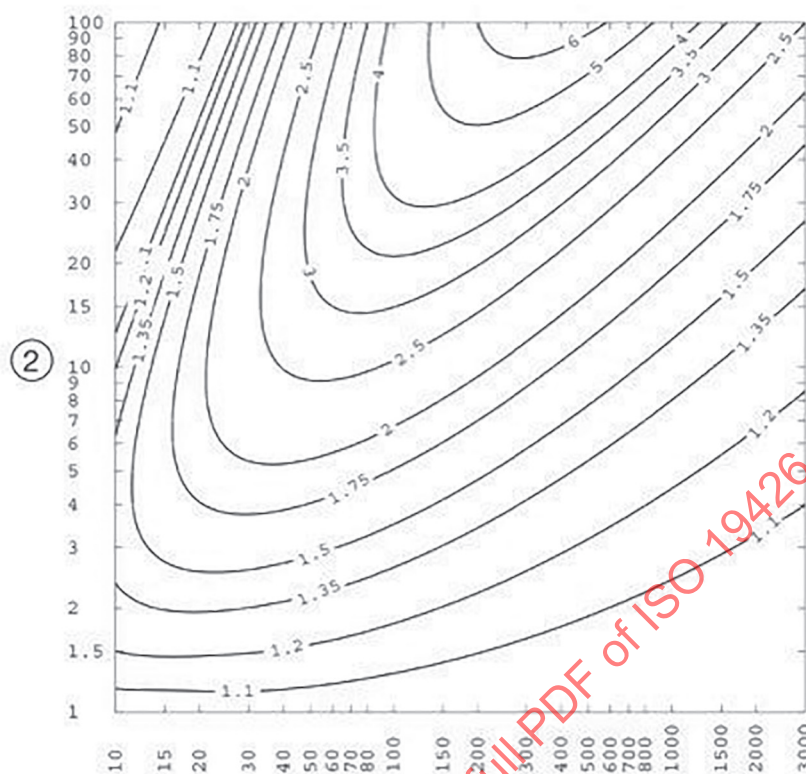
$r_{u,2}$ is the rebound velocity ratio on the less stiff side (obtained from [Figure 5](#));



Key

- 1 non-dimensional lateral steelwork stiffness at guide to bunton connection, k_b
2 steelwork stiffness ratio, r_k

Figure 4 — Contour plot of conveyance displacement coefficient, δ_s



Key

- 1 non-dimensional lateral steelwork stiffness at guide to bunton connection, k_b
- 2 steelwork stiffness ratio, r_k

Figure 5 — Contour plot of rebound velocity ratio, r_u

7.7 Provision for wear and corrosion

No allowance is made in this document for material loss due to wear or corrosion. Separate provisions shall be made to protect the equipment against wear and corrosion.

7.8 Design of protective platforms

Protective platforms shall cover the entire shaft cross section.

Where a protective platform comprises a structural platform with an overlying loose fill, the design procedure described in [Annex D](#) may be used.

8 Construction requirements

8.1 General

All construction shall be completed in compliance with the requirements of good engineering practice as described in the appropriate national standards and specifications.

8.2 Construction tolerances

All construction of shaft system structures shall comply with tolerances as specified by the appropriate national standards and specifications, and in addition the tolerances given in [Table 3](#).

Table 3 — Shaft system structures construction tolerances

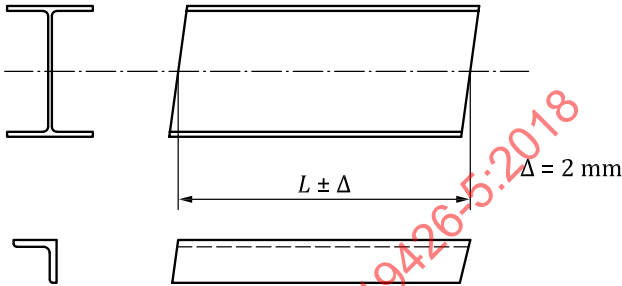
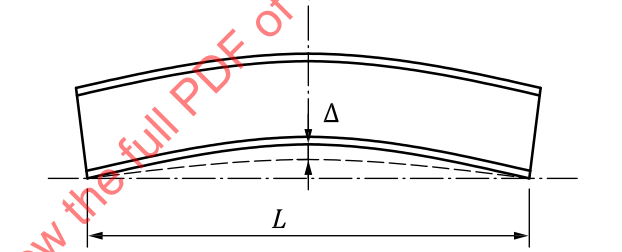
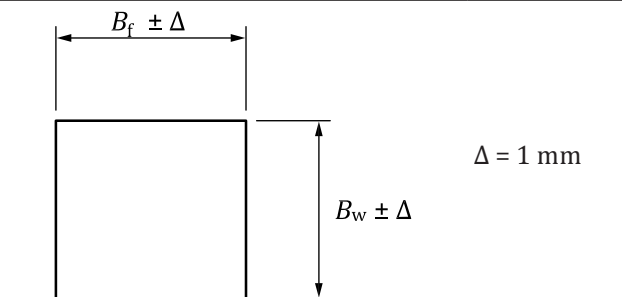
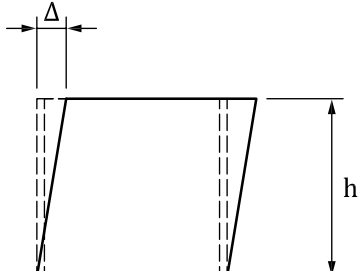
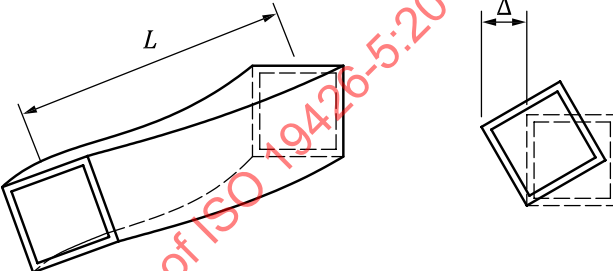
Aspect	Permissible deviation (Δ)
1 Length of mine shaft guides, L Length after cutting measured on the centre line of the section L_c is the member length of the guide	 In the case of mine shaft guides, the member length of the guide shall be $L_c^{+0}_{-\Delta}$
2 Curve or camber Deviation from intended curve or camber at the mid-length of the curved portion when measured with the web horizontal	 $\Delta = L/1\ 000$ or 6 mm whichever is the greater In the case of mine shaft guides, Δ shall not exceed $\frac{L_c}{2\ 000}$ or 3 mm, whichever is greater
3 Width and depth for hollow section mine shaft guides Width of B_f or B_w B_f and B_w are the two sides of the section	 $\Delta = 1\ \text{mm}$

Table 3 (continued)

	Aspect	Permissible deviation (Δ)
4	Squareness for hollow section mine shaft guides h is the overall width or depth of the section	 $\Delta = h/100$
5	Twist for hollow section mine shaft guides L_C is the member length of the guide	 $\Delta = \frac{L_C}{3\,000}$ but shall not exceed 2 mm

Annex A (normative)

Shaft zone classification

Mining operations and geological conditions lead to strains of differing magnitude in the rock immediately surrounding the shaft. As soon as mining operations commence, the natural strain in the rock changes due to extraction of rock. These changes in rock strain can have a significant influence on the functional performance of mine underground structures, and in particular on mine shaft structures. Four shaft zones are defined, based on the predicted strain changes not exceeding the limits given in Table A.1.

Table A.1 — Upper elastic strain change limits for shaft zones

Zone	Maximum strain changes (× 10 ⁻³)			
	Longitudinal		Transverse a	Distortion
	Tensile	Compressive		
A	0,35	0,25	50 (e/L)	0,075
B	1,00	1,00	100 (e/L)	2,00
C	No upper limits			
D	Reef intersection zone			
a The symbols used in this column are the following: e is the normal maximum moving beam misalignment of the guide; L is the guide span, bunton to bunton.				

Annex B (normative)

Shaft condition classification

B.1 General

Shafts shall be classified into condition categories as shown in [Tables B.1](#) and [B.2](#) because of the correlation between structural loading and maintenance. These tables may be applied in different ways by the designer. For example, if the designer anticipates poor maintenance of a shaft, the design will consider high loads. On the other hand, the operator of a shaft designed to accommodate only moderate forces shall make sure that the maintenance programme keeps the system performance within the appropriate range.

The individual or group that classifies a new or existing shaft shall be in a position to evaluate all the ramifications of the decision, including capital cost versus maintenance cost trade-offs. Specifying a system as category C for design and as category B during operation would be appropriate. Such a degradation by one category will ensure that the design will always be conservative relative to the expected performance of the structural system.

Shaft conditions can vary considerably within one shaft, and consequently different shaft classifications may be used for different portions of any shaft.

B.2 Vertical shafts

Table B.1 gives key values from which the shaft condition classification of existing vertical shafts may be determined, and from which the shaft condition classification of new vertical shafts may be predicted. [Table B.1](#) also gives the various factors used in this part of ISO 19426 for defining loads and fatigue cycles for vertical shafts.

B.3 Decline shafts

Table B.2 gives key values from which the shaft condition classification of existing decline shafts may be determined, and from which the shaft condition classification of new decline shafts may be predicted. [Table B.2](#) also gives the various factors used in this part of ISO 19426 for defining loads and fatigue cycles for decline shafts.

Table B.1 — Shaft condition classification for vertical shafts

Factors ^a	Maintenance category			
	Conveyance with guide rollers			Conveyance without guide rollers
	A Good	B Average	C Poor	D
e	Greater of 0,005 m or $L/1\,000$	Greater of 0,010 m or $L/500$	Greater of 0,020 m or $L/250$	Greater of 0,020 m or $L/250$
S_f	25 %	50 %	100 %	—
S_s	5 %	10 %	20 %	100 %
α_r	0,25	0,5	1,0	
Δ_e	0,005 m	0,007 m	0,012 m	0,007 m
Δ_{el}	0,003 m	0,005 m	0,010 m	0,005 m
Δ_w	0,012	0,012	0,012	0,012
Horizontal acceleration	<5 m/s ²	5 m/s ² to 10 m/s ²	10 m/s ² to 20 m/s ²	<5 m/s ²
Frequency of re-alignment	3 months	6 months	12 months	6 months
Expected fatigue life	256 n years	16 n years	n years	$n/5$ years

^a The symbols used in this column are the following:

e is the moving beam misalignment of a guide;

S_f is the frequency of guide roller load application;

S_s is the frequency of slipper plate load application;

α_r is the shaft condition factor;

Δ_e is the sum of the guide gauge and slipper gauge variations;

Δ_{el} is the maximum allowable guide gauge variation;

Δ_w is the slipper plate wear.

Table B.2 — Shaft condition classification for decline shafts

Factors ^a	Maintenance category		
	A Good	B Average	C Poor
a	0,002 m	0,004 m	0,006 m
d	0,001 m	0,002 m	0,005 m
e	0,005 m	0,010 m	0,020 m
b	Gauge/500	Gauge/250	Gauge/150
Δ_e	+5 mm, -3 mm	+10 mm, -5 mm	+15 mm, -7 mm

^a The symbols used in this column are the following:

a is the gap between the rails at a joint in a rail;

d is the transverse or normal differential at a joint in a rail;

e is the transverse or normal moving beam misalignment at the support of a rail;

b is the height difference between two rails at a support to the rails;

Δ_e is the rail gauge variation;

S_r is the frequency of rail impact load application;

α_H is the wheel horizontal load factor.

Table B.2 (continued)

Factors ^a	Maintenance category		
	A Good	B Average	C Poor
S_r	25 %	50 %	100 %
α_H	0,1	0,2	0,3
Hoisting speed	>5 m/s	1-5 m/s	<1 m/s
^a The symbols used in this column are the following: a is the gap between the rails at a joint in a rail; d is the transverse or normal differential at a joint in a rail; e is the transverse or normal moving beam misalignment at the support of a rail; b is the height difference between two rails at a support to the rails; Δ_e is the rail gauge variation; S_r is the frequency of rail impact load application; α_H is the wheel horizontal load factor.			

Annex C (informative)

Load factors and load combinations

C.1 General

This annex provides guidance with respect to load factors and load combinations which comply with the requirements of 7.1. The partial load factors and combination factors given in this annex provide for the level of reliability envisaged in ISO 22111 for ordinary consequences of failure.

NOTE Throughout this annex, “load” can also be read as “load effect”.

C.2 Operating conditions

C.2.1 Partial load factors and load combination factors

The appropriate values for partial load factors and load combination factors as given in [Table 1](#) should be used.

C.2.2 Load combinations

For load combinations, the design load, F , should be obtained from the following Formula:

$$F = \gamma_{g1}G_1 + \gamma_{g2}G_2 + \gamma_{f1}Q_1 + [\Psi_2\gamma_{f2}Q_2 + \dots + \Psi_n\gamma_{fn}Q_n] \quad (C.1)$$

where

- γ_{g1} and γ_{g2} are the partial load factors for permanent loads;
- γ_{fi} to γ_{fn} are the partial load factors for imposed loads;
- G_1 and G_2 are the permanent loads, including self-weight of the structure and structural components;
- Q_1 is the dominant imposed load under consideration [any one or more of Table C.1, column 1 (imposed loads)];
- Q_2 to Q_n are the additional independent imposed loads [any one or more of [Table C.1](#), column 1 (imposed loads)];
- Ψ_2 to Ψ_n are the load combination factors.