SOUTHERN AFRICAN INSTITUTE OF STEEL CONSTRUCTION

C O M M E N T A R Y
O N
SANS 10208:1 – 2005 Edition 3

SOUTH AFRICAN NATIONAL STANDARD

DESIGN OF STRUCTURES FOR THE MINING INDUSTRY

PART 1 — HEADGEAR STRUCTURES

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SOUTHERN AFRICAN INSTITUTE OF STEEL CONSTRUCTION
JOHANNESBURG, REPUBLIC OF SOUTH AFRICA, 2009
ISBN :

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Acknowledgement

This Commentary arises from the dedicated activity of the Southern African Institute of Steel Construction's Regulations Codes & Standards Committee and in particular that sub-committee responsible for the SANS 10208 series of Standards for the Design of Structures for the Mining Industry. The fact that the substantial contributions made by these committee members are on an honourary basis, makes their achievements that much worthier. The author and the SAISC express their gratitude to all those who have made both SANS 10208 and this Commentary a reality. Their efforts are much appreciated by the South African Steel Industry and all those engineers who are responsible for the design of structures for the mining industry.

The Institute's sub-committee, which has undertaken the task of revising SANS 10208 : Part 1 – Headgear Structures, consisted at various times of the following people:

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FOREWORD

Standards play a prominent and extremely important role in the work of the structural engineer. As a means for capturing in quantitative form what is known about the behaviour of structural elements and disseminating this information widely they are unequalled. Their value in bringing order to the design process and promoting consistency in the quality of design calculations can hardly be overestimated.

And yet, standards are widely criticised by structural engineers, often with justification. Criticism tends to centre on the following matters:

- Standards are legalistic and tend to force designers to follow set rules, thus discouraging engineering judgement and innovation born out of an in-depth understanding of structural behaviour.
- Standards often contain outdated information.
- Whilst appearing very authoritative, any standard is actually far from perfect, and it may lead designers to commit errors, for example when rules are applied to situations where they are not applicable.
- Standards often demand from the designer more calculation than is needed to establish the adequacy of a particular design, and every new generation of standards seem to be more demanding of designers' time.
- The introduction of a new standard inevitably results in a degree of confusion, and expense, such as for the purchase or development of new design aids. There may also be strife when at least some engineers are not convinced of the need for change.

The fundamental requirement for conciseness, and the fact that standards are produced only after the laborious interaction of many people with divergent views and priorities, makes it inevitable that any standard will attract comments like these. One thing can however be employed to soften the adverse effects and weaknesses of a new standard: a good commentary. A commentary allows the authors of a standard the opportunity to communicate with the users in a less formal and cryptic manner than demanded by the style commonly adopted for standards. Thus the commentary affords the user some insight into the reasoning behind every clause, so that he can interpret it correctly, and know its limitations.

Inevitably, a commentary becomes somewhat of an extension of the standard it deals with. Additional information is given, and the interpretation of the standard requirements is made more precise. This will have unavoidable legal implications in any case where the adequacy of a design is questioned, thus lending extra weight to the need for designers to familiarise themselves with the contents of the commentary.

The purpose of this commentary on the South Afrian National Standard for design of structures for the mining industry — SANS 10208-1 "Design of

Structures for the Mining Industry. Part 1: Headgear Structures", is as follows:

- To provide additional information which might be of use to designers.
- To provide information regarding the origins of, and reasons for, the standard requirements.
- To explain the requirements of the standard and its implications to the user where it is considered that explanation may be helpful.
- To highlight the main changes in this revision of the standard.

It is hoped that this commentary will facilitate the use of the standard, and generate a greater interest in discussion about the behaviour of structures within shaft systems, which can lead to an even better standard in the future.

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INTRODUCTION

SANS 10208 — The South African national standard for the design of structures for the Mining Industry, is currently published in four parts viz.:

Part 1 Headgear Structures

Part 2 Stages

Part 3 Conveyances

Part 4 Shaft System Structures

This commentary has been written to cover Part 1, Headgear Structures, and is intended to provide a better understanding of the design loads and design procedures employed in their structural design. References to "SANS 10208-1" are thus to SANS 10208-1 "Design of Structures for the Mining Industry. Part 1: Headgear Structures".

SANS 10208-1 was introduced with the aim of achieving the following objectives:

1. Defining current practice clearly and succinctly, to facilitate new development. Design standards have been accused of retarding innovation, but it is the hope that in defining current practice, its strength and shortfalls will become clearer, and that engineers will be enabled to more rationally and confidently introduce innovations.

2. Enabling more engineers to competently design the structures required at the head of shafts. Many structural and mechanical engineers have the basic skills required to design these structures, but are not well informed about the specific requirements, and may thus easily overlook certain items. This design standard will help to address this difficulty.

3. Introducing a unified design procedure which is acceptable to all the mining companies. In the past there have been substantial differences between the design procedures and requirements of different mining companies. This has led to confusion amongst suppliers, differing expectations, and even different margins of safety at different mines. A unified design approach will benefit the whole industry.

The shaft is a vital lifeline to any underground mine, so the proper design, maintenance, and workmanlike repair of the headgear structures is essential to continued smooth operations in the mine.

SANS 10208-1 intends to define appropriate loads and design procedures for all the different components and functions required in headgear structures, including rope support, emergency arresting of conveyances, and the handling of men, materials, and rock at the head of the shaft. In doing so, the first important step is taken towards long-term shaft safety and reliability – facilitating a good initial design. Because of the interaction between headgears, shafts and conveyances, there is a certain amount of material in SANS 10208-1 which is the same as, or very similar to material in Part 3, and material in Part 4, of SANS 10208.

Common material has been repeated to avoid the need for frequent cross-referencing between the various parts of SANS 10208.

In drafting SANS 10208-1, an effort was made to incorporate as much as possible of the most recent knowledge and results of research undertaken under the guidance of the mining industry in South Africa. There are however several instances of loads which have been defined without the benefits of recent research. In such cases the definition of loads has relied on the long operational experience of the South African mining industry. These loads are defined at magnitudes which would lead to sizes of members which are commonly known to be acceptable and reliable. The committee has attempted to write SANS 10208-1 in a form which is simple and explicit, and furthermore to avoid unnecessary changes from procedures which are familiar to designers. Much debate has taken place in the drafting committee in an effort to reconcile differing design philosophies, so that SANS 10208-1 can hopefully be universally acceptable to the South African mining industry.

The numbering of paragraphs in this commentary corresponds to the numbering of clauses in SANS 10208-1. Extra information dealing with legal and safety aspects, fabrication, and other matters, is also given in addition to the clause clarification.

MAJOR CHANGES FROM THE 1995 VERSION OF SANS 10208-1

The main changes that have been introduced are the following:

- Title of SANS 10208-1
  The title of SANS 10208-1 has been changed from “Headgear and Collar Structures” to “Headgear Structures”. This has been done in accordance with the general assumption in the Mining Industry that the headgear is the structure from the foundations upwards, not only the portion above ground level. Thus, the headgear structure, as the term is used throughout SANS 10208-1, refers to the entire structure from the foundation level below ground, up to the crane above the top sheave level. See the definition of what is included as part of the headgear structure in the Scope (Clause 1).

  Some of the loads defined may be applied at the collar level or the bank level. For example, this would apply to the loads on bank doors during sinking, and to support of the conveyances during doubling down. Other loads may be applied below the bank level. For example, the tail rope loads during installation and replacement of conveyances on friction winders are typically resisted on a platform below bank level.

- Numbering of clauses has been changed to comply with the norms now used by South African Bureau of Standards: Standards Division.

- Several annexes provided information in addition to SANS 10208-1 clauses. Some of this information was informative only, whereas some was designated as normative. The drafting committee preferred to place all of the informative material in this commentary, and incorporate the normative material in the body of SANS 10208-1. The annexes removed were:

  - Annex A: Loads from rope guides
  - Annex B: Working doubling-down loads
  - Annex C: Emergency conditions for friction winders

- Clauses dealing with “Friction winder” loads have been changed to refer to “Headgear – mounted winder” loads. These clauses (6.2.5 and 6.5.4) deal with loads applied by the winder to the headgear. Where a friction winder is ground-mounted these loads do not apply. Although it is very rare to mount fixed rope winders in the headgear, these loads do apply if this is done.

- Clause 6.3 has been changed completely. In the 1995 version of SANS 10208-1 this clause dealt with “Conveyance rope doubling-down loads”. In general, there are more loads due to rope handling than just those due to doubling-down. The clause now deals more generally with “Rope or conveyance installation loads”. Doubling-down is one of the loads specified in this clause.

- The ordering of clauses has been changed, and extra clauses have been added. This makes the ordering of the material more logical, and ensures that this part of SANS 10208 is consistent with Parts 3 and 4. All normal operating rope loads and rope installation loads have been placed together in Clauses 6.3 and 6.4. Clause 8, dealing with design procedures and the serviceability limit state has been added. In the 1995 edition of SANS 10208-1, Clause 4 defined the design procedures and design standards to be used. In this edition of SANS 10208-1, Clause 4 defines the materials to be used, and the design procedures and standards are defined in the new Clause 7.

- A final change, that does not influence the content of SANS 10208-1, but does influence its acceptability within the Mining Industry, is the SANS committee responsible for approval of SANS 10208-1. Previously, the SANS 10208 series of standards fell generally under the “Construction Standards” committee, SANS TC 5120.61. It now falls under the “Mining Equipment” committee, SANS TC 82, as SC 82E “Mining Structures”. This is an important change in terms of who receives circulation of draft documents, and who is party to approval of the final standard.

CLAUSE COMMENTARY

Commentary dealing with the various clauses of SANS 10208-1 is given under the appropriate clause number. Where there is no comment made on a particular clause, that clause number is omitted.

The clause commentary provides one or more of the following types of information where appropriate:

(a) Background information, explaining the origin of the clause requirements.

(b) Information to clarify and expand the clause requirements where the need for succinctly written clause has not allowed for a complete explanation in SANS 10208-1.

(c) Description of possible alternative rational methods of deriving loads or impact factors.

(d) Examples to demonstrate the application of the clause or alternative rational methods.

1 SCOPE

SANS 10208-1 covers the loads and design procedures to be adopted for all structural members of headgears. Functions typically provided by headgears include:

- Support of winding ropes, and sometimes winders, during the sinking and permanent phases.
- Support of stage ropes during sinking.
- Support of rope guides, and rope guide tensioning equipment where these are used.
- Tipping arrangement for rock hoisting, with bins and chutes for rock handling.
- Personnel loading platforms, above or below bank level.
- Emergency egress platforms below the jack catch level.
- Support of chain blocks or cranes for handling equipment, and for handling conveyances into and out of, the shaft.

- A range of emergency equipment, including safety doors and crash doors during the sinking phase, and crash beams, jack catches, catch plates, and energy absorbing devices during the permanent phase.
- Platforms to provide access for maintenance, rope examination, and emergency exit from cages.
- Platform to handle head ropes where friction winders are used. This platform is usually located above the operating levels, and below the winder level in the headgear.
- Platform to handle tail ropes where friction winders are used. This platform is usually located in the sub-bank area.
- Support of a maintenance crane at the top of the headgear.
- Support of fixed guides for all compartments.

2 NORMATIVE REFERENCES

No comments are necessary here.

3 DEFINITIONS

3.1 Bank doors

Previously defined as "safety doors" these doors are located at bank level, to serve as a working floor preventing personnel or equipment falling down the shaft. They typically carry light working loads and the weight of the kibbles with payload and impact. The doors are usually closed, but are opened to allow the kibbles to pass through, after which they are again closed and the kibbles are lowered onto them for loading/unloading personnel and equipment.

3.5 Crash doors

It is fairly common in small sinking headgears for the crash doors to be located at the bank level, in which case one set of doors serves the purpose of bank doors and crash doors.

3.6 Doubling-down

The doubling down procedure is required for a variety of functions that are necessary on fixed rope winders. These functions include:

(a) Tensioning of the back end of the winding rope.

If the tension in the bottom layer of winding rope coils on the winder drum is too low damage to the winding rope will result. The rope tension in these coils will be low following installation of a new rope, and it may reduce if hoisting is done with low payloads. The function of doubling down is uncoil the entire length of the winding rope, in order to apply a high tension to the bottom layer of rope on the winder drum.

(b) Cutting “back-ends”.

The coiling of winding rope on the winding drum results in specific “cross-over” points at which the winding rope coils in consecutive layers crosses over the winding rope coils on the previous layer of winding rope. These cross-overs occur at a specific locastion on the drum, and lead to localised damage to the winding rope. It is thus prudent to change the point in the winding rope at which the cross-overs occur from time to time. This is done by doubling down to uncoil all the winding rope from the winding drum, releasing the winding rope from the winding drum, cutting a short length off the back-end of the winding rope, and then re-attaching the winding rope to the winding drum.

Doubling-down of the rope generally follows the procedure below (see Figure 1, and see also Table 1):

(a) The conveyance is supported on temporary beams across the shaft, or on slings fixed in the headgear.

(b) The winding rope is then detached from the conveyance, and a temporary sheave is attached in its place.

(c) The winding rope is taken around the temporary sheave on the conveyance, and is attached to an anchor point in the headgear.

(d) When doubling-down is done to tension the back end of the rope, a heavy payload is placed in the conveyance, to achieve as high a rope tension as possible.

(e) The conveyance is then lowered in the shaft.

This procedure enables the entire length of winding rope to be wound off the winder drum.

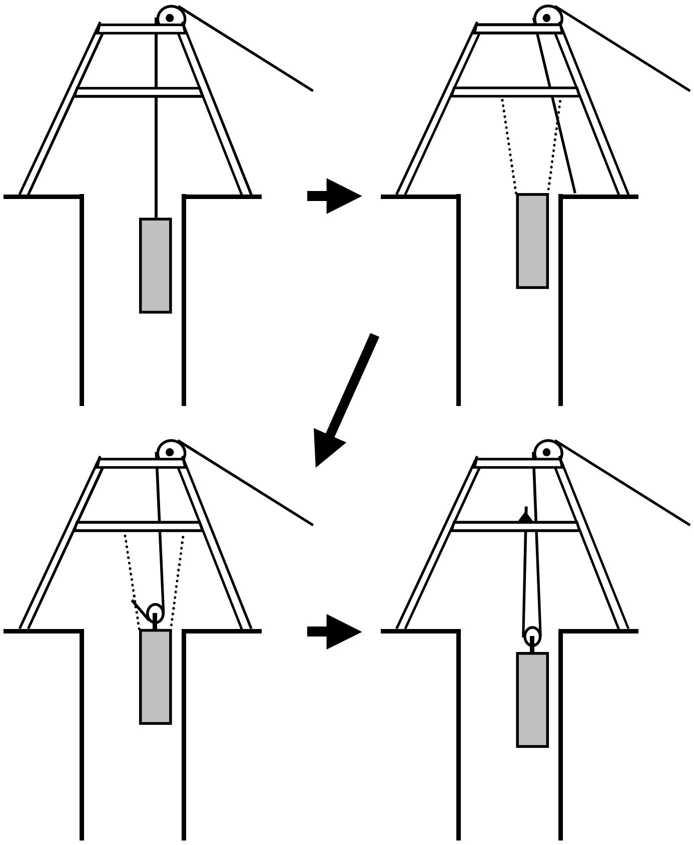


Figure 1: Doubling-down

4 SYMBOLS

No comments are necessary here.

5 MATERIALS

Headgear structures are generally constructed of standard structural steel or concrete.

Where structural steel is used, it is currently standard practice in South Africa to use Gr 300WA steel or Gr 350WA steel.

Where structural concrete is used, a cube strength of 30 MPa is generally specified. Use of a higher strength concrete would allow the use of thinner walls for the headgear, but it is debateable whether this is desirable or not, because the headgear then becomes more flexible.

6 NOMINAL LOADS

6.1 Permanent Loads

6.1.3 Additional Permanent loads

These are loads which, once applied are more-or-less constant over long periods of time, so their behaviour is generally equivalent to permanent loads. However, the possibility does exist that they may be removed at some stage whilst use of the headgear is still reqired. Some care in their application is thus necessary.

6.2 Imposed Loads (excluding rope loads)

6.2.1 General

Imposed loads such as wind loads are to be determined in accordance with SANS 10160. With respect to the action of these loads there is no difference between a headgear structure and any other structure.

Earthquake loads are also dealt with as specified by SANS 10160. The committee drafting SANS 10208-1 had a certain amount of discussion about whether specific requirements should be drafted for earthquake loading, because mining-induced sesimic activity tends to have higher frequencies and lower displacements than tectonic plate-related earthquakes. However, as far as the committee is aware, there has not been any experience of seismic-related damage to headgears in South Africa, even though few headgears have in the past been designed to withstand earthquake conditions. It was thus felt that design in accordance with SANS 10160 would be quite acceptable, if deemed necessary by the Structural Designer. Where sesimic design is done it is important to allow for the mass of machinery which is mounted in the headgear, particularly where there is a headgear-mounted winder. Allowance must also be made for the mass of material in bins.

6.2.2 Floor and platform loads

Part (b) of this clause is intended to make provision for all important loads that may arise during installation or maintenance.

- Spare sheaves may well be placed temporarily, or even permanently stored, on the sheave beam level, or an adjacent platform.

- Where winders are mounted in the headgear, gearboxes or motors may be placed on the winder level platform during maintenance. Spare motors, gearboxes, or spare parts may also be permanently stored in the headgear for convenience. It is good practice to specifically designate areas, with load allowance marked, for the storage of spare parts.

- Quite heavy rope tensioning equipment may be necessary when rope guides are used.

6.2.3 Bin material loads and chute material loads

It is assumed that bins and chutes may block, or be filled because a conveyor has tripped. The load is calculated using the material density provided by the mining company. It must be remembered that during sinking of the shaft, materials of different densities may be encountered. Often the ore being mined has a higher density than the surrounding waste material, but there are be cases (such as when coal is being mined) when the surrounding material may have a substantially higher density.

6.2.4 Conveyance operating loads

Various operations with conveyances are necessary in the headgear. Typical loads include:

- Guide load as conveyances travel in the headgear.
- Tipping load when skips are tipped. Some specifications call for a tipping load of 50 kN or a percentage (typically 10 %) of the rope end load, but SANS 10208-1 requires the use of SANS 10208-3. Tipping paths with sharp radii, and flatter tipping sections lead to higher forces so they should be avoided, although they do allow for a shorter tipping distance and thus a lower headgear.
- Loading or unloading of material.
- Chairing of conveyances for minor in-shaft maintenance, doubling down of the rope, etc.

6.2.5 Headgear- mounted winder loads

(a) The starting torque on electrical motors may be very much higher than the specified rms (root-mean-square) torque and the torque during acceleration and steady speed hoisting. The actual increase in torque depends on whether the winder is AC or DC and on what controls are used.

The starting torque is usually taken as about 7 or 8 times the rms torque. Fuller Vecor normally use 10 times the rms torque for the design of the mechanical components of winders. This value must be obtained from the winder manufacturer.

(b) Trip-out braking is not usually considered, because although it leads to higher loads than normal braking, it happens very seldom. The braking loads are significantly less than the emergency rope loads, so they are only important when considering fatigue life of the supporting structures.

Trip-out braking generally occurs too seldom to have much effect on fatigue life.

Fixed rope winders are very seldom mounted in the headgear, although this is a theoretical possibility. This clause thus typically applies to friction winders which are very commonly mounted in the headgear.

Friction winders require balance loads, provided by tail ropes, to ensure sufficient tension in the winding ropes to enable the winder system to operate. It is important that these loads are not omitted from the assessment of headgear loads.

6.2.6 Kibble Loads

Using the principle of equating the potential energy of a kibble that is dropped onto the bank doors to the strain energy induced into the bank door structure, the impact factor can be shown to vary as shown in Figure 2. The static deflection is the deflection of the bank doors calculated when they are carrying the fully loaded kibble. The fall height is the height the kibble is allowed to drop onto the bank doors.

The appropriate kibble impact factor can be derived from Figure 2, where the fall height and static stiffness are known.

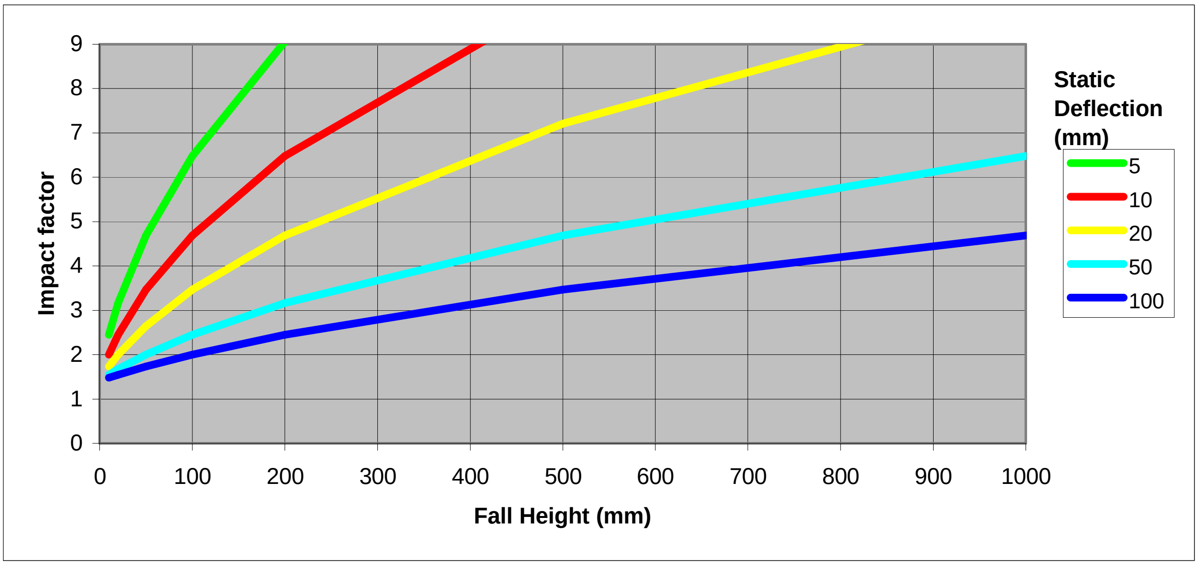


Figure 2: Impact Factor for Kibble Falling onto Bank Doors

6.2.8 Abnormal Loads

Abnormal loads are unusual occurrences. The clause dealing with abnormal loads is primarily a reminder to Designers that there may be other loads imposed on the headgear at some stage. Generally, abnormal loads are dealt with as special cases, with special care being taken to control the hoisting operation and minimise impact factors. A special design check is usually done when the abnormal load must be moved, rather than this being an initial design condition.

Abnormal loads that may be imposed on headgears arise from:

(a) During sinking

- Jumbo drilling rigs may have to be carried up or down the shaft on the kibble winder

(b) During permanent operation

- Major components of underground winders, in particular drums, drum shafts and motors
- Major components of refrigeration plants
- Underground crushers

6.3 Rope or Conveyance Installation Loads

The handling of ropes in the headgear is a common requirement. A range of different impact factors is specified for use under differing conditions. It is necessary for the Engineer or Designer to understand the nature of possible impact conditions to properly assess the appropriate impact factor to use.

Two standard cases, and various other cases are included.

- The impact factor, α_c, is taken as 1,0 when the rope is supported on the structure in a steady-state condition. In this case there is no impact, as there is no movement energy or strain energy transfer.
- The impact factor, α_c, is taken as 2,0 when the tension in the rope is suddenly applied to the structure. This is a standard case of impact, in which it is well known that there is an impact factor of 2,0.
- The impact factor, α_c, is taken as 1,3 when the rope is held and moved by some mechanical means. Impact loads should be small under these conditions, but there is the possibility of the rope slipping marginally, and movements of the equipment will inevitably lead to some impact loading. Ideally, the suppliers of the rope handling equipment should provide appropriate impact factors to be used with their equipment.
- The impact factor, α_c, is taken as 3,0 when the rope is in creep motion and is stopped by means of clamps applied onto the structure. It is important to note that an impact factor of 3,0 will only cover the case of creep motion, up to a speed of approximately 1,0 m/s. The impact factor resulting from stopping ropes moving at higher speeds may be much higher than 3,0. Figure 3 shows the variation of impact factors on slings used to support conveyances during doubling down operations, based on the length of the slings and the travelling speed. The solid

lines in Figure 3 are derived from a dynamic simulation, and the dotted lines are derived from simple energy equations.

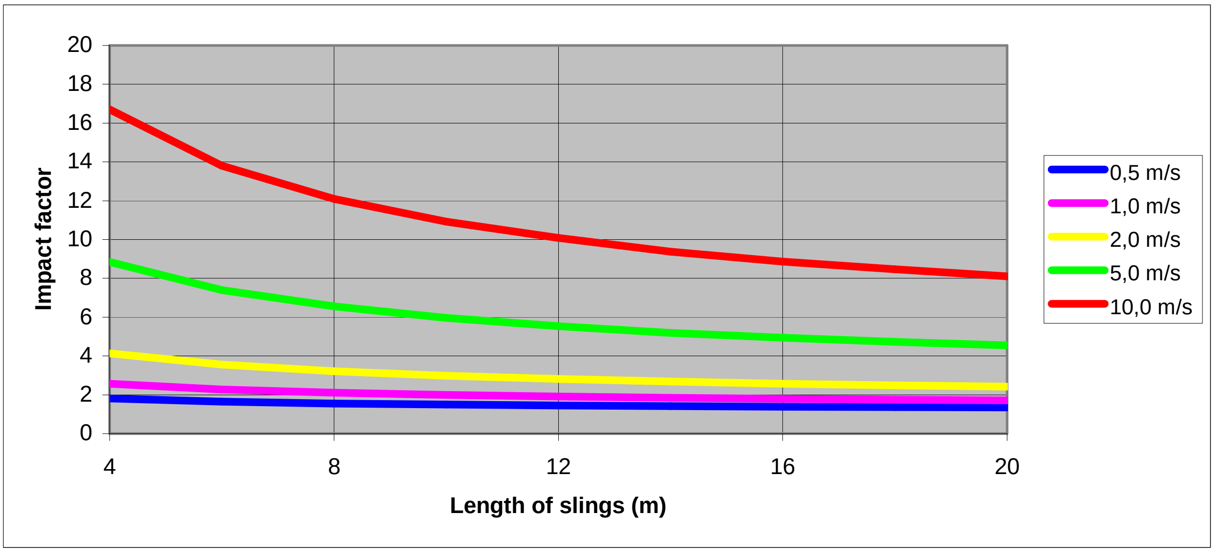


Figure 3: Impact Factors on Slings used to Arrest Moving Conveyance

– The impact factor, α_c, may always be assessed by means of rational analysis. The appropriate rational analysis will generally be a dynamic simulation of the actual rope handling operation. In some cases, it may also be possible to use energy methods, or simplified dynamic calculations.

6.3.2 Winding rope installation and doubling-down loads

Special provision needs to be made in headgear structures for unusual loading situations, viz:

(a) to support fully loaded conveyances temporarily to facilitate rope tensioning on the winding drum, and cutting the back end of ropes where they are attached to the winding drum; this procedure is commonly known as “doubling-down” of ropes.

(b) a similar procedure to doubling-down may be utilized when heavy equipment is transported in the shaft. This may be for example, when refrigeration equipment or the drums of a winder to be installed in a sub-vertical shaft are being lowered.

(c) the load used during doubling down may exceed the normal conveyance payload, to ensure a high rope tension.

The example below deals specifically with a typical sequence of events for the doubling-down of skip ropes. It is illustrated in Table 1, and relates to a single skip. Doubling down procedures may vary from mine to mine, so care should be taken to establish the precise requirements of the Client. For the doubling-down of two skips, some of the loadings on the bank steelwork will double.

EXAMPLE

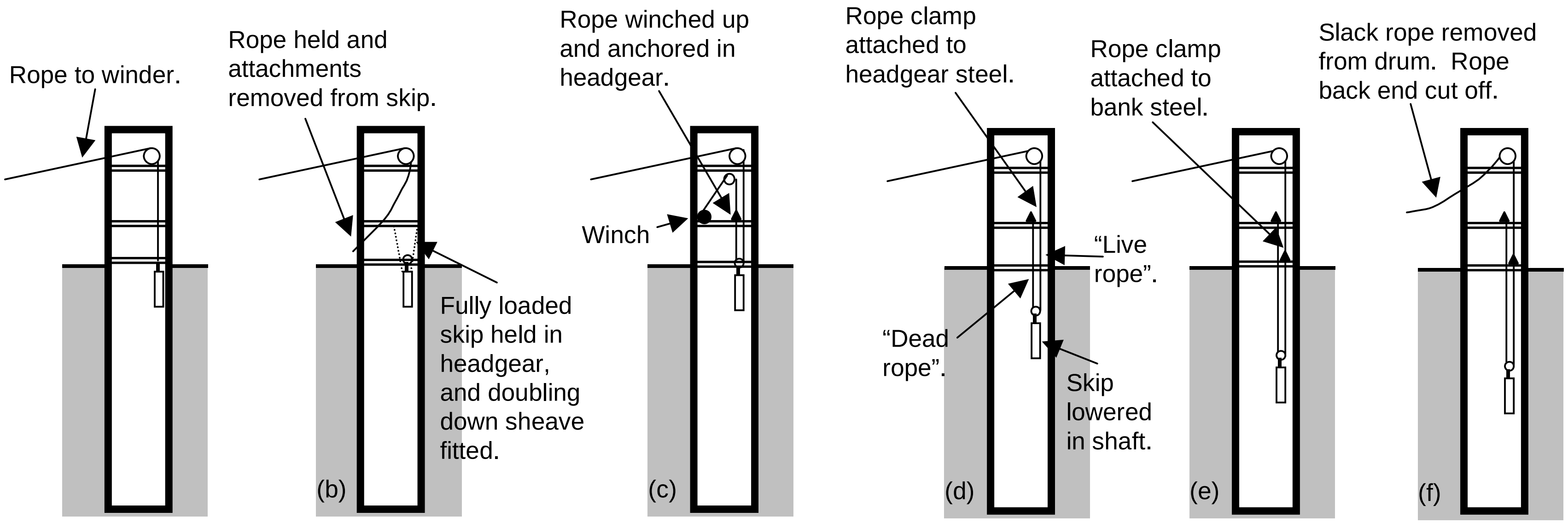
Assume the following design parameters:

Shaft depth	2500 m
Doubling down depth	1300 m
Rope diameter	64 mm
Rope mass	17,7 kg/m
Skip mass	12 207 kg
Payload	16 000 kg
Total mass on rope	28 207 kg

Mass of 1 300 m of rope: 23 010 kg

Anchor point loading: 28 207/2 + 23 010

= 37 114 kg, i.e. 364 kN



1	2	3	4	5	6	7
Operation	Reference figure	Skip load dynamic factor α_c	Rope configuration		Loading at anchor kN	Loading on bank kN
			"Dead rope"	"Live" rope		
Loaded skip lowered onto bank steel	a	3	Attached to skip and winder		0	3 x 277
Detaching hook removed, sheave attached, rope anchored in headgear	b, c	1	Anchored in headgear	Attached to winder	0	277
Skip raised off bank	d	2			2 x (277/2)	0
Travelling down shaft	d	1,5 (trip out)	Anchored in headgear	Attached to winder	1,5x364=546	0
Skip midway, clamp attached to rope at bank	e	1	Anchored in headgear	Attached to winder	364	0
Rope back end released, rope cut	f	2	Anchored in headgear	Clamped at bank	364	2 x 364
Rope re-attached to winder	e	1	Attached to winder	Attached to winder	364	364
Travelling up shaft	d	1,5	Anchored in headgear	Attached to winder	1,5x364=546	0
Skip raised to surface, lowered onto bank steel	c	3	Anchored in headgear	Attached to winder	0	3 x 277
Rope re-attached to skip and slack wound in	a	1	Attached to skip and winder		0	277
Normal winding		0	Attached to skip and winder		0	0

Table 1 – Doubling-down of ropes for a single skip

6.3.4 Rope Guide Load and Rubbing Rope Installation Loads

Rope guides may in some cases be used in hoisting installations in preference to fixed guides. Rope guides are anchored in the headgear and at shaft bottom, and typically have a fairly high tension applied, in order to limit the likely deflection of conveyances travelling in the shaft. Rubbing ropes may be installed between conveyances, to eliminate any possibility of a head-on collision between the conveyances. Typically, rubbing ropes also have a fairly high tension applied.

The total static load on rope guides suspended from the headgear is a function of the depth of the shaft, the type of rope used, and various operational factors of the conveyances.

Rope guides and their tensioning devices provide loads of considerable magnitude but are subject to only small dynamic forces. The dynamic forces are typically ignored in the design of headgear structures.

Tensioning devices usually consist of weights suspended from the bottom of rope guides (typically referred to as "cheese weights"), jacked spring devices, or hydraulic devices mounted in the headgear.

- Where cheese weights are used, the maximum tension is always well known, as it cannot exceed the weight of the cheese weights plus the weight of the rope guide. Cases have been known where spillage builds up to the underside of the weights, or the weights are flooded. In both cases the tension on the rope guide is substantially reduced.

- Where jacked spring devices or hydraulic tensioning devices are used, the rope is effectively anchored at the shaft bottom and in the headgear. The maximum rope guide tension may exceed the nominal tension for various reasons. If the shaft temperature reduces for any reason, the rope guides will contract, leading to an increase in tension. It is also possible for the tensioning devices to apply too high a tension. Available information suggests that rope guide tensions may commonly be up to about 10 % to 15 % above their specified value, using these tensioning methods. It would thus be reasonable to increase the specified tension by a factor of 1,15 to obtain the nominal load for design.

In general, it is recommended that the rope guide tension should ideally be obtained from the Client. If this is not possible for any reason, then it may be obtained approximately as discussed under (a), (b), (c), (d), (e), or (f) below.

(a) Early South African recommendations for rope guide tension were based on the equation:

$$P = \frac{4Fa}{\ell} \qquad (1)$$

where F = recommended tension force

P = horizontal load applied at midlength

ℓ = free length of rope guide

a = horizontal displacement caused by P

These are shown in figure 4.

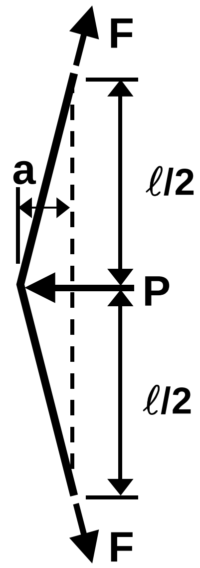


Figure 4: Rope guide Forces

Manipulation of equation 1 gives:

$$F = \frac{P\ell}{4a} \qquad 2$$

It was earlier assumed that P = 0,09 kN (20 lb) and a = 0,15 m (6"), so that the tensioning force was defined as:

$$F = 0{,}15\,\ell$$

This leads to high tensioning forces which are beneficial for rope guide hoisting installations. The dotted line in Figure 5 shows these tension values.

(b) The NCB (The previous National Coal Board of the UK) gives the tensioning forces shown in Table 2.

(c) In the early 1980s Hardcastle and Richards (H&R) of Australia recommended the use of similar values, which are shown in Figure 5. This is based on:

$F = 0{,}075\ \ell \quad (1\,\text{short ton/yd})$ for shafts shallower than 457 m (500 yds)

(Note: A short ton (an american ton) is equivalent to 907 kg

A long ton (a british ton) is equivalent to 1016 kg)

(d) Using a factor of safety of 6 as previously required by the South African regulations prior to 1999, and the H&R recommendations, to define appropriate rope guide tensions and sizes, the information previously defined in SANS 10208 Part 1 1995 can be obtained. This has now been removed from SANS 10208-1, as it is no more than an estimate of possible rope guide tensions. This information is reproduced as Figure 5.

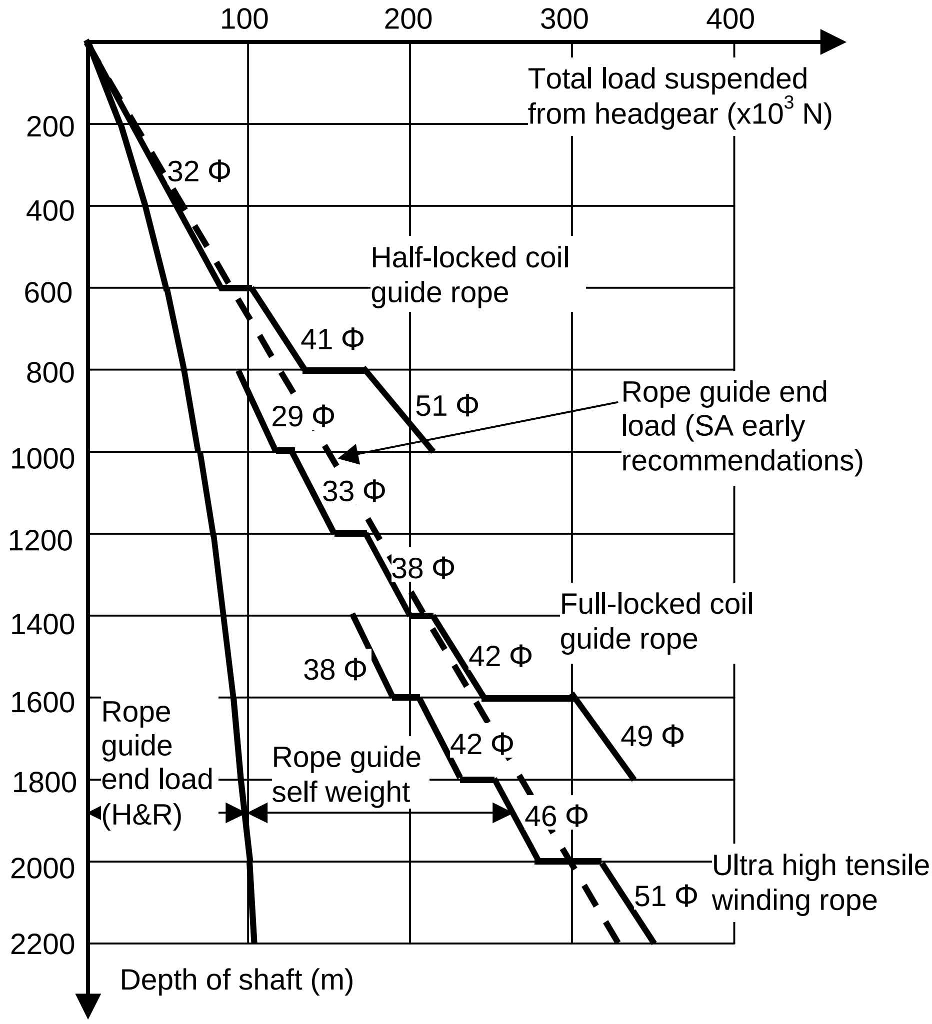
Table 2: NCB Tensioning Masses for Rope guides

Shaft Depth		Tension Mass	
(m)	**(yds)**	**(tonne)**	**short (tons)**
183	200	1,8	2,0
274	300	2,7	3,0
366	400	3,6	4,0
457	500	4,5	5,0
549	600	5,0	5,6
640	700	5,4	6,1
732	800	6,0	6,7
823	900	6,5	7,3
914	1000	7,0	7,9
1006	1100	7,5	8,4
1097	1200	8,0	9,0

(e) Alternatively, if the rope guide size is known, the maximum rope guide load may be obtained by dividing the breaking strength of the rope by the statutory factor of safety. In South Africa, the regulations currently require a factor of safety of 5 for rope guides. Most of the Canadian provinces also require a factor of safety of 5. The Australian Standard “Underground mining – Shaft Equipment”. Part 5 – “Headframes” defines the rope guide load as 1,2 times the rope guide breaking strength divided by the statutory factor of safety for rope guides.

The rope guide load could thus be taken as:

$$F = \frac{\text{Guide Rope Breaking Strength}}{5}$$



NOTES:

1 Curves for three different types of rope guide are shown. The figures next to these curves indicate the rope diameter, in millimetres.

2 A safety factor of 6 was used to derive adequate rope guide diameters for a given shaft depth.

Figure 5 — Loads from rope guides of various diameters

The individual tensions in ropes are often varied, typically by about 5 kN, to prevent sympathetic vibrations. The design load for each rope should be taken as that for the rope carrying the maximum load. The addition of 10% to 20% to the stated rope guide loads for use in design is recommended to take into account those dynamic loads which may occur during operation. Since these loads are permanently maintained it is recommended that the maximum allowable stresses for the supporting beams are reduced by 10% to make allowance for possible creep effects, in concrete supporting members.

(f) There is also powerful computer software available to simulate the behaviour of conveyances guided by rope guides, and give a more rational assessment of the rope guide tension required.

6.3.5 Conveyance Change-over Loads

The impact factor, α_V, is specified as being 3,0 in the absence of better information. This assumes fairly rough handling of the conveyance during the change-over. Most commonly, the old conveyance is taken out of the shaft onto a trolley, and the new conveyance is lifted off a similar trolley into the shaft, as shown in Figure 6. In this case a significantly lower impact factor of 2,0 or even 1,5 will apply.

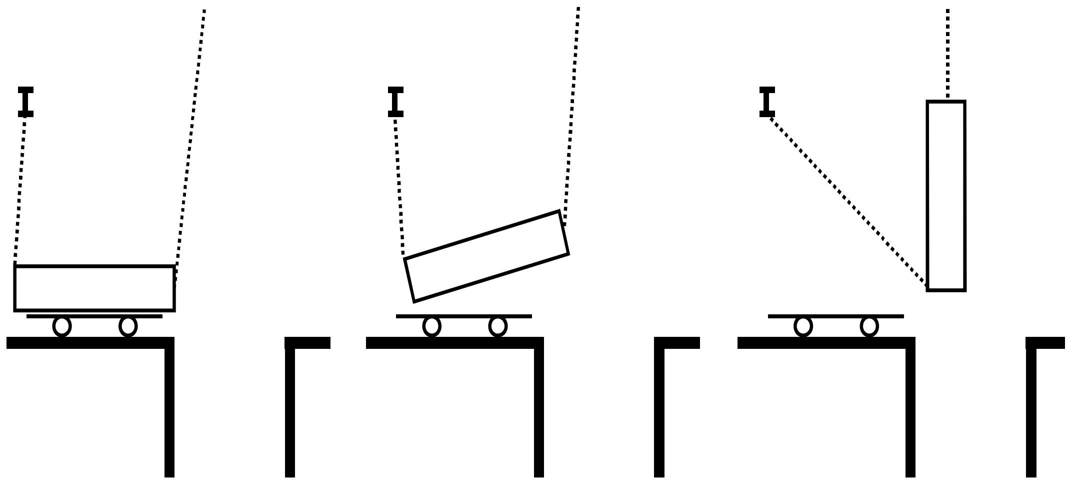


Figure 6: Conveyance Installation

This load should be distributed between the two axles on the trolley, based on where the conveyance is supported on the trolley, and where the impact load is likely to be applied.

The dynamic wheel loads on the bogies supporting conveyances during change-over may be determined by energy principles. The applicable proportion of self-weight of the conveyance should be applied on the bogie at the creep speed setting of the winder (typically 0,5 m/s to 0,75 m/s).

6.4 Rope Operating Loads

The winding rope is the normal industry term for the rope, or ropes, attaching the conveyance to the winder. This term applies to all winders, whether fixed rope winders or friction winders. The conveyance rope load is the winding rope load during normal hoisting operations.

The definitions of the winding rope load applies to all conveyances, thus including cages, skips, kibbles, and counterweights. It does not apply to stages or equipping skeletons. For these, see the clause dealing with stage rope loads.

The contents of a conveyance would include:

- People, material, or equipment in cages or kibbles.
- Rock in skips or kibbles.

Underslung loads or the weight of tail ropes must also be considered where appropriate.

When defining the load effect due to numerous ropes supported on the headgear the maximum and minimum rope loads should be considered. The maximum load typically occurs when a full conveyance is located at the bottom of the shaft, and includes:

- The conveyance self weight
- The conveyance contents
- The weight of rope over the full depth of the shaft.

The minimum load typically occurs when an empty conveyance is located in the headgear, and includes:

- The conveyance of self weight.
- The weight of rope from the sheave to the conveyance location in the headgear.

The working winding rope loads are typically applied to headgear design without any dynamic impact factors.

The lateral rope load of 3,5 % allows for the fleeting angle and a rope whip component. A fleeting angle of 1,75^{o} gives a lateral load of 3,05 % of the rope tension.

6.5 Emergency Loads

Emergency loads on rope guides and rubbing ropes (previously 5.4.1.3) have been removed from SANS 10208-1. Previously, the emergency load on rope guides was based on the assumption that a loose broken strand could lead to the formation of a "bird-cage" if the wire snagged on the rubbing block, and that this could cause an entire conveyance to hang up on one rope guide, possibly leading to the rope guide breaking. The emergency load was thus previously defined as the rope break load.

No members of the committee have had any experience of this happening, nor are they aware of any similar incidents. As far as could be established, apart from a few installations in Germany, this is not a design requirement elsewhere, suggesting that there is no evidence of this happening. The NCB document NG/E/2 "The Design of Headframes and Winder Towers" recommends the use of a 10% overload on guide ropes and rubbing ropes. Earlier drafts of the Australian Standard (AS3785.5 - 1998) "Underground mining – Shaft equipment. Part 5: Headframes" included an overload on guide ropes of 20 %, but this has been removed from the current edition. Some Canadian provinces also require the use of a 10% overload. Guide ropes are generally half-locked coil, or even full locked coil rope construction, which means that even if a wire breaks, it is still held within the weave of the rope. The wires in guide ropes and rubbing ropes are also quite brittle, so even if one were to come loose, the likelihood is that the passing conveyance would break it off rather than forming a bird-cage strong enough to cause the conveyance to hang up.

Typical design loads for rope guide and rubbing rope anchor points appear to be the working tension plus a small amount, commonly 10 % to 20 %. This is catered for in the impact factors specified under working loads. It was thus felt to be realistic to omit this emergency load condition.

6.5.1 Rope emergency load

It should be noted that the emergency rope load as specified for the design of the headgear is the load that will act on the sheaves in the case of a ground mounted winder, or on the winder drum in the case of a headgear mounted winder. The emergency load is defined differently for fixed rope winders (typically double drum winders and BMR winders) and for friction winders (Koepe winders).

6.5.1.1 Conveyances with fixed rope winders

A winding rope may break at a load of less than the rope strength, due to kinking of the rope, the rope pulling out of the thimble, or the rope being cut in the incident. Rope test measurements suggest that the rope may pull out of thimble attachments at about 90 % of rope break. However, these are not well defined, and they may not happen, so the emergency load is defined as rope break in all cases.

It is important to note that the 3,5 % lateral load from winding ropes must be applied under emergency conditions as well.

6.5.1.2 Conveyances with friction winders

Friction winders are sometimes tower-mounted (i.e. mounted in the headgear), and sometimes ground-mounted.

(a) Tower-mounted friction winders

Ideally, the emergency rope loads applied to a friction winder should be derived from a dynamic simulation of the entire conveyance/winding rope/winder system.

If this is not possible, then the following equations can be used to provide some guidance. Where the winding ropes are on the point of slipping on the winding drum, the following equations apply:

$$\frac{E_{r1}}{E_{r2}} = e^{\mu\theta} \qquad E_{r1} = nE_{rC}$$

$$E_{r2} = \frac{E_{r1}}{e^{\mu\theta}}$$

(See also Figure 9).

This will give a value of E_{r2} less than E_{r1}. Under emergency conditions it is possible that the winding ropes may slip, and that E_{r2} will have a smaller value. It is also possible, due to the dynamic behaviour of the system, that E_{r2} may have a greater value, up to a value equal to E_{r1}. As an upper bound assumption, the worst case for vertical load on the headgear is given by:

$$E_{r1} = E_{r2} = nE_{rC}$$

E_{rF} is the resultant force due to E_{r1} and E_{r2}.

In the equations above:

n is the number of winding ropes

θ is the angle of wrap of the rope on the winder drum (radians)

E_{rC} is the winding rope breaking load (for a single rope)

μ is the friction coefficient between the rope and the groove or groove liners. It is not possible to give a typical value of μ because it varies widely between different materials. The appropriate value must be obtained from the Client, or the Supplier of the winder.

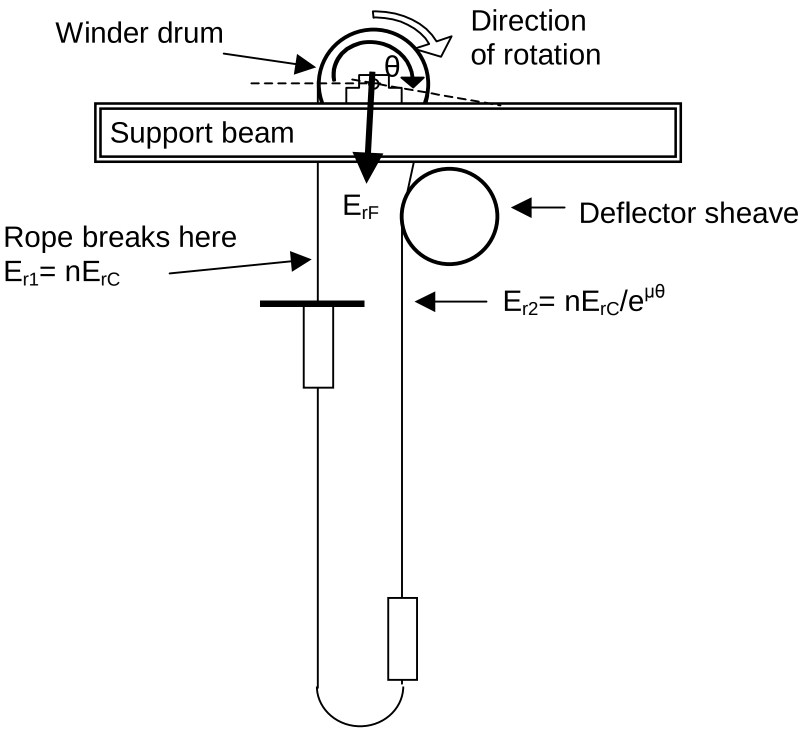
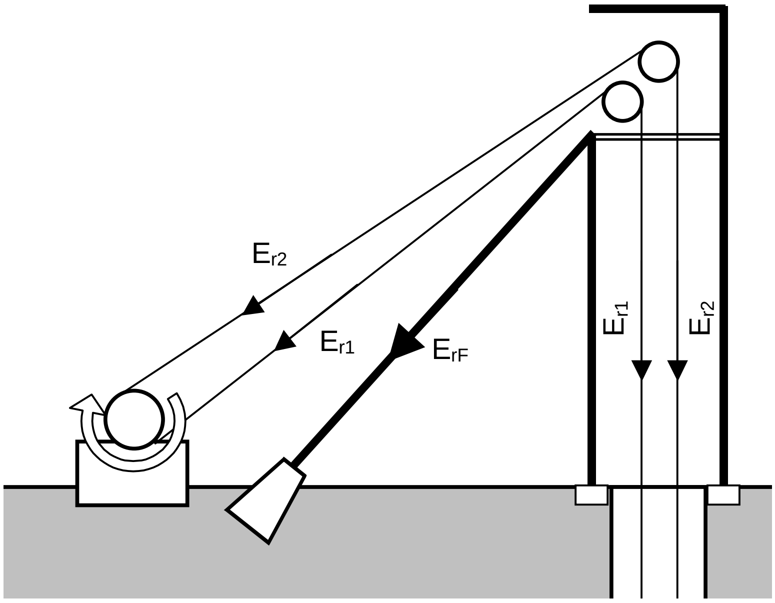


Figure 7 – Tower-mounted friction winders

(b) Ground-mounted friction winders

The calculations are similar, but instead of passing over the winding drum in the headgear, each set of winding ropes passes over a set of sheaves in the headgear. Thus, one set of sheaves has a winding rope tension of E_{r1} applied diagonally towards the winder as well as downwards, and the other set of sheaves has a winding rope tension of E_{r2} applied similarly.

For tower-mounted and ground-mounted friction winders, it is recommended that E_{r2} should never be taken as less than 0,5 times E_{r1}, even where a high friction coefficient exists. This is because any moisture or grease on the grooves can reduce friction, and the sliding friction when the winding ropes slip is less than static friction.



NOTE : Slack rope can become tight rope depending on the sense of rotation of the winder drum.

Figure 8 – Ground-mounted friction winders

Variation of the force on the side of the slack rope with the coefficient of friction between the rope and the drum for friction winders.

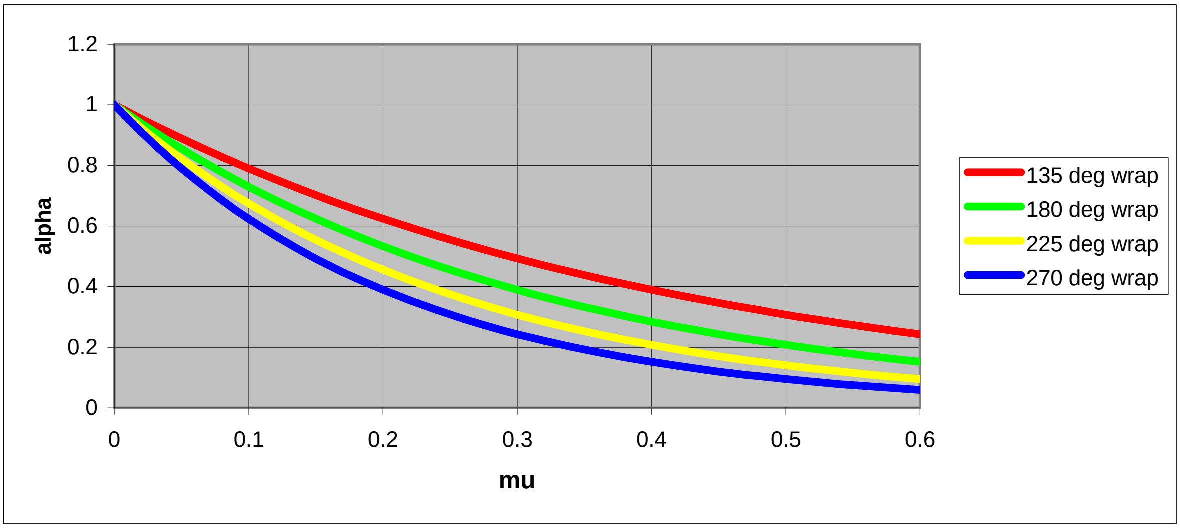


Figure 9 – Friction winders plot of μ vs α

Simulation of friction winder installations carried out by ATD has indicated that in general it is possible to break the winding ropes on a friction winder. The simulations also show that under fairly common conditions where the height of the headgear and the lower hoisting speed approaching bank level are taken into account, the maximum load can be reduced to as low as 50 % of the rope break load. There are complex dynamic interactions, so it is necessary to undertake a full simulation before using any emergency load less than the combined winding rope break loads.

6.5.1.3 Stage rope emergency loads

The emergency load on stage ropes is defined as three times the weight of the stage. It has been suggested that a rope tension of 1,2 times the maximum stage winder pull should be considered, or even stage rope break should be considered. However, none of the members of the drafting committee were aware of stage ropes ever having broken, except where they were cut by falling objects. Stage are moved very slowly, and they are only moved under supervision, so it is felt to be reasonable to use a lower emergency load than is used for ordinary winding applications.

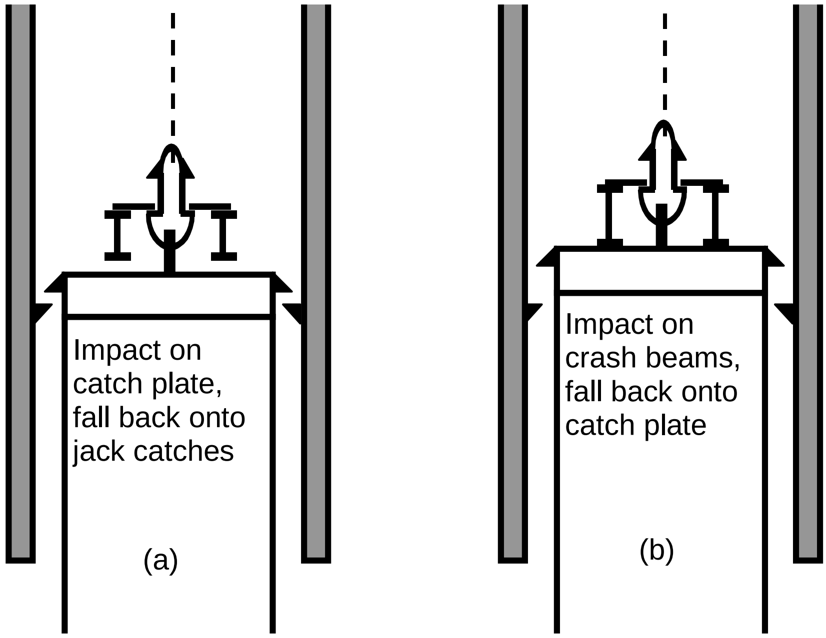
6.5.2 Emergency dropback loads

SANS 10208-1 does not specify the distance through which conveyances may drop back following detachment of the winding rope. The basic distance through which a conveyance may drop back is determined by the geometry of the top of the conveyance the underside of the crash beams, and jack catches. The primary components of the geometry are the location of the shoulders of the detaching hook, the distance between the catch plate and the underside of the crash beams, and the elevation of the jack catches. Some possibilities are shown in Figure 10.

There may be occasions when it is advisable to include some “throw-back” velocity in the drop back distance calculations. The conveyance will always have some velocity when it impacts the crash beams. This will lead to elastic deformation of the crash beams. Once the conveyance has stopped, the stored elastic energy in the crash beams will fling the conveyance downwards, so that its impact velocity on the catch plate or jack catches will exceed what might be expected if the conveyance simply fell through the height defined by the geometry. If it is assumed that the entire impact and rebound is elastic, then the rebound velocity after impact may be assumed to be equal in magnitude to the impact velocity. Experience shows that most overwind events occur at winder creep speed, which is commonly of the order of 0,5 m/s. The rebound velocity V_R would be the same as if the conveyance had dropped from a distance S_R above its stopping location.

$$S_R = \frac{V_R^2}{2 \times 9{,}81}$$

If an impact velocity of 1 m/s, i.e. double the common creep speed, is assumed, then this equation gives an extra drop back distance of 50 mm. The Designer must determine whether this extra distance should be included in the drop back distance used, or not.



Note that (b) is the preferred geometry.

Figure 10 – Crash beam, catch plate and jack catch geometry

6.5.4 Headgear-mounted winder emergency loads

The short circuit torque on winder motors can be very high, but is of very short duration. The information must be obtained from equipment manufacturers, but typical information is as listed below:

(a) Direct coupled DC winders – Short circuit torque is about 7 times full load torque for a duration of about 50 milliseconds.

(b) Direct coupled AC winders – Short circuit torque is about 6 to 10 times full load torque for a duration of about 50 milliseconds.

Application of this very high torque as a quasi-static load to the headgear is not recommended, as it will lead to very high member forces. This load should thus be treated as a dynamic load, in which case its short duration will mean that it does not have a large effect on most of the headgear structure.

6.5.5 Energy release following rope break

During a rope break event a large amount of elastic strain energy is stored in the headgear structure. As soon as the rope breaks, this stored elastic energy is released, causing a “kick-back” effect in the headgear. As a conservative approach, the load specified under this condition is equal in magnitude, but opposite in direction, to the rope break load. A full dynamic analysis may demonstrate a smaller load, but is probably not warranted.

7 LOAD FACTORS AND LOAD COMBINATIONS

7.1 Operating conditions

7.1.1 Partial load factors and load combination factors

In assessing the appropriate permanent loads it is important to understand how the loads are to be combined, and what is the implication of specifying a load as permanent. The self weight of the headgear is always a permanent load. Any equipment that may be stored in the headgear for any length of time is also generally defined as permanent load. However, where this would have a beneficial effect, such as when considering overall stability of the headgear, the equipment should only be considered as permanent load if it actually is located in the headgear permanently. Sheaves, headgear-mounted winders, energy absorbing devices such as Technogrid or SELDA arrestors, and cranes, are all types of equipment that are likely to effectively be permanent load.

The concept of “additional permanent load” has been introduced to deal with rope guide and rubbing rope loads. Initially, these are not permanent load, as they will act as imposed load on the headgear during their installation, or later replacement. However, for most of the operational life of the headgear, rope guides and rubbing ropes, where they are used, will act more like permanent load. However, it is possible for these ropes to break, or to be removed, so their minimum value for overturning calculations is taken as zero.

The special imposed loads are loads that will only be applied under carefully controlled conditions. However, when these loads are applied, it may simultaneously be necessary to apply other loads. For example, when an abnormal loads is being transported down the shaft, it may be necessary to use lifting tackle installed in the headgear and to drive a trolley or a mobile crane onto platforms at bank level. All these associated loads must be combined using a load combination factor of 1,0, whilst the specified load combination factors must be used for other loads. The load factor for abnormal loads is low at 1,2 because any abnormal load has to be an accurately known load for licensing purposes. Abnormal loads require careful handling, so impact factors are likely to be low as well, but this must be assessed on a case-by-case basis.

It should be noted that there are load factors specified here for some of the emergency loads, but not for rope break loads. Rope break loads are dealt with in a different manner, as specified in Clause 7.3. The load combination factor being 0,0 indicates that these emergency loads are not considered in combination with any loads other than the permanent and operating rope loads. In other words these emergency loads are only considered in combination with other permanent and effectively permanent loads.

The partial load factor for rock loads is lower than that for other imposed loads (1,4 is used as compared with 1,6 for other imposed loads). This should be understood in the context of the normal assumptions that are made about rock density. The bulk density of broken rock varies quite widely. It is thus common practice, when calculating the required volume of bins and chutes, to make a low assumption of rock density, to ensure that the bin is capable of containing the specified payload, even under low density conditions. On the other hand, when calculating the strength of the bin or chute, a high assumption of the rock density is made, to ensure that the bin has sufficient strength even with rock of high bulk density. Where this practice is not followed, it would be more appropriate to use a load factor of 1,6 for rock loads.

7.2 Emergency conditions

The general load factor used under emergency conditions is 1,05. The use of this factor presumes certain operational requirements:

(a) Following any emergency the portions of the headgear subjected to the emergency loads are fully inspected by a competent person before the headgear is used.

(b) Some minor damage is acceptable, provided no major structural failure occurs. However, all damage must be repaired before further use of the headgear.

8 DESIGN PROCEDURES

8.2 Design Standards

Design is generally to be in accordance with the relevant South African design standards, and it is assumed that construction tolerances will comply with normal good practice in South African, and the relevant South African construction standards.

It should be noted that SANS 10208-1 does not allow any increase in the resistance factors specified in the appropriate materials design standards.

This is in contrast to SANS 10208-3 “Conveyances” which allows the use of a resistance factor of 1,1 under certain conditions with emergency loads.

There are three reasons for this difference:

(a) The ropes from several winders may be supported on the same sheave platform. Following an emergency in the shaft is important that the unaffected winders can still be used, so no damage or deformation to the sheave platform can be tolerated.

(b) Repairs to damaged headgear beams would be far more onerous than repairs to damaged conveyances.

(c) There is an energy usage overhead for moving the conveyance self weight up and down the shaft. It is thus important, within acceptable safety norms, to minimise the weight of the conveyance. This does not apply to the headgear.

8.3 Overall Stability

The drafting committee has debated this clause at some length. The following issues were of particular concern:

– Whether any special requirements should be defined. There is a very high amount of strain energy stored in headgears if the load in one of the winding ropes were to approach the rope break load. When the rope breaks, this strain energy is then released, causing dynamic effects that would cause the entire headgear to rebound backwards. The maximum effect of this would be equivalent to the application of the rope break load in the opposite direction. However all other rope loads would still be applied in their normal direction, so the likely negative load effect would be less than the load effect induced by rope break loads. It was thus felt to be unnecessary to introduce any specific requirements to cover this possibility.

– What different effects may be applicable to small headgears, where the self weight is small in relation to rope break loads. None of the members of the committee have been aware of any major overall structural stability problems arising during rope break incidents, so it was felt that normal overall structural stability requirements would be sufficient.

– If nothing specific was to be specified, it was considered possible to omit this clause on the basis that it is covered by other structural design standards. It was however felt that overall stability is of sufficient importance that Structural Engineers and Designers should be reminded that it must be checked, so the clause was retained.

The normal limit states approach to overall stability, or overturning, is to be applied. The normal load factors are applied to loads acting in a direction that tends to cause overturning, and reduced load factors (typically less than 1,0 and 0,0 in the case of rope guides and rubbing ropes) are applied to loads acting in a direction that tends to resist overturning. Thus for typical headgear structures, wind loads and the horizontal components of rope loads have the normal load factors applied, whereas the headgear self weight and the vertical components of rope loads have reduced load factors applied.

Recommend a factor against overturning of :

1,5 for normal operation

1,2 for emergency conditions

This leads to the apparent inconsistency that a rope which has a single, constant tension, has different load factors applied at different places, and hence different ultimate design loads are used. This is a problem that has not finally been satisfactorily resolved within limit states design philosophy. Until a better solution to this problem is developed, the approach described in the paragraph above should be used.

8.4 Serviceability limit state

The standard specifies a maximum deflection of height divided by 500. Experience has shown that compliance with this limit may still allow noticeable movement of the headgear, when personnel work on the higher levels of the headgear during operation of the winders. In most cases where complaints have been received, the problem was traced to a specific cause such as misaligned sheaves, unbalance of headgear-mounted winders or a headgear design that did not comply with the height divided by 500 limitation. However, in a few cases of complaints there was no obvious cause identified. The possibility of introducing a more stringent limitation on headgear deflection was considered by the committee, but it was felt that this would be too onerous, and that too few complaints were received to justify it.

8.4.3 Headgear-mounted winders

Lateral Oscillation

Headgear-mounted winders may lead to noticeable oscillation of the headgear, which may be disconcerting to the winder driver, or other personnel working in the headgear for any length of time. Generally accepted norms for human sensitivity to vibration should be applied.

The frequency of excitation of the headgear will typically be the rotation frequency of the winder drum. Large winders have drum diameters in the region of 4 m to 6 m, and the hoisting speed is 15 m/s to 18 m/s. This gives a drum rotation frequency approximately in the range 0,8 Hz up to 1,5 Hz. In this frequency range, the acceleration limit is set at about 0,1 m/s^2 by most relevant standards and specifications. This gives a displacement amplitude limit as shown in Table 3.

Table 3: Recommended headgear oscillation limit

Drum rotation frequency (revs/sec - Hz)	(rads/sec - ω)	Acceleration limit (m/s²)	Displacement amplitude limit (mm)
0,5	3,14	0,1	10,0
1,0	6,28		2,5
1,5	9,42		1,1
2,0	12,57		0,6

Winder drums are typically balanced using balance masses of the order of 50 kg. If two 50 kg balance masses are required to balance a winder drum with a total mass of 30 000 kg, and a diameter of 5,5 m, the initial eccentricity is:

$$e = \frac{2 \times 50 \times \frac{5,5}{2}}{30\,000 + 2 \times 50} = 0,0046 \text{ m}$$

Assuming that a winder drum with an eccentricity of 0,0046 m is not balanced, the horizontal and vertical dynamic forces, F_H and F_V respectively, resulting from rotation of the drum are given by:

$$F_H = me\omega^2 \sin(\omega t)$$

$$F_V = me\omega^2 \cos(\omega t)$$

If the hoisting speed is 16 m/s, the drum rotation speed is:

$$\omega = 2\pi \frac{16}{5,5\pi} = 5,82 \text{ rad/s}$$

The amplitude of the forces is thus:

$$F_H \text{ and } F_V = 30000 \times 0,0046 \times 5,82^2 = 4671 \text{ N}$$

The lateral deflection caused by the horizontal force must be less than the limit given in Table 3 to ensure that the vibration is acceptable.

Where winders are mounted in the headgear there is the possibility that imbalance of the drum may lead to vibration of the headgear. The magnitude of this vibration is very unlikely to be significant, unless:

a) the drum is not balanced,

b) there is resonance between the rotation speed of the drum and the national frequency of the headgear.

According to winder manufacturers, winders may be balanced by means of balance masses bolted to the drum, when they are headgear mounted. This ensures that only very small imbalance forces are applied to the headgear.

However, they may not be balanced, leading to a 5 mm to 10 mm eccentricity of the winder drum.

In order to ensure that resonance does not occur under these eccentric mass conditions, it is recommended that the fundamental natural frequency of the headgear should be at least 1,5 times the frequency of rotation of the winder drum f_d. The frequency of rotation of the drum is given by:

$$f_d = \frac{V}{\pi D}$$

where V = hoisting speed (m/s)

D = drum diameter (m)

The fundamental frequency of the headgear may be taken as:

$$f_h = \frac{1}{2\pi}\sqrt{\frac{3 E I_H}{M_E L^3}}$$

where:

E	=	the elastic modulus of the headgear material (N/m^2)
I_H	=	the second moment of area of the headgear (m^4)
L	=	the height to the centre of the winder (m)
M_E	=	the equivalent mass of the headgear (kg)
	=	$M_w + 0{,}24\, M_H$
M_W	=	the mass of the winder (kg)
M_H	=	the mass of the headgear (kg)

There will not be resonance if :

$$f_h \geq 1{,}5\, f_d$$

$$\text{i.e. } \frac{1}{2\pi}\sqrt{\frac{3 E I_H}{M_E L^3}} \geq 1{,}5\,\frac{V}{\pi D}$$

EXAMPLE

Consider a concrete headgear 20 m x 20 m in plan, with walls 300 mm thick. The centre of the winder is 85 m above ground, its total mass (drum, motor, switchgear, control panels, etc) is 400 tons, and its drum diameter is 5,5 m. the hoisting speed is 18 m/s

Assume that E = 30×10^9 N/m^2

$$I_H = \frac{20 \times 20^3}{12} - \frac{19{,}4 \times 19{,}4^3}{12} = 1529 \text{ m}^4$$

Assume that the concrete volume is the volume of the walls increased by 20% to allow for internal walls and floors, and that the walls extend 8 m above the winder. Take the density of the concrete as 2,5 ton/m³. Then:

$$M_H = (4 \text{ x } 20 \text{ x } 0{,}3 \text{ x } 93 \text{ x } 1{,}2 \text{ x } 2{,}5)\text{x}10^3 = 6696\text{x}10^3 \text{ kg}$$

$$M_E = 400 \text{ x } 0{,}24 \text{ x } 6696\text{x}10^3 = 2007\text{x}10^3 \text{ kg}$$

The frequency of rotation of the drum is:

$$\frac{V}{\pi D} = \frac{18}{\pi \text{ x } 5{,}5} = 1{,}04 \text{ Hz}$$

The fundamental natural frequency of the headgear is:

$$\frac{1}{2\pi}\sqrt{\frac{3E\,I_H}{M_E\,L^3}} = \frac{1}{2\pi}\sqrt{\frac{3 \text{ x } 30 \text{ x } 10^9 \text{ x } 1529}{2007\text{x}10^3 \text{ x } 85^3}} = 1{,}68 \text{ Hz}$$

$> 1{,}5 \text{ x } 1{,}04$ OK

BIBLIOGRAPHY

NCB (1984) The design of Headframes and Winder Towers, Notes for Guidance (Engineering) NG/E/2, National Coal Board Mining Department, London.

AS 3785.5 (1998) "Underground mining – Shaft equipment. Part 5: Headframes", Standards Australia.

HISTORY

Work on drafting of SANS 10208-1 commenced in the early 1980's. An initial survey of headgear design parameters was conducted amongst the main mining companies, and replies were received from Anglo American Corporation, Anglovaal, Goldfields of South Africa, and Gencor. The survey provided useful background information for drafting SANS 10208-1, and is summarised in Table 4 as a record of the survey results. Note that the information in Table 4 should not be construed as part of the SANS 10208-1 requirements, it is included here only as historical background.

Dates of Prior Editions of SANS 10208-1

(a) SABS 0208-1 was first published by SABS in 1986, in a format that permitted design by either allowable stress methods or limit states methods.

(b) Edition 2 of SANS 10208-1 was published by Standards South Africa in 1995. This version required all design to be done using limit states design procedures.

Table 4: Preliminary Survey of Headgear Design Parameters

Parameter	Response	Comments
Permanent load	Permanent gravity loads as per SANS 10160.	
Live load on floors and platforms	5 kN/m^2 plus centre point load of 50 kN on secondary sheave level beams. 7,5 kN/m^2 on sheave platforms.	
Wind load	SANS 10160.	
Normal working rope loads	Maximum: Static tension at sheave (long rope weight + payload + conveyance weight) x 1,10 to allow for friction and acceleration. Minimum: Static tension at sheave (short rope + conveyance weight) x 1,00.	
Lateral load imparted by ropes	Loads from fleet of rope 1º30’. Rope whip load calculation. 2,5 % of rope load.	Applies to sheave stool. Locally applied at tread tangent point.
Rope breaking loads	100 % of rope strength. 105 % of rope strength. 110 % of rope strength.	German code 100 %, but the calculated load is 13 % to 15 % above the actual load because of “spinning loss”.
Upward load imparted to crash beams	100 % of rope break load. Calculation based on impact strength of materials.	
Upward load imparted to catch plate	Calculation. As specified by detaching hook Supplier.	
Downward load imparted to catch plate	Weight of the full conveyance + 20 %. As specified by the detaching hook Supplier. Calculate from maximum weight of full conveyance dropping back the maximum distance allowed by geometry, typically 100 mm to 150 mm.	
Downward load imparted to jack catches	3,5 x static load (when buffers are used). Weight of full conveyance + 20 %. Rope break load divided by number of catches. Calculated in accordance with the resilience of the system assuming a full conveyance and not more than two catches acting. Calculated using impact strain theory with 100 mm drop.	

Parameter	Response	Comments
Load imparted by falling kibble to safety doors	Calculated in accordance with the resilience of the system assuming a full kibble. Calculated using impact strain theory with 1500 mm drop.	
Lateral loads applied to guide tower during tipping	10 % of gross weight of conveyance. 20 % of rope end load. 20 % of rope end load where body of skip moves out of plane of winding to tip (i.e. swing body skip).	
Loads applied to guide tower from guides	10 % of gross weight of conveyance. 10 % of rope end loads (vertical and horizontal). ½ of 10 % rope end load used at full speed.	
Stage rope loads	1 rope breaking, others working load. 1,2 x maximum rope pull of winder, or twice maximum rope breaking load. 150 % of maximum attached load + rope weight.	
Bin and chute loading	SANS 10160. Normal structural design. Self weight of material + 20 % 150 % of static load. Bins must be considered full and chutes blocked. Impact loads due to dumping of material should be considered.	
Earthquake loading	SANS 10160.	Generally not a criterion.
Other loads	Horizontal pull from conveyors. Dead + live loads increased by 1,15 when not combined with rope break loads. Crane loads from SANS 10160.	
Rope guides	1,2 x working tension load.	
Koepe type winders	--	No responses.
Design procedures	SANS 10162 allowable stress design. Allow 25 % increase in stresses for wind loading. Allow increase varying in different responses from 0 % up to yield with emergency loading. Allow increase varying in different responses from 25 % up to yield with emergency loading and wind loading.	
Factors for stability against overturning	Use 1,4 for all combinations of load. Use DIN 4118 (factor of 1,3) for all combinations of load. Use factor of 1,5 normally. 1,25 with wind loading. 1,2 with emergency loading. 1,1 with wind loading and emergency loading.	

Parameter	Response	Comments
Deflection limitations under working loads	Vertical H/360 or SANS 10162. Horizontal H/1000 where catch plates are not structurally connected to the A-frame structure.	One response felt no deflections need be calculated.
Deflection limitations under emergency loads.	Deflection not applicable.	Permanent deformations can be allowed on catch plates, crash beams, and safety doors under emergency loads.
General.	No fatigue life calculations are necessary, although care is required with details such as butt welded plate girders. With electricity cut off all winders brake simultaneously, although this is probably not as severe as rope break. Consideration should be given to vibration and sway.	

Note: Where more than one value is given this indicates that at the time of the survey, different Mining Houses used different values.