

---

---

## Mining structures — Underground structures

*Structures minières — Structures souterraines*

iTeh Standards  
(<https://standards.iteh.ai>)  
Document Preview

ISO 23872:2021

<https://standards.iteh.ai/catalog/standards/iso/18245f8b-b7ec-4785-9858-cbd71fe87381/iso-23872-2021>



**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[ISO 23872:2021](https://standards.iteh.ai/catalog/standards/iso/18245f8b-b7ec-4785-9858-cbd71fe87381/iso-23872-2021)

<https://standards.iteh.ai/catalog/standards/iso/18245f8b-b7ec-4785-9858-cbd71fe87381/iso-23872-2021>



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2021

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

Page

<b>Foreword</b>	<b>v</b>
<b>Introduction</b>	<b>vi</b>
<b>1 Scope</b>	<b>1</b>
<b>2 Normative references</b>	<b>1</b>
<b>3 Terms and definitions</b>	<b>2</b>
<b>4 Symbols</b>	<b>4</b>
<b>5 Materials</b>	<b>5</b>
5.1 Underground storage	5
5.2 Concrete	6
5.2.1 General	6
5.2.2 Target strength	6
5.2.3 Plums	6
5.2.4 Special recommendations for underground application	6
5.2.5 Water quality	6
5.2.6 Durability	6
5.3 Steel	6
5.3.1 General	6
5.3.2 Special requirements for underground application	7
5.3.3 Durability	7
5.3.4 Timber	7
<b>6 Nominal loads</b>	<b>8</b>
6.1 Operating loads	8
6.1.1 General loads	8
6.1.2 Spillage loads	8
6.1.3 Air pressure loads	8
6.1.4 Thermal loads	8
6.1.5 Loads on box fronts	9
6.1.6 Loads on high-pressure bulkheads	10
6.1.7 Liquid pressure	11
6.1.8 Loads on pipe supports	11
6.2 Ground displacement loads	11
6.2.1 Initial relaxation	11
6.2.2 Long-term ground displacement	11
6.2.3 Sudden ground displacement	12
6.3 Seismic loads	12
6.4 Emergency loads	12
6.4.1 General	12
6.4.2 Explosion loads	12
6.4.3 Air blast loads	12
6.4.4 Mud-rush loads	13
6.4.5 Vehicle impact loads	13
6.4.6 Ground or rock impact loads	13
6.4.7 Emergency load on pipe supports	13
<b>7 Design procedure</b>	<b>13</b>
7.1 Risk assessment	13
7.2 Design procedure	14
7.3 Partial safety factors	14
7.4 Provision for excavation variations	14
7.5 Design of high-pressure bulkheads	14
7.5.1 Types of high-pressure bulkheads	14
7.5.2 Strength requirements	15
7.5.3 Watertightness requirements	16

7.6	Design of underground head frames .....	16
<b>8</b>	<b>Construction requirements .....</b>	<b>16</b>
8.1	Transport and storage .....	16
8.2	Anchoring into ground .....	16
8.2.1	Chemical grouted anchors .....	16
8.2.2	Cementitious grouted anchors .....	17
8.2.3	Mechanical anchors .....	17
8.2.4	Shear loads on rock anchors .....	17
8.2.5	Intact ground .....	17
8.2.6	Fractured ground .....	17
8.2.7	Anchor tests .....	17
8.2.8	Lifting or pulling from rock anchors .....	17
8.3	Bearing against ground .....	17
8.3.1	Intact ground .....	17
8.3.2	Fractured ground .....	17
8.4	Excavation tolerances .....	18
8.5	Construction of high-pressure bulkheads .....	18
<b>Annex A (informative) Transportation, handling and storage .....</b>		<b>19</b>
<b>Annex B (informative) Use of concrete underground .....</b>		<b>20</b>
<b>Annex C (informative) Design and construction of parallel sided high-pressure bulkheads by mortar intrusion .....</b>		<b>28</b>
<b>Bibliography .....</b>		<b>43</b>

iTeh Standards  
(<https://standards.itih.ai>)  
Document Preview

ISO 23872:2021

<https://standards.itih.ai/catalog/standards/iso/18245f8b-b7ec-4785-9858-cbd71fe87381/iso-23872-2021>

## 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](http://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](http://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 of 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 [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

ISO 23872:2021

<https://standards.iteh.ai/catalog/standards/iso/18245f8b-b7ec-4785-9858-cbd71fe87381/iso-23872-2021>

## Introduction

Many mining companies, and many of the engineering companies that provide designs for mines, operate globally, therefore this document was developed in response to a desire for a unified global approach to the design of safe and reliable structures used in underground mines. The characteristics of ore bodies, such as their depth and shape, and the geotechnical parameters, 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 this document will facilitate improved safety and operational reliability.

There are many reasons, based on mining processes, mining equipment, technical, timing, and cost factors why certain structures can be constructed underground for a particular application rather than on surface, and these are carefully assessed at feasibility stage of any mining project. While this document is not meant to provide comments or recommendations regarding the advantages and disadvantages of using any type of structure underground, it covers specific design aspects that need be considered when using structures in underground mines. It is thus primarily intended to provide the technical information necessary to ensure good engineering of structures where their construction and use underground is the chosen solution.

The majority of the material in this document deals with the loads to be applied in the design of structures used in underground mines. Many of the loads and design considerations for underground structures are identical to the loads and design considerations for similar structures on surface. However, the underground context introduces some specific differences and challenges that must be addressed in order to achieve safe and cost-effective structures. This document deals with those issues and concepts that are specific to structures used in underground mines.

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.

## Document Preview

[ISO 23872:2021](https://standards.iteh.ai/ISO/23872-2021)

<https://standards.iteh.ai/catalog/standards/iso/18245f8b-b7ec-4785-9858-cbd71fe87381/iso-23872-2021>

# Mining structures — Underground structures

## 1 Scope

This document specifies the design loads and the design procedures for the design of structures used in underground mines. It covers all steel and concrete structures used in underground mines, irrespective of the depth of the mine or the product being mined.

This document adopts a limit states design philosophy.

Typical underground structures covered by this document include, but are not limited to:

- box front structures at the bottom of rock passes;
- conveyor gantry and transfer structures;
- chairlift support structures;
- crusher support structures;
- fan support structures;
- fixed or retractable arresting structures for ramps (see ISO 19426-5);
- foundations for pumps, fans, winches and underground winders;
- high-pressure bulkheads;
- monorails;
- overhead crane gantries for workshops, pump stations and sub shaft winder chambers;
- settler structures;
- silo bulkhead structures;
- silo structures;
- structures supporting loose rock;
- tip structures, including dump structures;
- underground head frames;
- ventilation control doors and other ventilation structures;
- walls and floors for safety bays, refuge stations and sub-stations;
- water control doors;
- water retaining structures.

This document does not cover matters of operational safety or layout of the underground structures.

## 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 2394, *General principles on reliability for structures*

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

ISO 4354, *Wind actions on structures*

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

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

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

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

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

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

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

EN 1997-1, *Eurocode 7: Geotechnical design – Part 1: General rules*

### 3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1

##### **arresting structure**

structure installed in a ramp or inclined roadway to arrest the motion of a runaway vehicle, or installed in a roadway approaching a vertical or decline shaft to prevent vehicles inadvertently entering the shaft

Note 1 to entry: See emergency arresting dropset in ISO 19426-1.

#### 3.2

##### **bagcrete**

required dry ingredients to prepare a specified strength of concrete, put into a bag with the cement in a smaller waterproof bag inside the larger bag and sealed

### 3.3 Bulkheads

#### 3.3.1

##### **high-pressure bulkhead**

liquid-retaining structure constructed in underground excavations, primarily designed to prevent water or other liquid from entering a working area of a mine or to prevent compressed air from escaping, and where the pressure exceeds 70 m head of water

#### 3.3.2

##### **silo bulkhead**

structure at the bottom of an underground silo that contains the weight of material in the silo

#### 3.4

##### **development**

tunnel excavated through *ground* (3.7) to gain access and provide a ventilation airway to the orebody and infrastructure required to mine the orebody



**3.5****dump structure**

structure installed at the top of a rock pass to receive rock into the rock pass

Note 1 to entry: A dump structure is often constructed of concrete lined with steel plates, and can be equipped with a rock sizing mechanism.

**3.6****floor**

*ground* (3.7) across the bottom of an underground excavation

**3.7****ground**

surrounding rock

natural material (hard or soft) surrounding an excavation or underground workings in a mine

**3.8****initial relaxation**

strain in the *ground* (3.7) that occurs when an underground excavation is made due to reduction or redistribution of the ground stress at the excavation from some higher value to zero

**3.9****injection**

process of introducing *injection grout* (3.9.1) at pressure into the ground-mortar contact area or into fractured or fissured *ground* (3.7)

**3.9.1****injection grout**

mixture of cement and water, that can include chemicals, injected into the ground-bulkhead contact area and the surrounding *ground* (3.7) under pressure to meet the designed hydraulic gradient requirements around the bulkhead

Note 1 to entry: In the context of this document, this refers to bulkhead constructions.

**3.10****intrusion**

process of introducing *intrusion mortar* (3.10.1) into previously placed aggregate, such that the pressure at the mortar outlet pipe is no more than is just required to introduce the mortar over the full area of the placed aggregate

**3.10.1****intrusion mortar**

mix of fine aggregate, cement and water, that can include chemicals, intruded into the entire volume of the *high-pressure bulkhead* (3.3.1) once placement of the *plums* (3.11) and coarse aggregate has been completed

Note 1 to entry: In the context of this document, this refers to bulkhead constructions.

**3.10.2****intrusion pipes**

small bore pipes in the *high-pressure bulkhead* (3.3.1) structure, placed to facilitate an even placement of *intrusion mortar* (3.10.1) within previously placed aggregate and *plums* (3.11)

**3.11****plum**

cobble

piece of rock larger than standard aggregate, that can be added to concrete in specified circumstances

**3.12****return airway**

tunnel, or *development* (3.4), used to exhaust the air from the working areas of the mine

**3.13**

**roof**

hanging wall

back

*ground* (3.7) across the top of an underground excavation

**3.14**

**deflector plate**

shedder plate

plate placed over equipment and inclined in such manner as to deflect any spillage away from the equipment

**3.15**

**side wall**

*ground* (3.7) at the side of an underground excavation

**3.16**

**slick line**

pipe installed in a shaft or a borehole (normally during sinking) to convey wet concrete from the batch plant to the point of use

**3.17**

**slinging**

operation of suspending equipment or materials below a conveyance for transport in the mine shaft

**3.18**

**tightening**

high-pressure *injection* (3.9) of grout around the perimeter of the mortar *intrusion* (3.10) *high-pressure bulkhead* (3.3.1) in order to seal the interface between the bulkhead and the surrounding *ground* (3.7) and render the bulkhead watertight

**3.18.1**

**tightening pipe**

pipe of a suitable diameter in the *high-pressure bulkhead* (3.3.1) structure to allow re-drilling in the bulkhead structure to enable the sealing [*tightening* (3.18)] of the mortar-ground interface and surrounding *ground* (3.7) fractures

## 4 Symbols

$a_n$  seismic acceleration ( $\text{m/s}^2$ )

$A_B$  area of bearing between the high-pressure bulkhead and the surrounding ground ( $\text{m}^2$ )

$A_H$  surface area of the high-pressure bulkhead ( $\text{m}^2$ )

$b_1$  bearing strength of the surrounding ground ( $\text{N/m}^2$ )

$B_1$  bearing resistance of the interface between the high-pressure bulkhead and the surrounding ground ( $\text{N/m}^2$ )

$d_i$  deformation of the relevant structural component (m)

$F$  design load, or load effect (N, Nm)

$F_H$  additional permanent load due to water head (N)

$F_R$  factored parallel sided high-pressure bulkhead design strength (N)

$F_U$  ultimate parallel sided high-pressure bulkhead design load (N)

$g$	acceleration due to gravity ( $\text{m/s}^2$ )
$G$	permanent load or effect (N, Nm)
$h_b$	design height of the rock pass (m)
$h_d$	height through which the rock falls; to be taken as the depth of the rock pass (m)
$H$	maximum height of liquid above the centre of the high-pressure bulkhead (m)
$i$	hydraulic gradient
$L$	length of the high-pressure bulkhead (m)
$m_r$	mass of the largest rock (kg)
$p_h$	reference pressure (Pa)
$q$	water pressure (Pa)
$q_n$	additional hydraulic pressure due to seismic action (Pa)
$R_D$	relative density of the liquid
$R_i$	single rock impact load on the box front (N)
$v_l$	shear strength of the surrounding ground ( $\text{N/m}^2$ )
$V_l$	shear resistance of the interface between the high-pressure bulkhead and the surrounding ground (N)
$Z_i$	impact energy of the falling rock (J)
$\alpha_i$	proportion of potential energy transferred into impact energy on the box front
$\gamma$	unit weight of water ( $\text{N/m}^3$ )
$\rho_L$	density of the liquid ( $\text{kg/m}^3$ )
$\rho$	density of the rock pass contents ( $\text{kg/m}^3$ )
$\varphi_H$	load factor for the additional permanent water head load
$\phi_H$	resistance factor for the shear resistance between the high-pressure bulkhead and the surrounding ground

## 5 Materials

### 5.1 Underground storage

The owner of the mine shall specify the storage location and conditions for underground storage of construction materials, bearing in mind the adverse environment, the length of time for storage and possible rough handling.

Specific requirements for storage are made in [5.2](#) and [5.3](#), and further recommendations for underground storage are made in [Annexes A, B and C](#).

## 5.2 Concrete

### 5.2.1 General

The materials used in the construction of concrete structures for underground mines structural concrete shall comply with ISO 19338. The design strength of the concrete to be used shall be specified on the structural drawings, using the common designation for “cylinder strength “or “cube strength”.

### 5.2.2 Target strength

The target strength of the concrete to be used shall be defined in order to ensure that the specified design strength is achieved. [Annex B](#) provides guidance.

### 5.2.3 Plums

Plums can be used in high-pressure bulkheads, and can be used in other large structures with the approval of the design engineer.

Plums shall be brushed and washed to remove all contamination and fines immediately prior to placement.

Plums should consist of hard, intact rock. Any rock that is friable, fractured or subject to deterioration on contact with oxygen should not be used.

Plums should consist of sizes with a mass not exceeding what can be handled by one person.

### 5.2.4 Special recommendations for underground application

[Annex B](#) provides general guidance on the use of concrete underground.

[Annex C](#) provides guidance for high-pressure bulkheads constructed by mortar intrusion.

### 5.2.5 Water quality

Some water present in underground mines (e.g. hyper saline and containing sulphates and chlorides) can be very deleterious to concrete structures. Where water other than potable water is used, samples should be tested and the owner of the mine should provide the results to the designer of concrete structures.

### 5.2.6 Durability

The designer shall specify any specific concrete mix design criteria required to ensure the required durability of the completed concrete structure.

When a structure is constructed in any area containing exhaust air, or other contaminated air, the durability of the structure shall take this into account.

[Annex B](#) provides guidance.

## 5.3 Steel

### 5.3.1 General

The materials used in the construction of steel structures for underground mines shall be structural steel complying with ISO 10721-1. The material used shall be specified on the structural drawings.

### 5.3.2 Special requirements for underground application

#### 5.3.2.1 Corrosion protection

The owner of the mine shall specify the corrosion protection of steel for underground use. Steel structures underground are susceptible to dust build-up or ore spillage on horizontal surfaces. Some ores, when oxidized and in the presence of moisture, create corrosive products. Mine water used for wash-down can also be corrosive in nature. Careful detailing of structures is required to minimise surface build up or pockets for water collection. This can be achieved by means of appropriately positioned deflector plates, coatings or drain holes.

#### 5.3.2.2 Storage

Where it is necessary to store steel underground, the following precautions should be observed:

- the storage area should be well ventilated by clean air;
- the storage area should be dry, so that steel is not exposed to seepage from the roof or the side walls, or to drain water;
- stacked steel sections should be supported in such a manner that the weight of overlying steel does not damage underlying steel;
- stacked steel sections should not be nested in direct contact with underlying steel sections, but should be separated using a porous material.

Where it is not possible to achieve one or more of these precautions, specification of the corrosion protection should take this into account.

If any steel is stored underground for a period exceeding the period anticipated during design by more than three months, then that steel and corrosion protection shall be thoroughly inspected for deterioration prior to its installation. An inspection report shall be kept together with all construction documentation.

#### 5.3.3 Durability

An adequate corrosion protection system shall be applied to all steelwork to provide the durability required. Where the life of the corrosion protection system is anticipated to be less than the life of the mine, an inspection and repair strategy should be recommended to the owner of the mine.

The owner of the mine shall provide the following information for the specific excavation to guide selection of the appropriate corrosion protection system:

- temperature range;
- humidity range;
- air quality and gas content of the air;
- chemical analysis of ground water;
- chemical analysis of mine water;
- rock properties and their propensity to produce corrosive substances when oxidized or in the presence of moisture.

#### 5.3.4 Timber

The materials used in the construction of timber structures for underground mines shall be designed using characteristic strength as determined in ISO 12122. The material used shall be specified on the structural drawings.

## 6 Nominal loads

### 6.1 Operating loads

#### 6.1.1 General loads

The general loads shall be those specified by ISO 22111.

#### 6.1.2 Spillage loads

Due to the potential for dust or rock spillage build-up on underground structures, in combination with infrequent clean-up, consideration should be given to increasing the imposed spillage loads.

#### 6.1.3 Air pressure loads

Structures underground are not subjected to wind loads. However, many underground excavations have ventilation air circulating and air blast loads caused by the mining method. There can be various causes of air pressure applied to underground structures in different locations.

- a) Underground structures can be constructed in an air way.

The air velocity loads shall be determined in accordance with ISO 4354, where the site wind speed shall be taken as equal to the nominal velocity of ventilation air past the structure.

Where the velocity of ventilation air does not exceed 6 m/s, the loads due to air velocity are small and can be omitted.

The velocity of ventilation air is constant, and structures in underground mines are typically not slender. Wind dynamic effects can thus be omitted, provided the risk assessment concludes that this is acceptable.

- b) Walls or door structures can be used to separate ventilation zones or to separate intake and exhaust air ways.

Where an underground structure separates ventilation zones or intake and exhaust air ways, the ventilation air flow causes differential pressures on the two sides of the structure. The nominal differential pressure can be treated as a static load on the structure, unless the risk assessment and/or a ventilation flow analysis shows that there is potential for a significant increase in pressure due to some unintended event, such as failure of a fan, unblocking of an ore pass or sudden blockage of an air way.

- c) Structures subjected to air blast loads from mining methods shall be designed to resist such loads.
- d) Walls or gates can be used to contain compressed air. Where any wall or gate contains accumulated compressed air, the pressure shall be taken as the maximum pressure in the compressed air system.

#### 6.1.4 Thermal loads

Thermal loads shall be considered, unless specific provision is made to detail the structure in such a manner that expansion can take place freely.

The owner of the mine shall specify the temperature range to be considered.