DRAFT INTERNATIONAL STANDARD

ISO/DIS 23872

ISO/TC **82**	Secretariat: **DIN**
Voting begins on: **2021-01-06**	Voting terminates on: **2021-03-31**

Mining structures — Underground structures

ICS: 73.020

IMPORTANT — Please use this updated version dated 2020-11-17, and discard any previous version of this DIS. Note that we removed the reference to a consultation with ISO/TC 127.

This document is circulated as received from the committee secretariat.

Reference number
ISO/DIS 23872:2021(E)

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Published in Switzerland

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Foreword

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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*.

Introduction

Many mining companies, and many of the engineering companies which provide designs for mines, operate globally, therefore this standard 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 standard will facilitate improved safety and operational reliability.

The majority of the material in this standard deal 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 standard 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.

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. This standard 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.

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. This standard does not set out to provide comments or recommendations regarding the advantages and disadvantages of using any type of structure underground, but it covers specific design aspects considered when using structures in underground mines. This standard 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.

Typical underground structures covered by this standard 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
- Ventilation control doors and other ventilation structures
- Walls and floors for safety bays, refuge stations and sub-stations
- Water control doors
- Water retaining structures

- Underground head frames

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.

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

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*

ISO 31010, *Risk management – Risk assessment techniques*

ISO 22477-5, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 5: Testing of grouted anchors*

3 Terms and definitions

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

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

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

— IEC Electropedia: available at http://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 (see emergency arresting dropset in ISO 19426-1).

3.2
bagcrete
The required dry ingredients to be used 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 bulkhead

3.3.1
high pressure bulkhead
a liquid retaining structure that is 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
a structure at the bottom of an underground silo that contains the weight of material in the silo.

3.4
development
a tunnel excavated through ground to gain access and provide a ventilation airway to the orebody and infrastructure required to mine the orebody.

3.5
dump structure
a 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
the ground across the bottom of an underground excavation.

3.7
ground
(surrounding rock)
any natural material (hard or soft) surrounding an excavation or underground workings in a mine.

3.8
initial relaxation
the strain in the ground 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.

3.9.1
injection grout
a mixture of cement and water, which can include chemicals, that is injected into the ground-bulkhead contact area and the surrounding ground under pressure to meet the designed hydraulic gradient requirements around the bulkhead.

Note 1 to entry: In the context of this standard, this refers to bulkhead construction.

3.10
intrusion
process of introducing intrusion mortar (3.9.1) 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 placed aggregate.

3.10.1
intrusion mortar
a mix of fine aggregate, cement and water, which can include chemicals, that is intruded into the entire volume of the high pressure bulkhead once placement of the plums and coarse aggregate has been completed.

Note 1 to entry: In the context of this standard, this refers to bulkhead construction.

3.10.2
intrusion piping
small bore piping in the high pressure bulkhead structure, placed to facilitate an even placement of intrusion mortar within previously placed aggregate and plums.

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, used to exhaust the air from the working areas of the mine.

3.13
roof
(hanging wall, back)
the ground across the top of an underground excavation.

3.14
shedder plates
(deflector plates)
plates placed over equipment and inclined in such manner as to deflect any spillage away from the equipment.

3.15
side wall
the ground at the side of an underground excavation.

3.16
slick lines
pipes 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
the operation of suspending equipment or materials below a conveyance for transport in the mine shaft.

3.18
tightening
high pressure injection of grout around the perimeter of the mortar intrusion high pressure bulkhead in order to seal the interface between the bulkhead and the surrounding ground and render the bulkhead watertight.

3.18.1
tightening pipes
pipes of a suitable diameter in the high-pressure bulkhead structure to allow re-drilling in the bulkhead structure to enable the sealing (tightening) of the mortar-ground interface and surrounding ground fractures.

4 Symbols

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

a_n seismic acceleration (m/s^2)

A_B area of bearing between the high pressure bulkhead and the surrounding ground (m^2)

A_H surface area of the high pressure bulkhead (m^2)

b_l bearing strength of the surrounding ground (N/m^2)

B_l bearing resistance of the interface between the high pressure bulkhead and the surrounding ground (N)

d_i deformation of the relevant structural component, expressed in metres (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 (m/s^2)

G permanent load or effect (N, Nm)

h_b design height of the rock pass, expressed in metres (m)

h_d height through which the rock falls; to be taken as the depth of the rock pass, expressed in metres (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, expressed in kilograms (kg)

p_h reference pressure (Pa)

q water pressure (Pa)

q_n additional hydraulic pressure due to seismic action (Pa)

RD relative density of the liquid

R_i single rock impact load on the box front, expressed in newtons (N)

v_I shear strength of the surrounding ground (N/m^2)

V_I shear resistance of the interface between the high pressure bulkhead and the surrounding ground (N)

Z_i impact energy of the falling rock, expressed in joules (J)

αi proportion of potential energy transferred into impact energy on the box front

γ unit weight of water (N/m^3)

ρ_L density of the liquid (kg/m^3)

ρ density of the rock pass contents, expressed in kilograms per cubic metre (kg/m^3)

φ_H load factor for the additional permanent water head load

ϕ_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 below, and further recommendations for underground storage are made in Annexes B, C and D.

5.2 Concrete

5.2.1 Standards

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 C 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 requirements for underground application

Annex C provides general guidance on the use of concrete underground.

Annex D 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 results provided to the designer of concrete structures by the owner of the mine.

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 C provides guidance.

5.3 Steel

5.3.1 Standards

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 corrosion protection of steel for underground use, shall be specified by the owner of the mine. 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.