

Australian/New Zealand Standard™

Underground mining—Shaft equipment

Part 6: Fixed guides, rope guides and rubbing ropes for conveyances



AS/NZS 3785.6:2015

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-018, Mining Equipment, to supersede AS 3785.6—1992, *Underground mining—Shaft equipment*, Part 6: *Guides and rubbing ropes for conveyances*.

This Standard is one of a series on shaft equipment for underground mines. The other Standards in the series are as follows:

AS(/NZS)

- 3785 Underground mining—Shaft equipment
- 3785.1 Part 1: Shaft overwind safety catch system
- 3785.2 Part 2: Shaft winding arresting systems
- 3785.3 Part 3: Drum winding gripper systems
- 3785.4 Part 4: Conveyances for vertical shafts
- 3785.5 Part 5: Headframes
- 3785.7 Part 7: Sheaves
- 3785.8 Part 8: Personnel conveyances in other than vertical shafts

The objective of this Standard is to provide designers, manufacturers and users with a clear specification for the design, manufacture and maintenance of conveyance guidance systems for vertical mine shafts.

The objective of this revision is to—

- (a) update references and design criteria;
- (b) foster a move away from static to dynamic design criteria; and
- (c) provide a comprehensive dynamic design method that is heavily reliant on modern computational methods.

This Standard includes material that is adapted from—

- (i) SANS 10208-4, Ed. 2 (2011), *Design of Structures for the Mining Industry*, Part 4: *Shaft System Structures*; and
- (ii) SANS 10208-3, Ed. 3 (2012), *Design of Structures for the Mining Industry*, Part 3: *Conveyances*,

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The principal differences between this and the previous edition are as follows:

- (A) Introduction of dynamic analysis methods for design calculations.
- (B) Graphs clarified to make interpolation easier.
- (C) Wording revised and expanded to provide clearer explanation to users.

The term ‘informative’ has been used in this Standard to define the application of the appendix to which it applies. An ‘informative’ appendix is for information and guidance only.

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FOREWORD

Fixed guides, rope guides and rubbing ropes are installed in vertical shafts to guide conveyances as they travel up and down in the shaft or skyshaft (or both). Their function is to limit the motion of the conveyances to prevent them from colliding with one another or with the shaft walls and other fixtures and equipment installed in the shaft or skyshaft.

Fixed guides are normally much stiffer than rope guides and therefore permit conveyances to operate in the shaft with much smaller clearances than rope guides permit.

Rope guide installations normally require short sections of fixed guides to be installed at locations where the conveyances are loaded and unloaded to control deflections during loading and unloading.

Rubbing ropes are sometimes installed between rope-guided conveyances in order to reduce the risk of collision when two conveyances pass one another.

STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Underground mining—Shaft equipment

Part 6: Fixed guides, rope guides and rubbing ropes for conveyances

1 SCOPE

This Standard specifies requirements for fixed guides, rope guides and rubbing ropes for conveyances used in vertical mine shafts.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- | | |
|--------|--|
| 1720 | Timber structures |
| 1720.1 | Part 1: Design methods |
| 3569 | Steel wire ropes—Product specification |
| 3637 | Underground mining—Winding suspension equipment |
| 3637.1 | Part 1: General requirements |
| 3818 | Timber—Heavy structural products—Visually graded |
| 3818.5 | Part 5: Mine lift guides |
| 3990 | Mechanical equipment—Steelwork |
| 4100 | Steel structures |

AS/NZS

- | | |
|--------|---|
| 1170 | Structural design actions |
| 1170.1 | Part 1: Permanent, imposed and other actions |
| 4812 | Non-destructive examination and discard criteria for wire ropes in mine winding systems |

BS

- | | |
|------|--|
| 7608 | Guide to fatigue design and assessment of steel products |
|------|--|

COMRO

Design Guidelines for the Dynamic Performance of Shaft Steelwork and Conveyances

SANS

- | | |
|---------|--|
| 10208 | Design of Structures for the Mining Industry |
| 10208-3 | Part 3: Conveyances |
| 10208-4 | Part 4: Shaft System Structures |

3 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

3.1 Bunton/dividers

Structural members installed to support fixed guides, and where attached, ladders, piping, cables, brattice panels and other fixtures in the shaft.

3.2 Chairing

The operation of supporting a conveyance at some point in its normal vertical path by means other than the winding rope or gripper system.

3.3 Clearance

The distance between conveyances or between conveyances and the shaft walls and equipment. The clearance is measured in a direction perpendicular to the direction of conveyance travel, i.e. typically in the horizontal plane for a vertical shaft.

3.4 Competent person

A person having practical and theoretical knowledge and relevant experience of wire ropes, sufficient to enable that person to detect and evaluate any defects that may affect the strength of the rope.

3.5 Conveyance

Any car, carriage, cage, skip, kibble or stage in which persons, minerals or materials are hoisted through a shaft, and any counterweight.

3.6 Conveyance guide assemblies

Consist of guide wheels, guide shoes or guide slippers, which are fixed to the conveyance and operate in conjunction with the guides in the shaft.

3.7 Dynamic clearance

The minimum clearance that exists during operation of the system.

3.8 Fixed guides

Fixed structural members located in a mine shaft, skyshaft, or both, to limit lateral movement of the conveyance so as to prevent collision with other conveyances or with the shaft wall and equipment installed in the shaft.

3.9 Gauge

The horizontal face-to-face distance between two fixed guides or slipper plates on the conveyance.

3.10 Gripper system

A mechanism mounted on a conveyance which is designed to engage with the guides in response to a loss of winding rope tension, bringing the conveyance to rest and supporting its weight (including payload) when stationary.

3.11 Head rope

A rope connected to the top of a conveyance and used to raise and lower the conveyance.

3.12 Imposed loads

The load resulting on the guides and buntions from the operation of the conveyance and any attached services.

3.13 Moving beam misalignment

Misalignment of a guide at the buntion, measured as the deviation from a straight line from the buntion above to the buntion below the one in question.

3.14 Overwind

Unintentional travel of either an ascending or descending conveyance beyond its normal operating limits.

3.15 Permanent loads

The load due to the mass of all permanent components of the guides.

3.16 Rope break force

The minimum breaking force of a rope, as given by the rope manufacturer's catalogue or specification.

3.17 Rope guides

Suspended steel wire ropes in a mine shaft or skyshaft or both, to guide the conveyance and limit lateral movement of the conveyance so as to prevent collision with other conveyances or with the shaft wall and equipment installed in the shaft.

NOTE: The conveyance is normally permanently connected to the guide rope such that any lateral movement of the conveyance is resisted by the guide rope.

3.18 Rubbing ropes

Suspended steel wire ropes in a mine shaft, positioned between conveyances so as to prevent collision of passing conveyances.

NOTE: Conveyances are not connected to the rubbing ropes. The ropes only resist conveyance lateral movement after the conveyance has deflected sufficiently to come in contact with the rubbing ropes.

3.19 Shaft clearance envelope

In the context of rope guide systems, the shaft clearance envelope is the outline of the largest straight and vertical prismatic shape that can pass clear through the shaft, i.e. it allows for construction tolerances. Clearances around the conveyances are calculated to the clearance envelope.

3.20 Shaft sinking system

The equipment used in the process of mining to develop a mine shaft.

3.21 Shall

Indicates that a requirement is mandatory.

3.22 Should

Indicates a recommendation.

3.23 Slipper plate

A sacrificial wear plate to protect structural parts of the conveyance that engage with the fixed guides from wear damage.

3.24 Static clearance

The minimum clearance with the conveyances at rest in the nominal design locations.

3.25 Static design factor

The ratio between the ultimate failure load of a component in the particular manner of likely failure and the maximum static loading to which it may be subjected in service.

3.26 Tail rope

A rope which has one end connected to the bottom of one conveyance and the other to the bottom of the other conveyance.

4 MATERIALS

4.1 General

The materials for different types of guides and their fixings are specified in Clauses 4.2, 4.3 and 4.4.

Materials that do not comply with the Standards specified in those Clauses may be used when the mechanical properties and, when applicable, the chemical composition and weldability are verified by test to be suitable for the application.

4.2 Fixed steel guides

Materials for fixed steel guides and their fixings shall comply with those specified in AS 4100.

4.3 Fixed timber guides

Materials for fixed timber guides shall comply with those specified in AS 3818.5 or AS 1720.1, Grade F11, or higher. Materials for guide fixings shall comply with those specified in AS 4100.

4.4 Wire guide ropes and rubbing ropes

Materials for wire guide ropes and rubbing ropes shall comply with those specified in AS 3569.

4.5 Rope suspension glands

Materials for rope suspension glands should comply with AS 3637.1.

5 DESIGN—FIXED GUIDES

5.1 Design philosophy

Historically, simplified static design procedures have been used and have proved to be successful in many applications. The practice applies a horizontal acceleration of typically 1 m/s^2 acting through the conveyance centre of gravity (or a force equivalent to approximately 10% of the conveyance weight). This is reacted by forces acting at the points of contact between the conveyance and the guide. The most obvious deficiency of this method is that the design forces so derived are independent of the conveyance velocity. Whilst this approach may be suitable under some circumstances, it is not recommended unless used in conjunction with rigorous evaluation of the proposed design against existing successful designs. Factors for such evaluation should include the following:

- (a) Hoisting speed.
- (b) Conveyance mass.
- (c) Bunton spacing.
- (d) Guide-to-bunton stiffness ratio.
- (e) Conveyance slipper plate locations.
- (f) Guide misalignment tolerances.
- (g) Number and location of guides.

The method specified in this Standard is based on dynamic analysis methods. The method computes the forces arising from so called 'slamming' events whereby the conveyance travelling along the guides 'slams' into the guides with an initial velocity normal to the guide. This initial velocity is induced by the misalignment of the guides. In this method, forces are affected by the magnitude of guide misalignment, the conveyance mass, the conveyance vertical velocity and the stiffness of the guidance structure.

This design method typically results in a system where the variation in lateral guide stiffness between the guide at mid-span and at the supports is minimized and leads to stiffer guides and more flexible buntons or dividers.

The procedures in this Standard for calculation of horizontal loads, guide bending moments and deflections due to the conveyance are described in the Republic of South Africa Chamber of Mines Research Organization (COMRO) publication *Design Guidelines for the Dynamic Performance of Shaft Steelwork and Conveyances* and are also incorporated in South African National Standard SANS 10208-4.

NOTE: This Clause (5) includes material that is adapted from SANS 10208-4 Ed. 2 (2011), *Design of Structures for the Mining Industry*, Part 4: *Shaft System Structures*, and SANS 10208-3, Ed. 3 (2012), *Design of Structures for the Mining Industry*, Part 3: *Conveyances*, which is reproduced with permission from South African Bureau of Standards (SABS) in its capacity as the source and publisher of those documents. Any request to adopt any part of this Standard that includes SABS material should be addressed to SABS as well as Standards Australia Limited and Standards New Zealand.

5.2 Shaft condition classification for fixed guides

Shafts shall be classified into condition categories as indicated in Table 1. Table 1 provides the correlation between structural loading and maintenance requirements.

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

Table 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. It also gives the various factors used in this Standard for defining loads and fatigue cycles for vertical shafts.

TABLE 1
SHAFT CONDITION CLASSIFICATION FOR VERTICAL SHAFTS

1	2	3	4	5
Maintenance category	Conveyance			
	With guide rollers			Without guide rollers
	A Good	B Average	C Poor	D
e	Greater of 0.005 m or $L/1000$	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_{e1}	0.003 m	0.005 m	0.010 m	0.005 m
Horizontal acceleration	$<5 \text{ m/s}^2$	5 m/s^2 to 10 m/s^2	10 m/s^2 to 20 m/s^2	$<5 \text{ m/s}^2$
Expected fatigue life	256 n years	16 n years	n years	$n/5$ years

LEGEND

- e = the moving beam misalignment of a guide.
- s_f = the frequency of guide roller load application.
- s_s = the frequency of slipper plate load application.
- α_r = the shaft condition factor.
- Δ_e = the sum of the guide gauge and slipper gauge variations.
- Δ_{e1} = the maximum allowable guide gauge variation.
- L = the guide span, bunton to bunton.

5.3 Shaft zone classification

Mining operations and geological conditions lead to strains of differing magnitude in the rock immediately surrounding the shaft. Four shaft zones are defined, based on the likely strains not exceeding the limits given in Table 2.

TABLE 2
UPPER ELASTIC STRAIN LIMITS FOR SHAFT ZONES

1	2	3	4	5
Zone	Maximum strains ($\times 10^{-3}$)			
	Longitudinal		Transverse	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	Fault or ore body intersection zone			

LEGEND

e = the normal maximum moving beam misalignment of the guide.

L = the guide span, buntion to buntion.

5.4 Actions and effects

5.4.1 General

Shaft system structures shall be designed to resist imposed loads as assessed in accordance with AS/NZS 1170.1. In addition they shall be designed to resist the actions specified in this Clause (5.4).

5.4.2 Fixed guides in vertical shafts in shaft zone A

NOTE: See Table 2.

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

For shaft zone A, the lateral loads are (a) and (c) or (b) and (c) below, as the guide roller load and lateral slipper plate load cannot act in unison:

- (a) *Guide roller load (H_f)* The load normal to the guide face or the guide sides shall be taken as—

$$H_f = k_r \Delta_c + F_p$$

where

k_r = the roller assembly stiffness (N/m)

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

F_p = the guide roller preload (N)

- (b) *Lateral slipper plate load (H_s) in newtons (N)* 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. All slipper plates should be assessed. 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 buntion, considering the action of only one slipper at a time.

The lateral load between any slipper plate and the guide shall be taken as—

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

The proportion of the conveyance mass effectively acting at a slipper plate is—

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

The non-dimensional lateral stiffness at the guide-to-bunton connection is—

$$\overline{k}_b = \frac{k_b L^2}{m_e v^2}$$

The stiffness ratio is—

$$r_k = \frac{k_b}{k_g}$$

where (in the above equations)

α_n = the slipper plate impact factor, which shall be taken as 2.0

$\overline{P}_b$ = the slipper plate load coefficient (obtained from Figure 1)

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

v = the winding velocity (m/s)

e = the maximum moving beam misalignment of the guide (see Table 1) (m)

L = the guide span, bunton to bunton (m)

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

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

h_1, h_2 = the lever arm distances of the relevant slipper plate loads with respect to the relevant centroidal axes (m)

k_b = the lateral stiffness at the guide-to-bunton connection (N/m)

k_g = the lateral stiffness at the guide mid-span (N/m)

- (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.

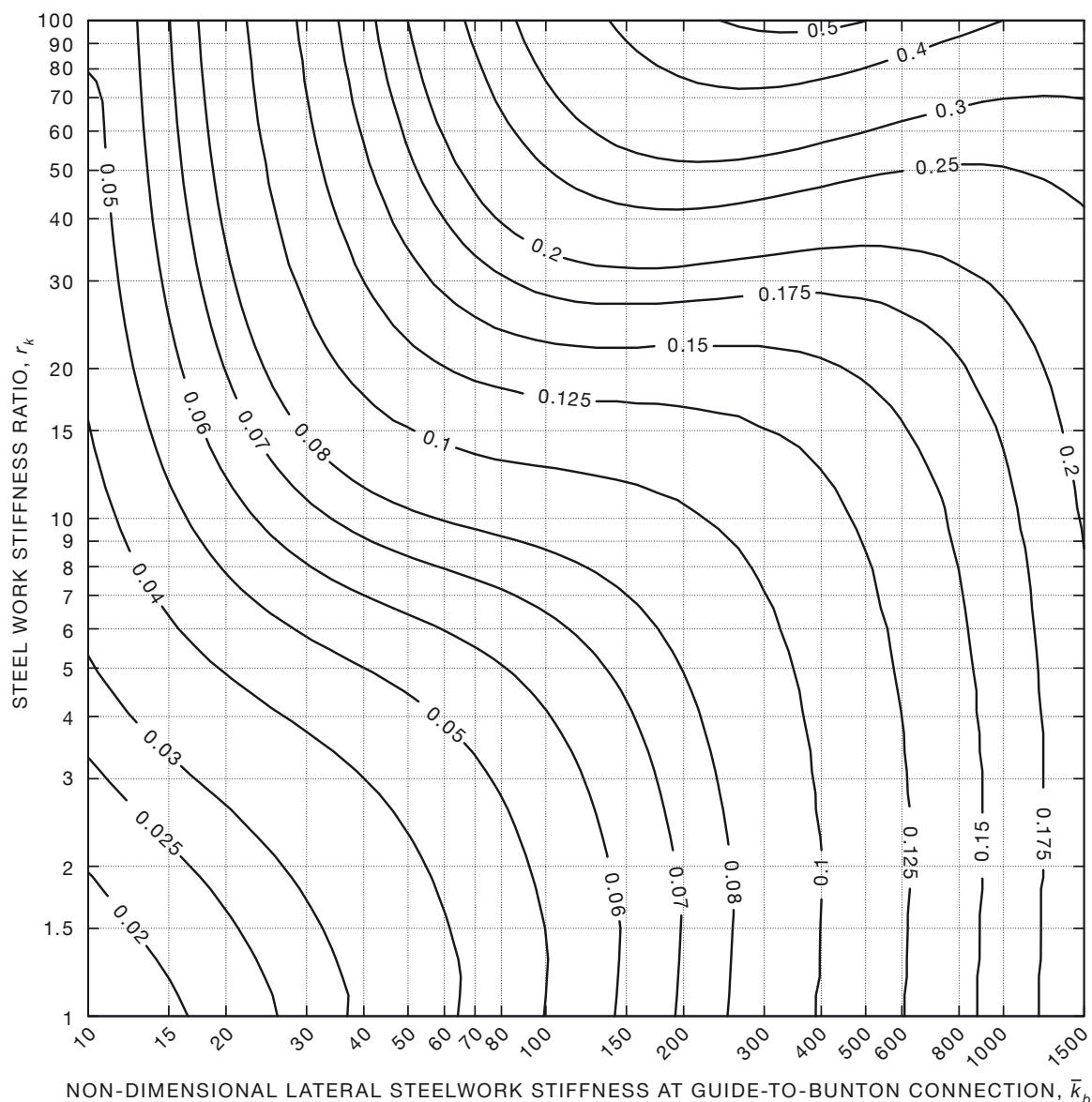
The maximum guide bending moment, M_g , shall be taken as—

$$M_g = \alpha_n \left(\overline{M} \frac{400m_e v^2 e}{L} \right)$$

where

α_n, m_e, v, e and L are as defined in Item (b) above

$\overline{M}$ = the guide bending moment coefficient (obtained from Figure 2)



NOTES:

- 1 The stiffness parameters k_b and k_g are the system stiffness, normally determined by applying unit loads in the appropriate directions to three-dimensional frame models of the shaft guidance structure.
- 2 The effective mass (and therefore the forces) are higher when the slipper plates are located close to the centre of gravity of the conveyance. Slipper plates should therefore preferably be located only at the extremities of the conveyance.

FIGURE 1 CONTOUR PLOT OF SLIPPER PLATE LOAD COEFFICIENT $\bar{P}_b$

The methods described above for computing the lateral loads assume that the conveyance behaves as a rigid body. In some circumstances, for example, where wall brackets are used, the rigid conveyance assumption tends to overestimate the forces. A more realistic estimate of the forces may be achieved by making allowance for the flexibility of the conveyance. Conveyance stiffness/flexibility may be estimated from structural models of the conveyance, subjected to unit loads applied in the appropriate direction at the slipper plates. Typically, the applied load is reacted by the conveyance inertia—this solution technique, known as ‘inertia relief’ is available in some structural analysis software codes.

Conveyance flexibility may be accounted for by replacing the term k_b with the term k_{be} , expressed as—